Board 163: Engineering Identity of 2nd-Grade Girls (Work-in-Progress)

Dr. 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.

Ms. Suzanne Tracy, Kent Place School

Suzanne (Sue) Tracy has over 25 years of teaching experience and is currently the Computer Science and Engineering Department Chair and the Computer Science and Engineering Instructor for first through sixth grades at Kent Place School in Summit, NJ. Sue is also the Robotics Team Coach for the Primary School and Co-Facilitator of the PS Girls' Leadership Institute at the school. Sue enjoys working with students to solve problems using the engineering design process. She earned her Bachelor of Science degree in Business Administration from The College of New Jersey and her Master of Arts degree from Kean University. Recently, Sue became a Certified Engineering is Elementary Teacher Instructor.

Engineering Identity of 2nd Grade Girls (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, independent school for girls. Prior to the establishment of the CS&E Department, computer programming and robotics courses were taught by staff members of the Technology Department. The staff members of the Technology Department were 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 profession" and cultivating students' engineering habits of mind and identity. The focus of this paper is to zoom in on a 2nd grade lesson that reflects the goals of the CS&E curricular scope and sequence.

At the Primary School level, which includes grades K-5, the pre-transformed curriculum enhanced students' knowledge of and skills with block-based coding and robotics. Building on this strength, and after a review of existing engineering curriculum options, the authors selected relevant modules from the *Engineering is Elementary* (EiE) [1] program. Modules were selected based on alignment with CS&E, math, science, and literacy learning objectives and with the school's mission to cultivate confident, intellectual, and ethical girls who advance the world. This paper will report on one particular unit on chemical engineering that was used with the 2nd grade class.

In particular, we were interested in assessing the feasibility of adapting the EiE curricular resources to meet CS&E learning objectives, understanding the impact this type of lesson would have on our students, and identifying connections with math, science, and literacy. 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 early childhood education and girls/women in engineering. From early childhood education literature, we are interested in students' development of identity and cognition. In particular, our work is grounded within research on self-efficacy [2]-[3] as a spoke of identity formation and constructivist [4]-[5] learning theory. Self-efficacy contributes to the development of analytic and strategic thinking, motivation and perseverance in the face of difficulties and setbacks, and resilience to adversity. Furthermore, Bandura et. al. [2] found a strong correlation between self-efficacy and future career aspirations. Constructivist-informed learning opportunities have the potential to enhance self-efficacy [6]. A constructivist approach to teaching and learning begins with the premise that students must be given an opportunity to build on previous knowledge and that learning occurs when individuals can make mental models or connections between prior and new knowledge.

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 [7]-[9] recommends utilizing a more empathy-based or human-centered approach to engineering design processes, centering engineering as a helping profession, cultivating students' self-efficacy, and connecting students' interests in engineering. With this in mind, we reviewed curricular resources that aligned with our school's mission, attended to best practices for advancing girls in engineering, and cultivated students' engineering habits of mind [10]. Based on convincing evidence, e.g. [11]-[12], we selected resources from the EiE curriculum to complement our CS&E curricular scope and sequence.

Relevant to this paper, an example of a selected EiE module is a chemical engineering unit. To assess the impact of this module on students, we adapted the Draw-an-Engineer Test and utilized an inductive coding scheme gathered from the research literature [13]-[14]. From the literature [14, we utilized an inductive coding consisting of three constructs: attributes, professions, and activities. When coding for *attributes*, we considered perceived gender, collaboration, and self-identification. For *profession*, we coded the type of work depicted or described in the drawing, e.g. designer, builder, train conductor, etc. Coding for *activities* involved tagging images or words related to action, e.g. laboratory work, engineering design process, drawings, etc. The following section describes the implementation of the module and the results from analyzing the drawings.

III. Implementation and Results

As noted above, we selected the chemical engineering unit that aligned with CS&E, science, and literacy learning objectives. The unit was taught within the CS&E course for second grade. A total of 26 students participated in the unit. To launch the unit, students listened to a story entitled <u>Michelle's MVP Award.</u> In this story Michelle, an artistic girl with Down Syndrome, uses play dough in a creative way to help her ice hockey team fund a trip. After reading the story, the second graders explored and tested various ways to fabricate play dough using just three ingredients: water, salt and flour. The students examined states of matter in the form of solids and liquids as they used chemical engineering skills to combine the play dough materials together. The students quickly realized that not only are the materials important, but the steps of the process used to combine the materials are often very important as well.

At the conclusion of the unit, students were asked to draw a chemical engineer. Students responded to the prompt: “What is a chemical engineer? Draw a picture of a chemical engineer at work. Label your picture.” Utilizing an inductive coding scheme [14], we coded 15 drawings for three constructs: attributes, activities, and professions. Two dimensions emerged from coding for *Attributes*: perceived gender and perceived self-portrait. Fourteen of the fifteen drawings depicted female engineers and 2 seemed to draw self-portraits by either labeling the picture as “me” or utilizing other self-identifying features. See Figure 1 for examples.

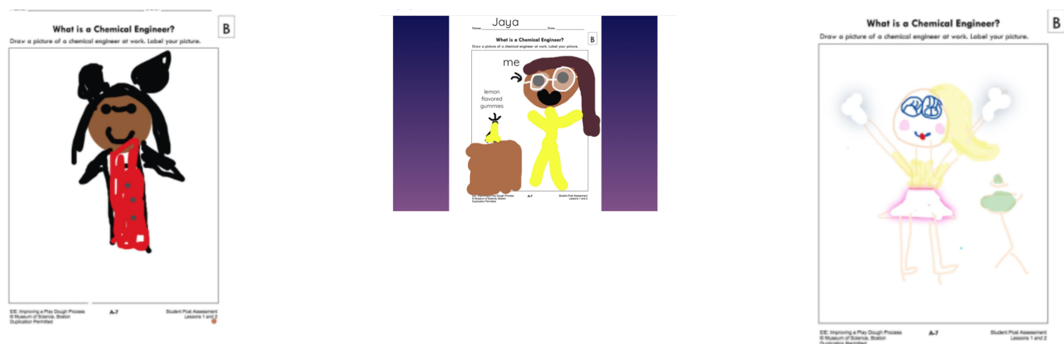

Figure 1: Examples of “Attributes”

Coding for *activities* involved tagging images or words related to action, e.g. laboratory work, engineering design process, drawings, etc. One dominant dimension emerged from the coding: lab work. Lab work was either depicted by the drawing or labeling of beakers, lab coats, goggles, or lab bench. All 15 drawings were coded for lab work. A second dimension emerged: engineering process. One picture was labeled “enginirring procces” (sic). See Figure 2 for examples.

Figure 2: Examples of "Activities"

For *profession*, we coded the type of work depicted or described in the drawing, e.g. designer, builder, train conductor, etc. This construct was difficult to code. While we could associate lab work with a scientist, we also need to be mindful of the "research" and "experiment" steps of the engineering design process that was introduced to and utilized by the students. Therefore, we identified one dimension as scientist/engineer. A second dimension was that of innovator/maker, as students noted an invention or "making" in their drawings. See Figure 3 for examples.

Figure 3: Examples of "Professions"

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 profession" and cultivating students' engineering habits of mind and identity. As described in this paper, we piloted the adaptation of EiE curricular resources via a 2nd grade lesson on chemical engineering. We were particularly interested in the impact the lesson had on students' sense of self and understanding of engineering as a profession.

Based on an analysis of students' artifacts from the Draw-an-Engineer task, students' drawings predominantly depicted female engineers, which is in contrast to evidence from the literature that documents the typical drawing of a male engineer. Being a school for girls, this result is especially promising as we continue to strive for instilling a strong sense of engineering identity among our students.

With many of the drawings reflecting research and active experimentation, we would like to unpack or find ways to have students make distinction between scientist and engineer as part of our future work. Also for future work, we would like to explore ways to code for self-efficacy and/or joy. As students noted "happy" or used many exclamation points (see Figure 3), we would like to explore data collection and analysis techniques to study the impact on the affective domain. Lastly, we would like to continue to collect and analyze more data sets, e.g. a pre-assessment, to inform and strengthen our findings.

Overall, the use of EiE resources were successfully adapted into 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] Engineering is Elementary, https://www.eie.org/. [Accessed February 2023]

[2] 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.*

[3] H. McNeill & D. Polly, "Exploring Primary Grades Teachers' Perceptions of Their Students' Mathematics Self-Efficacy and How They Differentiate Instruction," *Early Childhood Education Journal, vol. 51(1), pp. 79–88, 2023*

[4] S.O. Bada & S. Olusegun, "Constructivism learning theory: A paradigm for teaching and learning," *Journal of Research & Method in Education, vol. 5(6), pp. 66-70, 2015.*

[5] H. Hedges, J. Cullen, & B. Jordan, “Early years curriculum: funds of knowledge as a conceptual framework for children’s interests,” *Journal of Curriculum Studies, vol. 43(2), pp. 185–205, 2011.*

[6] N. McCaughtry, M. Fahlman, J.J Martin, & B. Shen, “Influences of constructivist-oriented nutrition education on urban middle school Students' nutrition knowledge, self-efficacy, and behaviors,” *American Journal of Health Education, vol. 42(5), pp. 276-285, 2011.*

[7] 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*.

[8] 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]

[9] 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*.

[10] 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.

[11] K. Hester & C. Cunningham, “Engineering Is Elementary: An Engineering And Technology Curriculum For Children” in *Proceedings of the ASEE Annual Conference & Exposition, Honolulu, Hawaii, USA, June 2007.*

[12] C. Cunningham & C. Lachapelle, “Engineering Is Elementary: Children’s Changing Understandings Of Engineering And Science,” in *Proceedings of the ASEE Annual Conference & Exposition, Honolulu, Hawaii, USA, June 2007.*

[13] R.L. Carr & H.A. Diefes-Dux, “Change in elementary student conceptions of engineering following an intervention as seen from the Draw-an-Engineer Test,” in *Proceedings of the ASEE Annual Conference & Exposition* (pp. 25-299), June 2012.

[14] T. Lightner, M.E. Cardella, N. Huggins, C. Hampton, W.C. Lee, & D.B. Knight, “Draw an Engineer: A Critical Examination of Efforts to Shift How Elementary-Aged Students Perceive Engineers,” in *Proceedings of the CoNECD, Virtual Conference, 2021*. Available: https://peer.asee.org/36080. [Accessed February 2023]