ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #35262

Informing Authentic P-12 Engineering Outreach Efforts

Dr. Jamie R Gurganus, University of Maryland Baltimore County

Dr. Jamie Gurganus is the undergraduate program coordinator and a faculty member in the Mechanical Engineering Department at UMBC, Director for the Center for the innovative, teaching, research and learning and she is the Associate Director of Engineering Education Initiatives at COEIT. Her research is focused on solving problems relating to educating and developing engineers, teachers, and the community at all levels (k12, undergraduate, graduate, post-graduate and faculty development). She seeks to identify best practices and develop assessments methods that assist faculty and teachers with student engagement, helping them to navigate the various pathways in STEM. A few of these key areas include engineering identity and mindsets, first year experiences in engineering, integrating service learning into the engineering classroom, implementing new instructional methodologies, and design optimization using additive manufacturing. Dr. Gurganus collaborates with a number of industry partners and consults throughout Maryland in STEM education initiatives. In 2019, Dr. Gurganus received the Northern Maryland Technology Council Leader Award in STEM education. She has written curricula and published a number of works in engineering education, including a Statics workbook for undergraduate engineering students. She is the Director of Innovation Programs and Operations for the non-profit research collaborative, Advancing Engineering Excellence in P-12 Engineering Education. Dr. Gurganus teaches several first and second year Mechanical Engineering classes along with the Mechanical Engineering Senior Capstone design course for UMBC.

Dr. Tanner J Huffman, The College of New Jersey

Dr. Tanner Huffman is an assistant professor in the Department of Integrative STEM Education and Director of the Center for Excellence in STEM Education in School of Engineering at The College of New Jersey. Dr. Huffman has served as a board member of the American Society of Engineering Education's Precollege Engineering Education Division; as an advisor for Carnegie Mellon University's CREATE Lab Satellite Network; as a committee member on the National Academy of Engineering project, Educator Capacity Building in PreK-12 Engineering Education; and advises the NSF funded INCLUDES project, STEM PUSH Network at the University of Pittsburgh.

Dr. Malinda S Zarske, University of Colorado Boulder

Malinda Zarske is the Associate Director with the Engineering Plus program at the University of Colorado Boulder and Chair of ASEE's Commission on P12 Engineering Education. She teaches undergraduate product design and core courses through Engineering Plus as well as STEM education courses for pre-service teachers through the CU Teach Engineering program. Her primary research interests include the impacts of project-based service-learning on student identity - especially women and nontraditional demographic groups in engineering - as well as pathways and retention to and through K-12 and undergraduate engineering, teacher education, and curriculum development. She is passionate about hands-on engineering design for every student, at every age level.

Informing Authentic P-12 Engineering Outreach Efforts
Work in Progress

Abstract

The Framework for P-12 Engineering Learning was developed through a synergistic collaboration of teachers, school administrators, and researchers alongside the leaders of the Advancing Excellence in P-12 Engineering Education (AE3) research collaborative and the American Society of Engineering Education. The framework provides practical guidance by identifying common P-12 engineering learning goals that all students should reach to become engineering literate. The Framework aims to add structure and coherence to the P-12 engineering community by serving as a foundation for the development of any and all engineering programs in schools, informing state and national standards-setting efforts, and providing the research community with a common "starting point" to better investigate and understand P-12 engineering learning. Key among the implementation targets for the Framework is educational outreach programs at schools and colleges of engineering throughout the country. These outreach programs reach thousands of students in every state and territory in the United States. Many of these programs, such as University of Colorado's TeachEngineering initiative, provide services to P-12 schools including high quality teacher professional development and access to curricular resources. The following paper will describe how the Framework and documents such as the Standards for Preparation and Professional Development for Teachers of Engineering can advance outreach efforts currently being carried out by engineering schools and colleges.

Introduction

In a continued effort to develop and provide well-informed engineering literate citizens, the Advancing Excellence in P12 Engineering Education research collaborative, in partnership with American Society of Engineering Education and a range of national experts, set forth to create and develop a Framework for P12 Engineering Learning that would help inform and reform standards, curriculum and enhance engineering literacy [1,2]. Beyond the P-12 curricular experience are outreach efforts facilitated by many colleges and universities. Outreach programs demonstrate further engagement with students and teachers providing deeper understanding of the engineering discipline and awareness of opportunities in higher education. Various models encompass summer, year-round, one-day, after-school or on-campus offerings. "Programs can be directed at preservice teachers, teachers, and/or students as well as specific groups such as females or minorities [3]." In this work-in-progress paper, the Framework for P-12 Engineering Leaning (Framework), associated Engineering Performance Matrices (EPMs), and the Standards for Preparation and Professional Development for Teachers of Engineering (PD Standards) will be discussed demonstrating how these documents could inform and advance existing or yet to be developed outreach efforts in engineering schools and colleges.

Outreach programs, Framework, EPMs & PD Standards

Over the last decade, several improvements have been made to provide more opportunity in the P-12 classroom for engineering learning. However, research and graduation data indicate continued disinterest and retention in the engineering discipline [4,5]. Furthermore, there is evidence that students who enroll in engineering programs lack the necessary skills to succeed in the first year of their program [5,6]. In response, colleges and universities use outreach efforts to bring awareness and supplement what is not taught in the P-12 education system. In a review of outreach efforts among various colleges and universities, Jeffers et al [3] found that most programs are developed with the goal of one or more of the following items:

- increase engineering enrollment,
- diversify engineering
- educating our future engineers
- teacher professional development, and
- undergraduate student development.

Recent research in P-12 engineering education may provide developers of engineering outreach programs with new resources to improve or expand efforts. The scholarship, including guidance on professional development for P-12 teachers of engineering and an organization of engineering topics relevant and age-appropriate for students, have been published by the American Society of Engineering Education and were developed by the engineering education research community as a way to ensure engineers and engineering educators have an avenue to influence how and what is being taught within concern to engineering to the nation's youth. Below, we have briefly summarized the "take-aways" from the *Framework for P-12 Engineering Learning, Engineering Performance Matrices*, and the *Standards for Preparation and Professional Development for Teachers of Engineering*.

The *Framework for P-12 Engineering Learning* provides elements to help inform content, standards, and pedagogical development. The framework includes a recommended P-12 content organization (what teachers should teach) and guiding principles for P-12 engineering (how programs should be developed). The content organization includes:

- Engineering Habits of Mind - Optimize, Persistence, Collaboration, Creativity, Conscientiousness, and Systems Thinking.
- Engineering Practice - Engineering Design, Materials Processing, Quantitative Analysis, and Professionalism.
- Engineering Knowledge - Engineering Sciences, Engineering Mathematics, and Engineering Technical Applications.

Additionally, the framework guiding principles for P-12 engineering are:

- Keep Equity at the Forefront.
- Strive for Authenticity to Engineering.
- Focus on Depth over Breadth.

- Build Upon Children's Natural Problem-Solving Abilities.
- Leverage Making as a Form of Active Learning.
- Connect with Student Interests, Culture, and Experiences.

Developed alongside the framework are the Engineering Performance Matrices (EPMs) for secondary learners.

> *EPM is a conceptual model (adapted from Strimel et al., 2020) to demonstrate ways in which the content identified in the framework can be used to guide engineering instruction and serve as an assessment blueprint for the development of engineering literacy and competence. EPMs are intended to provide teachers with a sharper understanding of how sub-concepts may be related and how they may build upon each other in order to influence more immediate and purposeful instructional practice. The goal is to help teachers think through novel concepts in engineering to improve their instruction from day to day or week to week. While these sample EPMs can indicate how to scaffold progress across different depths of student understanding from basic to advanced, learning must be shaped according to the individualities of students and their communities [1].*

A critical facet that influences engineering learning is the need for effective professional development for teachers. In the *Standards for Preparation and Professional Development for Teachers of Engineering*, Farmer, Nadelson, and Klein-Gardner have "identified standards for preparation and professional development for teachers of engineering that are aligned with current research in professional development and teaching and learning...[7]." Many outreach programs depend on the activity of having quality professional development to ensure the teacher "become comfortable and proficient with the engineering process [8].'' This document, which parallels well with the *Framework for P-12 Engineering Learning*, explains that "Engineering literacy requires understanding the fundamental nature, content, and practices of engineering, which may be organized into three categories [9]. These categories of engineering literacy include engineering design, engineering careers, and engineering and society.

In the next section, existing engineering outreach programs are explained and assessed for authentic practice of engineering learning and literacy using the aforementioned documents. It is important to note that the following programs were selected as a convivence sample at the institution of the authors and do not represent a comprehensive representation of all P-12 engineering outreach programs. The purpose of using the following examples is to provide insight on how one *might* use the document outlined in this paper to inform outreach programs at their institution.

Examples of the Outreach Programs

Below are examples of outreach programs from three different institutions; University of Colorado Boulder, The College of New Jersey (TCNJ) and University of Maryland Baltimore County (UMBC).

Teachinengineering.org - University of Colorado, Boulder

The *TeachEngineering* initiative is another example of an engineering education program that has a multi-faceted approach to providing research-based instruction and curricula for P12 engineering. The two main products of *TeachEngineering* include the widely popular digital library repository of searchable, standards-based, high-quality curricula for free use by teachers and engineering faculty to teach engineering in P12 settings and, for-credit P12 teacher professional development courses that combine the digital library curricula with alignment to engineering teacher professional development standards. The Teachengineering purpose of the professional development program is to introduce and support teachers to use engineering literacy - leveraging the three dimensions of NGSS and the habits of mind, practices and knowledge outlined in the Framework - to enable success in integrating engineering into teachers' existing classroom curriculum. The courses actively engage participants in hands-on exploration of teaching and learning engineering design and how it is similar to - and different from - teaching and learning in science and/or mathematics. Effective classroom management strategies for enabling students to benefit through hands-on engineering design are explored. The *TeachEngineering: Integrating Engineering Design into Your STEM Curriculum* professional development series is intentionally aligned to the 2014 Standards for Preparation and Professional Development for Teachers of Engineering and the associated matrix, earning the first Engineering Teacher Professional Development Endorsement through the American Society of Engineering Education.

Center for Excellence in STEM Education - TCNJ

During summer of 2020, the Center for Excellence in STEM Education in the School of Engineering at TCNJ provided virtual summer camps for 200 students from 11 states across the country. These virtual summer camps covered topics such as engineering, designing and making, and coding. Aligning with the framework guiding principles, the camp offerings were designed alongside professionals in STEM (Strive for Authenticity to Engineering). Additionally, access to the camp was provided at little or no cost to improve accessibility (Keep Equity at the Forefront). Finally, the instructors encouraged students to design and make their ideas and included explicit instruction of making with cardboard and available household materials (Leverage Making as a Form of Active Learning). Even though the camps were delivered remotely, aligning with the framework guiding principles ensured that the students were given a true engineering experience.

Summer Enrichment Academy - UMBC

At the University of Maryland, Baltimore County, a number of outreach STEM learning programs are facilitated through the Summer Enrichment Academy (SEA). Faculty from various disciplines offer curricular activities that will engage students to dive deeper into content areas, expanding their technical knowledge. Programs are provided in both summer and year-round settings. In engineering, both middle and high school engineering and computing programs are facilitated. An example of one of the enrichment activities offered in SEA is facilitated by a faculty member in mechanical engineering. In a weeklong summer session entitled, *Powered Up: Repurposing Energy with an Energy Harvester* students learn "(i) how energy harvesting technology can be used to realize energy-sustainable "Internet of Things" environment, (ii) how efficiently the environmental vibration energy can be captured, and (iii) how CAD and 3D printing technology can be used for effective design and manufacturing of energy harvester prototype [10]." Participants in this experience are able to make a vibration energy harvester which turns on LED when shaken by hand. Using the Engineering Performance Matrices, this outreach project aligns under the dimensions of engineering practices and knowledge. Students will gain experiences in practices of engineering in prototyping (EP-ED-5), engineering graphics (EP-ED-8), and manufacturing (EP-MP-1). In the knowledge dimension, students engage with the engineering science of dynamics (EK-ES-3) investigating and determining the work and energy of a system.

Recommendations and Future Work

Outreach efforts come in many shapes and sizes. The efforts outlined above were presented in order to show how the framework, EPMs, and PD standards may influence current outreach programs at the authors' institutions. To help inform similar efforts, the authors recommended that P-12 engineering outreach efforts seek guidance based on the intent and target audience of the effort. For example, institutions engaging in teacher professional development may find the PD standards a valuable resource. Furthermore, for programs such as summer camps and information sessions for K-12 students, developers should seek guidance on what engineering content is developmentally appropriate from the framework and EPMs. General alignment and institutional examples for several common P-12 outreach efforts are presented in Table 1.

Table 1: Outreach Program alignment to PD standards or Framework for P12 Engineering Learning (PD - Standards for Preparation and Professional Development for Teachers of Engineering; F - Framework for P-12 Engineering Learning; EPM - Engineering Performance Matrices).

P-12 Outreach Effort	Institutional Examples	PD	F	EPM
Teacher Professional Development	● https://centerforstem.tcnj.edu/ ● https://viterbik12.usc.edu/resources/ ● https://ceeo.tufts.edu/outreach/workshopsEducators.htm			

Online Teaching Resources for Teachers	● www.teachengineering.org ● https://sites.udel.edu/k12engineering/teachers/ ● https://viterbik12.usc.edu/resources/			
Summer Camps and Information Sessions for Students	● https://accessengineering.seas.upenn.edu/ ● https://wie.gatech.edu/engineering-career-conference ● https://outreach.engineering.asu.edu/camps/			
Online Resources for Students	● https://stem.northeastern.edu/programs/ayp/pathways/ ● http://nwp.engr.udel.edu/k-12/ ● https://outreach.engineering.asu.edu/k12-virtual-resources/			
Mentorship and Internships	● https://cwit.umbc.edu/tsite/ ● https://sites.udel.edu/k12engineering/internships/ ● https://wie.gatech.edu/coe-champions			

Programs aligning the standard setting efforts in P-12 engineering education can help create an outreach environment that can be researched on common program effectiveness criteria. For example, if a goal of all engineering outreach programs is to "connect with student interests, culture, and experiences", the community can develop appropriate research tools to measure the effectiveness of those programs to meet that specific goal. These developments can lead to a more vibrant research community around P-12 engineering outreach and could, ultimately, lead to better outcomes for the engineering workforce and the general public.

Conclusion

While this "work in progress paper" is brief, we believe research into how the framework, EPMs, and PD standards best inform outreach efforts will be necessary as P-12 engineering becomes more prevalent in schools. The framework is intended to inform the development of education standards that include engineering as a focus. As schools, state departments and national standards documents continue to align with the framework and PD standards, it will be important for outreach efforts to connect to new the learning and teaching practices suggested.

References:

[1] Advancing Excellence in P-12 Engineering Education & American Society of Engineering Education (2020). A Framework for P-12 Engineering Learning: A defined and cohesive educational foundation for P-12 engineering. American Society of Engineering Education. https://doi.org/10.18260/1-100-1153-1

[2]Strimel, G., Huffman, T., Grubbs, M., Kim, E., & Gurganus, J. (2020). Establishing a Content Taxonomy for the Coherent Study of Engineering in P-12 Schools. Journal of Pre-College Engineering Education Research (J-PEER), 10(1), Article 4.

[3]Jeffers, Andrew T., Angela G. Safferman, and Steven I. Safferman. "Understanding K–12 engineering outreach programs." *Journal of professional issues in engineering education and practice* 130.2 (2004): 95-108.

[4] Van Scoy, K. "Why The Demand For Engineering Graduates Is On The Rise." Top Universities, 2021. Accessed on: Feb. 28, 2021 [Online]. Available https://www.topuniversities.com/student-info/careers-advice/why-demand-engineering-graduates-rise

[5] Geisinger, Brandi N., and D. Raj Raman. "Why they leave: Understanding student attrition from engineering majors." International Journal of Engineering Education 29.4 (2013): 914.

[6] Daempfle, Peter A. "An analysis of the high attrition rates among first year college science, math, and engineering majors." Journal of College Student Retention: Research, Theory & Practice 5.1 (2003): 37-52.

[7] Reimers, Jackson E., Cheryl L. Farmer, and Stacy S. Klein-Gardner. "An introduction to the standards for preparation and professional development for teachers of engineering." Journal of Pre-College Engineering Education Research (J-PEER) 5.1 (2015)

[8] Brophy, S.B., Klein,S.S., Portsmore,M., Rogers,S.(2008). Advancing engineering education in P-12 classrooms. Journal of Engineering Education, 97(3), 369–387

[9] Farmer,C., Klein-Gardner, S., Nadleson,. L (2014) "Standards for Preparation and Professional Development for Teachers of Engineering." American Society of Engineering Education. Accessed on: Feb. 28, 2021 [Online]. Available https://www.asee.org/conferences-and-events/outreach/egfi-program/k12-teacher-professional-development

[10] Lee, S. "Powered Up: Repurposing Energy with an Energy Harvester." Accessed on: Feb. 28, 2021 [Online]. Available https://edlab.umbc.edu/outreach/