BOARD # 217: The design of a summer camp blending bioengineering and programming skills for middle school girls and gender minority students (Work in Progress)

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The importance of having an inclusive and diverse workforce in *S*cience, *T*echnology, *E*ngineering, and *M*athematics (STEM) fields is well known [1-4] and there is considerable effort underway to create such an inclusive and diverse workforce with varying degrees of success [5-9]. Focusing on the underrepresentation of individuals who identify as women in engineering, one can see that the disparity varies greatly by discipline [10]. For example, the percentage of bachelor's degrees awarded to women in 2020 in the field of bioengineering was 50% [10], whereas only 15.5% of electrical engineering and 14.5% of computer engineering bachelor's degree recipients were women [10]. The percentage of graduates who identify as women in computer science was also relatively low at about 20%. When you look at the volume of women BS recipients in recent years, bioengineering significantly outpaces electrical engineering and computer engineering, even though there are many more jobs for the other two disciplines. The US Bureau of Labor Statistics estimates for 2023 there were 19,700 jobs for bioengineering and biomedical engineers, yet there were 287,800 jobs for electrical engineers and 84,100 jobs for computer engineers [11]. The percentage of students identifying as women enrolled has not changed over the last 20 years in electrical and computer engineering (ECE) (also ~15% in 2002) while the percentage of women bioengineers has increased (up from 43%) [10].

It has been shown that there is no academic reason for the lack of women in STEM fields [12]; however, low interest and low self-efficacy are two important factors. Social Cognitive Career Theory provides a robust theoretical framework to understand the phenomena impacting the participation of women [13,14]. Research indicates that some of the reasons that women are interested in biomedical and related engineering fields include an interest in solving social problems, and that they are more altruistic and are attracted to what might be perceived as "helping" disciplines [15]. To attract more gender-diverse students to "traditional" engineering disciplines, it has been hypothesized that it is better to show how these disciplines are "helping" disciplines, rather than just hoping that increased interest in bioengineering and environmental engineering would also bring in more girls to disciplines like ECE [16].

There have been many efforts to introduce K-12 students and teachers to STEM disciplines. For example, there have been several emerging efforts to integrate computational thinking with STEM education [20], and there are many opportunities for students to learn about computers, computer programming and computational thinking in K-12. For example, Carnegie-Mellon University, Purdue University, the Computer Science Teachers' Association (CSTA), the International Society for Technology in Education (ISTE) and others are leading the way to bring computer science and computational thinking to K-12 through programs like CS4HS [21-24]. In elementary and middle schools, students can take enrichment programs in Scratch [25], Minecraft programming, LEGO, and GameMaker programming [26], etc. These courses are offered by many groups promoting STEM and with the arts, STEAM, including the C3 CyberClub [27], Cybersecurity Camps [28], BFIOT [29], Alexa Café [19], and the Johns Hopkins University Center for Talented Youth [30]. Online courses are also available for K-12 students from places like code.org [31] and youthdigital [32]. Interesting sites for girls might be "Girls Who Code" [33] and "Black Girls Code" [34].

Because middle school is an important time when students are forming their STEM identities [37,38], and in particular when girls may decide that they are not interested in STEM fields [18], we have designed a two-week intensive summer program targeting middle school girls and gender minority students, though inclusive of all gender identities. Our project-based learning (PBL) program will serve as an introduction to the fields of electrical and computer engineering, computer science (CS), and bioengineering and will emphasize the critical importance of the first two disciplines in bioengineering, particularly in the realm of medical devices. The synergy between ECE and bioengineering is well known by professionals (e.g. [17]), yet has not led to increased interest in ECE, as the percentage of women has remained flat for 20 years.

A key hypothesis of our research project is that increased interest in electrical and computer engineering and computer science will result by demonstrating the strong synergy between those disciplines and the “helping” disciplines like bioengineering. This underlying hypothesis differentiates our summer camp from the many others that are available to middle-school students. Our summer camp also differs from some existing programming courses in that our paradigm avoids block-based coding and utilizes hardware-driven learning and PBL to motivate and enhance the acquisition of engineering and programming knowledge, skills and abilities (KSAs). Furthermore, the synergy of the bioengineering-based hands-on project with the application of programming and other engineering KSAs should increase the value of those KSAs for the students and help them to see those disciplines (ECE and CS) as ones that can help address societal problems.

Our research questions focus on two primary objectives: (1) to what degree does our summer camp impact middle-school girls and gender minority students’ self-efficacy and interest in computer programming, electrical engineering, and bioengineering? and (2) what are the supports and barriers that facilitate or hinder students’ ability and desire to acquire the knowledge, skills and abilities needed to increase their self-efficacy and STEM identity? A sequential mixed-methods approach consisting of pre- and post-surveys, a semi-structured focus group on the last day of the camp, and direct observation will be utilized to obtain qualitative data on the participants’ experiences and their attitudes related to our research questions. Follow-on surveys two and four years out will help us gauge the persistence of participants in STEM-related activities.

We will use a combination of existing instruments and custom instruments to evaluate our research questions. All surveys beyond the collection of demographic information will be based on 5-point Likert scales from “Strongly Disagree” to Strongly Agree.” SCCT constructs of self-efficacy, outcome expectations, interests, choice goals and choice actions will be assessed by the SIC-STEM survey for engineering and technology [42]. Additional information on interest and self-efficacy will come from the engineering and technology questions from a STEM career interest survey (STEM-CIS) [43] and from a career interest questionnaire in which we replace “science” with “engineering” [44]. The custom Likert scale surveys will assess participants’ interests and understanding of bioengineering, electrical engineering, computer programming and the synergy between the three disciplines.

To recruit participants, we will work with our local middle school partners to identify and recommend students who might be interested in applying for the program. Through this outreach, we will recruit from a diverse range of races, ethnicities, and economic demographics for a diverse cohort. Applications received from interested students will be reviewed using a holistic process, including teacher recommendations and a student STEM interest and experience survey. Participants with minimal or no exposure to programming will be invited to online sessions to introduce basic concepts before the start of the camp.

The camp will follow a normal 9-5 schedule with significant community-building activities during the initial days, followed by more content-laden days in which course modules, comprised of a blend of passive and active learning activities, introduce the necessary knowledge and skills. The Raspberry Pi 5 computer (RPi) [35] will be used as the main vehicle for the summer camp. The course will teach Python 3.12, because it has a simple and clean syntax and is a scripting language (i.e., code will run line-by-line, which accelerates acquisition of programming skills by students new to computer programming) [36]. Furthermore, Python has an extensive set of libraries useful for internet access and graphics that will enhance the learning experience for middle school students. The instructional modules for the RPi and for Python programming have been developed by modifying modules that were previously reported [39] for a Python programming course for pre-service teachers. In addition to STEM-based computer projects, this course will emphasize computational thinking, both in designing computer codes and in designing bioengineering projects that can be quantified and enhanced with computer-controlled sensors and actuators.

The general order of topics for the summer camp is given in Table I. Teams of 2-3 participants will be formed early in the camp, and the teams will design, build, test, and evaluate medical devices. There will be four modules per day with breaks between modules. The first day will mainly have community-building activities with brief introductions to technical content and goals of the summer camp. For the next six days, the morning sessions will focus on active learning of Python syntax, best programming practices and computational thinking in a classroom with computers for each student. Preliminary afternoon modules will be dedicated to the exploration of basic circuit concepts and the operation of sensors and actuators by the participants. Later afternoon modules will focus on medical concepts and applications. The next two days will be dedicated to the fabrication, coding, and testing of their medical devices. The final day of the summer camp will be dedicated to the product showcase of the participants' creations followed by the program wrap-up, reflection, evaluation, and closing celebration.

To help determine appropriate biomedical devices for middle-school participants, we organized a focus group with five female students whose ages varied from 11 to 14. The students were introduced to a variety of working biosensors and were asked to gauge their interest in learning how to write the programs to control the sensors and how to construct the sensor circuits. All participants showed enthusiasm and curiosity while interacting with the sensors. Two participants expressed an interest in exploring additional medical devices and one participant developed a keen interest in the operational mechanics of the sensors and their medical applications. Based on the focus group feedback on the various biosensors presented, the conclusion was that two sensors should be utilized in the first summer camp. The HW827 heart rate sensor [40] should be introduced first because of the participants' interest and its simple interface. Second, participants would utilize the MH-ET MAX30102 heart rate / Pulse Oximeter sensor [41] after discussing the I2C communications protocol. Students will also experiment with off-the-shelf Pulse-Ox meters to help them contextualize their experience. Later iterations of the camp could possibly consider other sensors such as EKG measurements, Spirometers, elevated ST segment detectors, etc. after introducing the participants to the impact those devices have on diagnosing medical conditions.

Table I. General order of topics for the summer program		
Week 1 Monday	AM	Introduction to the summer program and icebreakers Introduction to the Python programming language
	PM	Community building activities. Introduction to basic circuit components and Kirchhoff's Laws
Tuesday	AM	Introduction to the Raspberry Pi & GPIO
	PM	Community building activities. Test and measurement equipment & circuits
Wednesday	AM	control flow – decisions and loops
	PM	Introduction to bio-medical devices
Thursday	AM	Functions, Arrays and I/O
	PM	Basic input and output on the GPIO (actuators & sensors)
Friday	AM	Computational Thinking, Pseudocode, debugging
	PM	Discussion and evaluation of the biomedical device to be built
Week 2 Monday	AM	Communication protocols (SPI), Data acquisition from the GPIO
	PM	Planning, Pseudocode development
Tuesday		Code development, hardware fabrication, and preliminary testing
Wednesday		Code development and additional testing
Thursday	AM	Code and hardware refinement, additional testing
	PM	Final data acquisition, report generation
Friday	AM	Course reflection, assessment
	PM	Project presentation and closeout

The HW827 is particularly simple to implement with only power, ground, and a single sense wire. Participants need to learn only a minimum of programming concepts: variables, if/else decisions, for/while loops, timing, and print statements, along with basic concepts related to the

GPIO operation. Students will be able then to print pulse rates on the screen and detect bradycardia and tachycardia. After learning about resistors, LEDs and buzzers, participants can light LEDs or make audible warnings for abnormal conditions or just use an LED to flash with each heartbeat. Only a few dozen lines of code are needed to implement any of these design variations.

Using the MAX30102 sensor (shown in Fig. 1) will require an introduction to the I2C communication protocol, though the functions required to initialize the sensor and extract data need only to be presented and not developed. Code development will be somewhat more involved as the sensor can detect both pulse rate and SPO2 values. In addition to printing SPO2 levels, participants will be asked to plot SPO2 levels over time and produce an audible warning if the SPO2 level falls below a certain value (typically 92%).

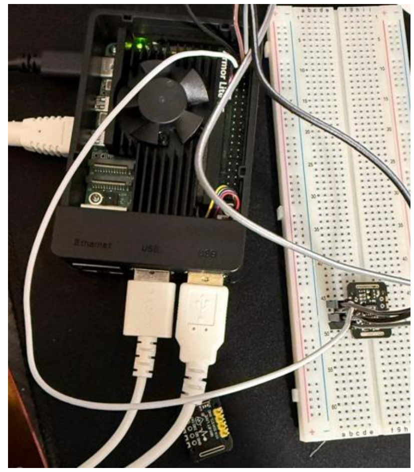

Fig. 1 The MAX30102 sensor connected to the RPi.

The ultimate goal of our research project is to inform on the best practices to develop and deliver instructional materials on bioengineering project-driven design, computational thinking, and programming skills to middle-school girls and gender minority students. It should also inform on the bioengineering applications that are most effective for instilling enthusiasm and interest in electrical engineering and computer science and an appreciation for the value of computational thinking in middle-school girls and gender minority students. We also expect to provide data regarding the effectiveness of enhancing the self-efficacy of girls and gender minority middle school students in STEM fields via our pedagogical strategy of combining concepts from biomedical engineering, electrical engineering, and computer science. Our initial focus group gave us positive feedback on our concept and helped us finalize the projects selected for the first offering of the summer course.

The modules developed during this program will be disseminated to the broader community at the end of the summer camp so that the projects can be readily replicated. Because the necessary hardware, including the Raspberry PIs, is inexpensive and compact, the summer camp can be implemented at low cost. The content could also be presented in other venues, such as after-school programs or internet courses.

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