Paper ID #19311

Using Modular Technology as a Platform to Study Youth Approaches to Engineering Practice (Work in Progress)

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Introduction and Motivation

The creation and adoption of the Next Generation Science Standards represents multiple shifts in the way science education is conceptualized in the K-12 classroom (NGSS, NGSS Lead States, 2013; Pruitt, 2014). One of the more striking shifts from previous science standards documents is the addition of engineering specific content and engineering practices. Engineering, in these documents, is defined as, "…any engagement in a systematic practice of design to achieve solutions to particular human problems" (National Research Council, 2012, p. 11). Its inclusion was specifically rooted in engineering design, a fundamental facet of the engineering field (Dym, Agogino, Eris, Frey, & Leifer, 2005). The NGSS writers have defined the engineering design facets included in the standards as *defining and delimiting engineering problems*, *designing solutions to engineering problems*, and *optimizing the design solution*. It is worth noting that these facets are significantly simplified from how others in the field of engineering would think about engineering design (Dym et al., 2005). This simplification was motivated by the hope that, "[p]roviding students a foundation in engineering design allows them to better engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead." (NGSS Lead States, 2013, Appendix I). Taken together, the new inclusion of engineering design within NGSS represents a unified effort to introduce engineering design earlier than post-secondary to students in a coordinated way, given engineering's recognized importance in societal problem solving.

This new vision for engineering design in the K-12 classroom is not without its challenges. The inclusion of engineering design within a K-12 standards document has widely been noted as novel (Pruitt, 2014). Though many efforts have arisen to help teachers understand engineering writ large, these efforts may not align specifically with NGSS definitions (Bybee, 2011; Cunningham & Carlsen, 2014). Further, little work has been done to understand what knowledge and background students can bring in navigating the NGSS engineering design facets. In the parallel literature on science practices, research on student understanding and learning of practices like argumentation and modeling have provided foundations for curricular supports and professional development (Osborne, Erduran, & Simon, 2004; Passmore, Gouvea, & Giere, 2014). Understanding how students conceptualize facets of engineering design could help inform the design of better supports for teachers and students. This analysis focuses specifically on the question of how students conceptualize problem definition in engineering design.

Methods Overview

This work is part of a larger, on-going project entitled *Sensors in a Shoebox*, which aims to connect young members of an urban population to their communities and empower them as emerging researchers through the adoption of cyber physical systems (CPS) technologies, together with qualitative research methods. In short, youth can begin to question and engage with their environment in a self-directed way. The technology that allows this to happen is the recently developed *Sensors in a Shoebox* urban sensing kit, a simplified, modular version of structural sensing technology. The kit consists of user-friendly, ruggedized sensors that can be installed in urban environments to allow communities to measure the world around them, including environmental parameters, noise, vibrations, and motion (Figure 1). These sensors are modular, allowing them to be adapted for particular uses, such as sensing noise in a park or air quality around a school, quite easily.

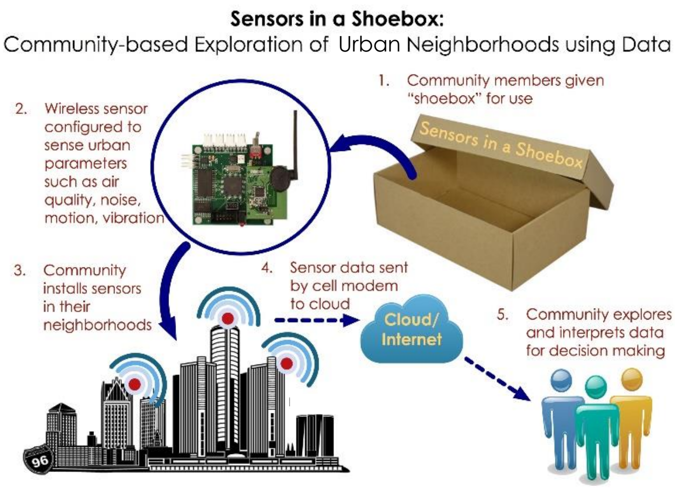

Figure 1. Working schematic of the use of *Sensors in a Shoebox* CPS technology in urban communities.

In the pilot phase of this project, after-school programming is being designed around these to engage students in urban environments in working with CPS technologies. We have chosen to focus this work on a vulnerable stage of the engineering education trajectory: 8^{th} and 9^{th} grade students (Carlone, Scott, & Lowder, 2014). Though children have been often described as natural engineers, opportunities for students in higher grade levels to engage in engineering experiences can be limited. It is in these later years of schooling that students begin to identify potential career paths, and whether or not the can see themselves in a particular role. Much work has been done on K-12 students establishing identities as engineers (Capobianco, French, & Diefes-Dux, 2012; Cunningham, Knight, Carlsen, & Kelly, 2007). As such, this age group strikes the research team as an important population to acknowledge as knowers, and to learn from in developing engineering curriculum.

During the afterschool programming, students in our project are being engaged with defining a problem they would like to address in their community using CPS. Currently in this process, students are bringing a variety of ideas of areas they are interested in studying, including water quality, air quality and walkability of their city. Using the refined ideas, the research team adapts the sensors to the students' question(s), and the student team(s) deploys the sensors. The teams also simultaneously engage in qualitative data collection that provides more face-to-face and in depth data about the identified community issue. Students then monitor and analyze data from the sensors to answer their question, and present their findings and potential solutions to community members, parents and family members, other youth, and city officials.

While also allowing the research team to evaluate CPS technology as a potential instructional support, the *Sensors in a Shoebox* programming presents a unique opportunity to characterize what types of knowledge and experiences students bring to *defining and delimiting engineering problems*. The modular nature of the kit allows students to think across a breadth of issues, but grapple with constraints and limitations in data collection, deployment, and solutions.

Through on-going interviews, observations and surveys, we continue to analyze the initial ideas students bring to the table related to defining a problem to study and solve, and how those ideas morph in the process, for common themes within these working ideas (e.g., Osborne et al., 2004). Our initial work with the students suggest that students bring a lot of ideas to *defining engineering problems* from their own experience, and are thoughtful about how to use these experiences in meaningful ways. This could prove to be an important space to affirm and acknowledge students in their engineering knowledge (Tan, Calabrese Barton, Kang, & O'Neill, 2013). Students may need more support with *delimiting engineering problems*, and understanding the depth of information needed to determine problem boundaries. More analysis will be needed to more fully understand student conceptualizations of problem definition.

Next Steps and Potential Implications

Beyond the pilot phase, the *Sensors in a Shoebox* team of engineers and education researchers will work with teachers at the schools to generate inquiry-based learning modules that aim to expose K-12 students, in an age-appropriate manner, to STEM and social science concepts, practices, and skills in the classroom (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). The learning modules will be structured to teach engineering concepts through solving problems that are derived from the sensors research program. For example, problem-based inquiry projects might ask students to create sensing solutions or to interpret data drawn from their own urban setting to solve a problem. We hope to inform these specifically from student voices in our pilot work.

In combination, the out-of-school and in-school work of *Sensors in a Shoebox* programming ultimately aims to connect youth in urban settings to their community through engineering and technology. This connection could serve to contextualize engineering as a means of problem-solving and strengthening a community, and engage students in the engineering problem definition process (Rodriguez & Berryman, 2002). Students will be engaging with technology and engineering in socially-relevant and transformative ways, and are given opportunities share this impact with their community. This could be important for non-traditionally engaged students to form strong identities with their city, and as future engineers. Using youth voice and knowledge to inform curriculum design around engineering will continue this contextualization and will also serve as support for teachers to begin to engage with engineering in their classrooms. Ideally, *Sensors in a Shoebox* programming hopes to expose more youth and teachers to engineering, not just as content, but as a force in societal problem solving.

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