Board 149: Advancing Participation in Engineering via Interdisciplinary Curricular Collaborations (Work in Progress)

Evelyn Hanna, Kent Place School

Dr. Evelyn Hanna currently serves as the Director of Curricular Innovation and STEM at Kent Place School. She also teaches computer science, engineering, and mathematics courses. Prior to joining Kent Place in 2018, Dr. Hanna worked at Princeton University and Rutgers School of Engineering to advance in- and out-of-classroom STEM opportunities for all students. She has received over $3M in support of her work from the National Science Foundation and other non-profit organizations. Dr. Hanna is the author of numerous peer-reviewed papers and a book, Teacher Discourse Community: What it reveals about knowledge of teaching mathematics. She is a graduate of Rutgers University, where she earned her doctorate in mathematics education and a bachelor's degree in mathematics. Dr. Hanna's research and teaching explore the intersection of STEM content knowledge, affect, and identity with the goal of ensuring excellence and equity in STEM.

Carey Gates
Michelle Stevenson, The Kent Place School

Department Chair of Student Health & Wellness and Physical Education at the Kent Place School in Summit, NJ.

Advancing Participation in Engineering via Interdisciplinary Curricular Collaborations (Work-in-Progress)

I. Introduction

As part of a larger project to transform the K-12 STEM curriculum scope and sequence, a Computer Science and Engineering (CS&E) Department was formed to support the growth of course offerings at a small-sized school for girls. Prior to the establishment of the CS&E Department, computer programming courses in Scratch, Java Script and Java were taught by staff members of the Technology Department. The staff members of the Technology Department were mainly responsible for the school's infrastructure, educational technology support, learning management system, and in-the-moment tech support for students, faculty, and staff. In support of advancing STEM opportunities for students and providing an academic structure to support the development of a robust computer science and engineering curriculum, the school allocated human, financial, and space resources to establish the CS&E Department.

The school's mission centers around empowering girls to be confident, intellectual, and ethical leaders who advance the world. With the school's mission in mind, the CS&E Department defined a curricular scope and sequence aimed at introducing the various disciplines of engineering, focusing on engineering as a "helping" and "creative" profession, and cultivating students' engineering habits of mind and identity. At the Upper School level (grades 9th - 12th), the pre-transformed curriculum offered three computer programming courses designed to introduce students to Java Script and Java languages. Building on this strength, the transformed program revised courses and added mission-aligned computer science and engineering electives to increase students' participation in and awareness of engineering, enhance their fluency with more than one programming language, and increase their content knowledge and engineering habits of mind.

As we launched the new electives, we were interested in evaluating the impact of the courses on students' participation and their awareness of and interest in various engineering disciplines. This paper reports on two of the six new CS&E courses: Engineering & the Arts (EA) and Engineering & the Lived Experience (ELE). Our guiding question is: To what extent do interdisciplinary engineering courses enhance students' participation in and awareness of the diverse field of engineering? The following sections present our theoretical and analytical frameworks, implementation and results, and conclusion and next steps.

II. Theoretical and Analytical Frameworks

The theoretical framework informing our work is rooted in literature on pre-college engineering education and girls/women in engineering. From pre-college engineering education literature, we are interested in students' development of their engineering habits of mind [1]-[2] and their understanding of engineering as a helping and creative profession. The National Academy of

Engineering has identified six important engineering "habits of mind": creativity, optimism, systems thinking, collaboration, communication and ethical considerations. These six habits of mind are essential for all learners to develop as they seek to solve problems in our ever-evolving and complex world.

Reviewing literature on girls in engineering, we are interested in situating our work within the broader context of developing girls' interest in engineering as well as cultivating their engineering habits of mind. The underrepresentation of women in engineering is well documented. To increase girls' interest in engineering, research [3]-[5] recommends utilizing a more empathy-based or human-centered approach to engineering design processes, centering engineering as a helping and creative profession, cultivating students' self-efficacy, and connecting students' interests to engineering. With this in mind, we reviewed research and curricular resources [6]-[8] that aligned with our school's mission, attended to best practices for advancing girls in engineering, and cultivated students' engineering habits of mind to design the engineering electives.

Students' artifacts were collected and analyzed. Our analytical framework is informed by grounded theory, specifically the open coding technique. Strauss and Corbin (1998) describe open coding as a three-step process of conceptualizing, identifying categories, and defining categories. Conceptualizing is a first pass of the data and allows the researcher to identify trends that might be helpful in answering the guiding research question(s). Trends inform the identification of categories. Within each category, the nuances or subcategories are identified. A narrative based on the categories is crafted to answer the research question(s). The following section describes the courses and the results from analyzing the drawings.

III. Implementation and Results

The mission of the school is to empower girls to be confident, intellectual, and ethical leaders who advance the world. Aligned with the mission, trimester-long engineering electives were developed. This paper reports on two interdisciplinary courses: Engineering and the Arts (EA) and Engineering and the Lived Experience (ELE). While EA was originally designed and taught in partnership with the Visual Arts Department, ELE was not originally offered in partnership with another academic department. After an unsuccessful first offering of ELE, we learned that students wanted another interdisciplinary experience. As such, we revamped the ELE curriculum in partnership with the Physical Education (PE) Department to offer a mission-aligned interdisciplinary course.

The EA course is co-taught by CS&E and Visual Arts faculty members. The purpose of the course is to have students live at the intersection of engineering and the arts by exploring principles of structural engineering and elements of art. Students learn the criteria, content, and

skills needed to critique structures through scientific, symbolic, and social lenses. Students design, prototype, iterate and communicate pieces of structural art that represent the structural engineering and elements of art taught throughout the course. They are trained on various tools in the Innovation and Fabrication Labs; such as 3D printers, laser cutters, and power tools. The overarching goal of the course is to enhance students' STEM literacy, engineering habits of mind, and awareness of various engineering fields.

The ELE course is co-taught by CS&E and PE faculty members. The course engages students in exploring and critiquing innovations through a human-centered lens. Specifically, students embark on a journey to answer the question: To what extent are biofeedback devices designed to serve me and people like me? Following this question, students learn hardware and software design as they design, build, and program their own personal biofeedback device (e.g., a heart rate monitor). From a PE perspective, students learn about Frequency-Intensity-Time-Type (FITT) principles and deepen their understanding as they design workouts and test their heart rates via the heart rate monitor they continue to fabricate, test, and iterate.

Since we were interested in students' engineering habits of mind and perception of engineering, we analyzed their submitted work (class assessments) and coded instances that spoke to their engineering habits of mind and their perception of engineering. Assessments included reflections on content/topics presented in a given class, mini-challenges (small projects that utilized one topic strand from the course), and a final project (large-scale project that utilized two or more topic strands from the course).

Engineering Habits of Mind emerged as a code. The dimensions of this code include students' mention of creativity, optimism, systems thinking, collaboration, communication, or ethical consideration. *Intersectionality* also emerged as a code. Students would describe their work at the intersection of engineering and the arts or engineering and PE. Dimensions of the *Intersectionality* code included description of the interconnected nature of engineering and art design principles and/or engineered biometric feedback devices and FITT principles. Finally, *Engineering Identity* also emerged as a code. The dimensions of this code included mention of a changed perspective or an individual's own view of herself as an engineer. Table 1 provides a summary of the codes with examples from the data.

Table 1: Codes with Examples

Code	*Example*	*Student Initials and Date*
Engineering Habits of Mind - Creativity	I was incredibly excited for my final project, and all the creative possibilities I know (sic) had with all of	CG, 11/21/2020

	the knowledge and skills I had acquired in Engineering and the Arts.	
Engineering Habits of Mind - Optimism	I have never worked with circuits and electrical components before. Based on today's lesson I am at about a 2 (level of comfort with knowledge/skills) and I am excited to get started!	MC, 9/23/2021
Engineering Habits of Mind - Systems Thinking	We are currently going back through the engineering process of assessing the solution and debugging the issues.	JM, 11/19/2021
Engineering Habits of Mind - Ethical Consideration	I was also surprised at how intertwined ethics and engineering are and that there is likely an ethic issue in every situation.	12/02/2021
Intersectionality - Engineering and the Arts	I learned about the elements and principles of design which tie into the art and engineering aspect of the class... In addition, I learned about what goes into the engineering thought process and how to account for live loads and dead loads as well as cantilevers, cables, columns and arches… To be an artist-engineer would mean having to think creatively while also thinking about how to solve problems. There are a lot of things that go into building something as simple as a toy box, but I have to think about how to make it look nice and how to make sure it can solve problems.	ZH, 11/21/2020
Intersectionality - Engineering and Health/Wellness	Our final project encompassed both physical education and engineering. The Engineering component was in our Arduino project and coding... We chose to work on a (Arduino) stopwatch because it would be useful for our FITT exercises, and beneficial in challenging our engineering skills.	SJ, 11/19/2021
Engineering Identity	Learning about structural engineering affected how I see my everyday life, specifically my home and school.	AH, 11/21/2020
Engineering Identity	I had never really thought about the fact that most medicines were engineered for the majority of patients	MA, 12/02/2021
Engineering Identity	I read the grand challenge about Engineering the tools of scientific discovery because there was so much cool and inspiring information on that page about the future of our space exploration. I hope to be a part of that or	JC, 12/02/2021

	do something with/like it sometime in the future!	
Engineering Identity	For me, using the table saw during the Picture Frame Mini Challenge was the hardest because it looked especially scary, but in the end after I learned how to use it and actually tried it, it wasn't as bad as I had thought... I also learned how to plan and execute an engineering project completely on my own through completing my final project, and problem solve when something wasn't measured quite right or there wasn't a specific material available.	SG, 2/15/2022

IV. Conclusion and Next Steps

As part of a larger project to transform the K-12 STEM curriculum scope and sequence, our school recently established a CS&E Department to advance mission-aligned STEM opportunities for students. The school's mission centers around empowering girls to be confident, intellectual, and ethical leaders who advance the world. With the school's mission in mind, the CS&E Department defined a curricular scope and sequence aimed at introducing the various disciplines of engineering, focusing on engineering as a helping and creative profession, and cultivating students' engineering habits of mind. As described in this paper, we launched a series of engineering electives and analyzed the impact of two courses.

It seems that offering cross-disciplinary experiences for students impacts students' perceptions of engineering as a helping and creative profession. The collaboration with the Art and Physical Education Departments provided an opportunity for students to learn and create at the intersection of seemingly different disciplines. Over the past two years, we've seen an increase in students' participation based on enrollment numbers in the courses. Based on an analysis of students' artifacts from class assignments and assessments, students demonstrated their engineering habits of mind, a recognition of the interdisciplinary work of engineers, and an impact on their engineering identity. Being a school for girls, these results are especially promising as we continue to cultivate students' STEM content knowledge, skills, and habits of mind.

With many of the artifacts documenting the interdisciplinary nature of engineering and engineering habits of mind, we would like to unpack or find ways to have students dive deeper into complex design projects for our future work. Also for future work, we would like to explore ways to code for self-efficacy and/or joy. Overall, the launch of the courses were successful and aligned with the newly defined CS&E curricular scope and sequence. As we continue to scale up our program, we will continue to utilize action research practices to study the impact of our curriculum on students' content knowledge, affect, and habits of mind.

References

[1] National Academies of Engineering and National Research Council. (2009). Engineering in K-12 Education: Understanding the Status and Improving the Prospects. Washington, D.C.: National Academies Press.

[2] M.D. Lammi & T.J. Branoff, "High School Students' Habits of Mind and Action in Engineering Design" in *Proceedings of the ASEE Annual Conference & Exposition*, *San Antonio, Texas, USA, 2012*.

[3] D. Besser, K. Brown, A. Haugh Nowariak, T. Brass, R.A. Leininger, & A. Thomas, "Empathy, Engineering, and Girls" in *Proceedings of the ASEE Virtual Annual Conference, Content Access, Virtual Online, 2020*.

[4] A. Bandura, C. Barbaranelli, G.V. Caprara, C. Pastorelli, A. Bandura, G.V. Caprara, & C. Pastorelli, "Self-efficacy beliefs as shapers of children's aspirations and career trajectories," *Child Development, vol. 72(1), pp. 187–206, 2001*.

[5] C.I. Sneider & M.K. Ravel, "Insights from Two Decades of P-12 Engineering Education Research," *Journal of Pre-College Engineering Education Research*, *11(2), Article 5, 2021*. Available: https://doi.org/10.7771/2157-9288.1277. [Accessed February 2023]

[6] E.H. Laffey, M.E. Garlock, & A. Bhatia, "Enhancing student cognition and affect through the creative art of structural and civil engineering" in *Proceedings of the ASEE Annual Conference and Exposition, New Orleans, Louisiana, USA, 2016.*

[7] C. Farmer, D.T. Allen, L.K. Berland, R.H. Crawford, & L. Guerra, "Engineer Your World: An Innovative Approach to Developing a High School Engineering Design Course," in *Proceedings of the ASEE Annual Conference & Exposition, San Antonio, Texas, USA, 2012.*

[8] M.M Hynes, C. Mathis, S. Purzer, A. Rynearson, & E. Siverling, "Systematic review of research in P-12 engineering education from 2000–2015," *International Journal of Engineering Education, vol. 33(1), pp. 453-462, 2017.*

[9] A. Strauss & J. Corbin, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory (Second ed.)*. Thousand Oaks: CA: Sage Publications, 1998.