Development and Implementation of a Bioengineering Module for NSBE SEEK (Work in Progress, Diversity)

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Abstract

The diversification and enlargement of the pipeline into engineering is of great interest in education today. One way to address this issue is to expand national outreach-based STEM programs aimed at underrepresented minorities. In 2007, the National Society of Black Engineers (NSBE) created the Summer Engineering Experience for Kids (SEEK) program to address the underrepresentation of African American students in STEM fields. Today, this nationwide program is hosted each summer at sites throughout the U.S., providing access to engaging and educational engineering curricula emphasizing hands-on activities and design. Through SEEK, children between third and fifth grade participate in three engineering modules. Each one-week module focuses on a specific discipline or application within engineering, but the SEEK program does not currently have a bio(medical)engineering curriculum. Bioengineering has among the highest rates of female undergraduate enrollment among engineering disciplines (nearly 50%) and the inclusion of such a module may help increase female student interest. The authors propose two new SEEK curriculum modules in bioengineering. One module was developed to emphasize the skills and methodology that bioengineers employ, such as computer-aided design, circuitry, and programming, using the free TinkerCAD website. To reinforce the development of these skills in the context of bioengineering, students design and build their own thermometer for testing. The second module emphasizes the engineering design cycle, focusing on prototyping, testing and iteration by learning about anatomy and physiology, and iteratively designing a protective bicycle helmet. This paper reports on the development of these modules by bioengineering faculty at the University of Illinois at Chicago.

Introduction

In the United States, there is both a shortage of engineers and a recognized gender and racial disparity in engineering [1]. Despite representing 51% of the US population[2], women accounted for only 20.9% of all B.S. degrees granted in engineering in 2016, up only marginally from 1997 [3]. Furthermore, during the same year, African Americans accounted for only 3.9% of those degrees, with African American women accounting for only 1% of the total [4].

There have been several approaches at the pre-college level to address the persistent concern about the lack of diversity and insufficient STEM professionals [1]. One example is out-of-school programs, including after-school, before-school, and summer-based activities. These programs tend to serve low-income and minority children at higher rates than the general population [5] and can therefore help narrow the achievement gap while fostering greater awareness of engineering. Examples of a variety of such programs are presented below.

Out-of-school programs vary widely in structure but tend to focus on hands-on applications of STEM principles. For example, one residential STEAM camp, “miniGEMS”, specifically targets low-income 6-8th grade girls from schools with high numbers of underrepresented minorities [6]. The RAMP-UP program [7] at North Carolina University hosts monthly family STEM nights at local elementary and middle schools to increase student awareness of STEM.
Another model is the ExxonMobil Bernard Harris Summer Science Camp [8]. This free camp has been offered at more than a dozen universities across the country aiming to build self-confidence and interest in STEM among middle school students, particularly from underrepresented populations, using a project-based inquiring learning model. However, the majority of these programs are not designed for early elementary grades, despite findings that early exposure positively impacts students' perceptions and dispositions toward STEM [9], [10], which increase the likelihood that students will ultimately pursue STEM careers [11].

One OST program that does specifically target early elementary school children is the Summer Engineering Experience for Kids (SEEK), which has been offered by the National Society of Black Engineers (NSBE) since 2007 to serve children from low-income communities [12]. The overall goal of the SEEK program is to enhance knowledge and engagement in engineering through hands-on, problem-based activities. SEEK has reached more than 20,000 underserved children in 16 cities across the country, utilizing nearly 500 mentors who are NSBE student members themselves [13]. SEEK is offered every summer at various sites across the country for children between the third and fifth grade, where they participate in three one-week-long modules, focusing on specific disciplines or engineering applications [14].

SEEK sites currently choose modules from a collection of 12 curricula that include computer science, mechanical engineering, civil engineering, electrical engineering, and chemical engineering. However, to date, there are no NSBE SEEK modules which represent bioengineering. Bioengineering differs from other engineering specialties in that more than 40% of B.S. degrees are awarded to females [15], [16]. Moreover, bioengineering has a minimal wage gap between men and women [17], [18] indicating bioengineering is a more equitable career path for women.

A 2018 study noted that girls perceived teaming less positively than boys in the SEEK program [19], and the inclusion of bioengineering modules may help to mitigate these differences and enhance learning, self-efficacy, and continued STEM interest in girls. Therefore, we developed two bioengineering curriculum modules for the NSBE SEEK program. These two modules are influenced by the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas [20] published by the National Resource Council in 2012. This framework provides an approach to strengthen and diversify the STEM pipeline through three dimensions: core ideas, scientific and engineering practices, and cross-cutting concepts. This framework, which additionally calls to address lack of diversity in STEM by equalizing opportunities to learn, serves as the basis of the NGSS [21]. We used this framework to drive the design of our modules. We report here on the development of the two modules for integration into the NSBE SEEK program.

**Methods**

Each module provides instruction booklets for the instructors and students. Instructor booklets provide all necessary details to execute the module, including background information and theory, vocabulary, student exercises, purchasing information, recommended schedules, and preparation of necessary equipment/materials. Student booklets contain background information and theory, vocabulary, with worksheets which correspond to module content. Each module provides roughly 25 contact hours (spread evenly across 5 days) appropriate for a group of
roughly 15 students from a single grade. Two classes for each grade are offered, accounting to a total of roughly 100 children per site. Modules can be scaled according to grade with the inclusion or exclusion of certain activities, as determined by the instructors. Modules are delivered by two college student instructors, one from a STEM background and another from an education background. Instructors are typically NSBE student members.

In general, days 1-4 of each module are devoted to the delivery of content and day 5 is reserved for team-based competitions. Content delivery in days 1-4 is multi-modal and rapid, with a myriad of activities and short breaks to maintain the students’ attention and prepare them for the final day. On day 5, student teams engage in three challenges: Presentation, Vocabulary, and Performance. Presentation and Vocabulary challenges allow teams to demonstrate their knowledge and understanding of the module subject matter, whereas the Performance challenge allows teams to demonstrate the functionality of something they built in a competitive setting. Challenges are judged by site sponsors and/or parents of participants. Across all three modules, every student participates in each of the challenges. SEEK also conducts assessments to determine the effects of the module curriculum on participant’s mathematical and science comprehension, as described by Knight et al. [14].

**Module 1**

Module 1 emphasizes the development of core engineering skills in the context of health and wellness. This module introduces students to relevant NGSS content, including developing and optimizing design solutions in the context of medical devices and instrumentation by asking questions and defining problems, developing models, using mathematics, designing solutions, and communicating information. On days 1-3, students are introduced to computer-aided design (CAD), circuitry, and basic computer programming. These skills are developed using a dynamic and interactive inquiry-based approach that combines teamwork, arts and crafts, computer use, group discussion, worksheets, and mathematics. Skills are introduced and practiced using the free TinkerCAD website (Autodesk, Inc., San Rafael, California) which offers age-appropriate exposure to this technical content through a safe and intuitive graphical interface. These skills are consistently related back to bioengineering where the practical application is reinforced. On day 4, the students utilize their skills to build a medical device - a thermometer. The thermometer consists of an Arduino microprocessor, thermistor, RGB LED, a resistor, associated wires, and a customized housing. Students spend the day constructing a functional circuit and housing, assembling the device, and verifying its functionality. Student teams also use this day to prepare for the challenges on day 5. The day 5 competition includes the application of the thermometer on a doll with insertable hot/cold packs. The objective of this challenge is to diagnose the doll accurately (i.e., hypo-, normo-, or hyper-thermia).

**Module 2**

Module 2 emphasizes the understanding and application of the engineering design cycle in the context of health and wellness. This module introduces students to relevant NGSS framework content, including defining problems, developing and using models, carrying out investigations, designing solutions, engaging in argument from evidence, and
evaluating and communicating information. Students use their experiences to make connections between cause and effect, and structure and function. On day 1, students learn about the engineering design cycle and practice this methodology to develop protection for a raw egg. On day 2, students expand on their experience with the design cycle by designing a helmet to protect the brain. Students iteratively design the helmet using practical arts and crafts materials and engage in testing to determine the performance of their design. Students also reflect on their designs to influence further iterations. On day 3, students use the engineering design cycle to iteratively design surgical tools. Students evaluate their tools by performing mock surgeries on gelatin models to remove embedded masses. Students evaluate their tool performance and use that to inform further design improvements. On day 4, students revise their tools to enhance performance and prepare for day 5 challenges. The day 5 competition includes the application of student teams’ surgical instruments on a new type of gelatin model with unknown constraints. Teams are assessed for ability to perform required surgical techniques and minimizing damage to the gelatin model.

**Discussion**

This report describes the first two bioengineering modules designed specifically for the NSBE SEEK program. These modules were designed to be complementary but distinct, as well as increase female minority interest in engineering. The first module introduces children to practical engineering skills and their application to bioengineering. The second module introduces children to a methodical framework, the engineering design cycle, for the design of medical devices. These modules were iteratively developed by bioengineering faculty at the University of Illinois at Chicago over the span of several months. Development was greatly informed by on-site observation over the span of a week during a SEEK camp in the summer of 2019. This visitation allowed us to better understand the SEEK module structure for appropriate framing of these modules. Further, visitation allowed for feedback on existing modules from instructors, which ultimately led to incorporation of greater activity variety, appropriate scheduling, and diversity of learning modes as appropriate for grade school children. These insights and their incorporation into our modules would ideally decrease the workload of instructors in the preparation and execution of the module. These modules are also beneficial in that they do not require customized development kits, with all materials being readily available from online and/or local vendors. Additionally, total cost is ~$700/module*class (excluding the computers necessary for module 1), making these modules economically feasible as well, which is in keeping with SEEK’s mission to reach economically underrepresented youth [12].

Modules were finalized in fall 2019 and are intended for implementation in summer 2020. Ideally, the pragmatic and immersion-based development of these modules will ultimately benefit the program participants. Pre- and post-program assessment would be beneficial to evaluate module impact on interest in bioengineering, particularly among girls. Further, it would be useful to assess engagement and perception between boys and girls using this module, as reported by Beauchamp et. al. [19]. Since the authors will have no further direct interaction with SEEK participants, these assessments should be integrated into existing pre- and post-program assessments already conducted by program leadership. By incorporating applications of engineering to health and well-being, we propose that these modules will expand perceptions of
engineering, particularly among female students, and enhance their learning, self-efficacy, and continued STEM interest.

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**Works Cited**


