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Workshops in Computer Science and Cybersecurity: Preparing Underrepresented Minority and Female Students in STEM and Non-STEM Majors

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Abstract

Over the past decades, the urgent need to boost the pipeline of science, technology, engineering and mathematics (STEM) professionals, particularly in engineering and computer science has become increasingly critical. This paper addresses the challenge of preparing underrepresented minorities (URM) and female students in computer science, particularly in cybersecurity, through the integration of diverse academic backgrounds, including both STEM and non-STEM majors. We detail the implementation of five workshops throughout the academic year that successfully enhanced participants' knowledge in computer science, cybersecurity, and engineering.

The curriculum was designed to facilitate learning primarily through hands-on activities, utilizing a low-cost, single-board computer such as the Raspberry Pi and Micro-bit, interfacing with various IoT sensors, and network simulation software such as Packet Tracer. In addition to outlining the curriculum and practical activities conducted during the 2023-2024 academic year, this paper highlights the challenges encountered during the initial workshop sessions due to the diversity of technical backgrounds and knowledge. It also emphasizes the motivation and determination exhibited by students, which contributed to successfully completing the workshop series. By sharing these insights, we aim to provide valuable information to educators and institutions looking to foster greater inclusion and engagement in the STEM fields.

Introduction

For the last few decades, STEM programs have been underrepresented by minority students, primarily female students in higher education. Fields such as computer science and engineering are where the absence of minority and female students is more noticeable; however, subjects such as biology, chemistry, and life sciences are more attractive to female students when selecting a college degree and potential career paths [1]. To address this disparity and increase the diversity of students in computer science and cybersecurity, especially underrepresented minorities (URM) and women, it is necessary to create awareness and foster interest from an early age [2]. Implementing effective STEM programs in the K-12 system [3] or at early stages in college is essential to inspire and increase the number of underrepresented minorities and women to consider STEM fields. Without these early interventions, it may be too late for many students to explore and pursue STEM opportunities later in their academic journey [4].

According to the U.S. Bureau of Labor Statistics' Occupational Outlook Handbook [5], information security analysis is one of the fastest growing occupations followed by software developers, software quality assurance and testers with diverse responsibilities to oversee and prevent security vulnerabilities in organization's infrastructure and systems. In Georgia, these occupations are rated one of the fastest-growing jobs through 2030 [6]. Georgia Department of Labor predicts a similar trend and considers information security analysis, computer and information systems, and other computer-related occupations as ‘hot careers’ through 2032 [7] highlighting the increase demand for skilled professionals in this area.

The workshop series was an initiative from the Consortium on National Critical Infrastructure Security (CONCISE) NSF grant to develop cybersecurity and computer science knowledge and skills for underrepresented minority students. This program involved collaboration between The University of Texas at San Antonio and Savannah State University during the 2023-2024 academic year. A key aspect of the CONCISE initiative was providing student stipends to attend conferences and participate in a series of workshops. The participants’ selection process was not limited to STEM majors but to Homeland Security, Forensic Science, Information Systems, and other related study areas. The student selection process was based on GPA (minimum 3.0) and interest in cybersecurity, computer science, or engineering.

This paper describes the five workshops designed to introduce computer science and cybersecurity concepts to high-quality undergraduate students across several disciplines. By promoting awareness and understanding of computing, these workshops aim to empower participants and inspire them to consider careers in these critical fields.

Workshop Goal, Structure and Curriculum Overview

The workshops aimed to encourage and broaden student exposure to computer science and cybersecurity, providing participant with foundational knowledge and practical skills. While the majority of the selected students were sophomores and juniors pursuing STEM disciplines, a significant number were non-STEM majors. This diversity in academic background presented unique difficulties during the initial workshop sessions.

Many non-STEM students had limited prior exposure to fundamental concepts in computer science, cyber security or engineering, without the essential terminology and principles. To address these disparities, we implemented a peer-assisted learning approach, pairing student with stronger background in technical subject with those who less experienced. This strategy not only facilitated knowledge transfer but also foster collaboration and engagement among participants.

Recognizing the need for a tailored instructional approach, the workshops incorporated introductory modules designed specifically for non-STEM majors. The curriculum emphasized hands-on activities in computer science, learning fundamental programming concepts such as conditional statements, iteration structures, and lists using C and C++. In addition, cybersecurity principles (CIA – Confidentiality, Integrity, and Availability) were introduced by completing several hands-on activities on cryptography (encryption and decryption), password cracking, and network traffic monitoring. By providing a supportive learning environment that acknowledged and embraced the diverse backgrounds of all participants, we aimed to bridge the knowledge gap and empower every student to engage meaningfully with the material.

Finally, the workshops sought to not only enhance technical knowledge but also to inspire a sense of belonging and confidence in students who may have previously felt intimidated by the complexity of STEM disciplines [8]. The workshop sessions aimed to raise awareness of computing and engineering disciplines among 25 undergraduate scholars through hands-on activities and collaborative peer-assisted learning.

Learning Objectives

Students were provided with the knowledge and skills to:

- Understand fundamental concepts of computing and engineering
- Work with Internet of Things (IoT) sensors, Raspberry Pi, and Arduino microcontroller
- Use Micro:bit
- Utilize specialized software (Packet Tracer) to simulate a network environment
- Gain exposure to Cybersecurity tools for password cracking and vulnerability assessment

Activities

During the five Saturday workshops, students were first introduced to the cybersecurity Triad principles/practices, including Confidentiality, Integrity, and Availability (CIA). These three concepts were explained in detail by providing relevant information about the importance of the CIA-Triad in today's technology. During the first workshop, since there was a diverse population of undergraduate students with different educational backgrounds, students were paired with either a computer science or engineering technology student. This approach not only facilitated collaboration but also provided additional support to the faculty members during troubleshooting activities, allowing students to learn from one another and gain confidence in their abilities.

The workshop covered essential concepts of encryption and decryption, and participants were introduced to two specialized software tools to monitor network traffic and attempt password cracking. These practical applications helped students to get a solid understanding of the theoretical knowledge presented.

Furthermore, to enhance participants knowledge, fundamental computer science and programming concepts were introduced using the Micro:bit [9] microcontroller, a small device suitable for teaching and introducing computing concepts. In order to introduce the participants to programming concepts, Makecode [10] block-based programming was used to complete several hands-on activities. Makecode is a simple online user-friendly simulator tool that allows students to learn programming by visually see in real-time how their program runs before uploading it to the device. Figures 1, 2, and 3 show the hands-on activities in which students interfaced the Micro:bit with the Makecode. The breakdown of the module learned and time is shown in Table 1.

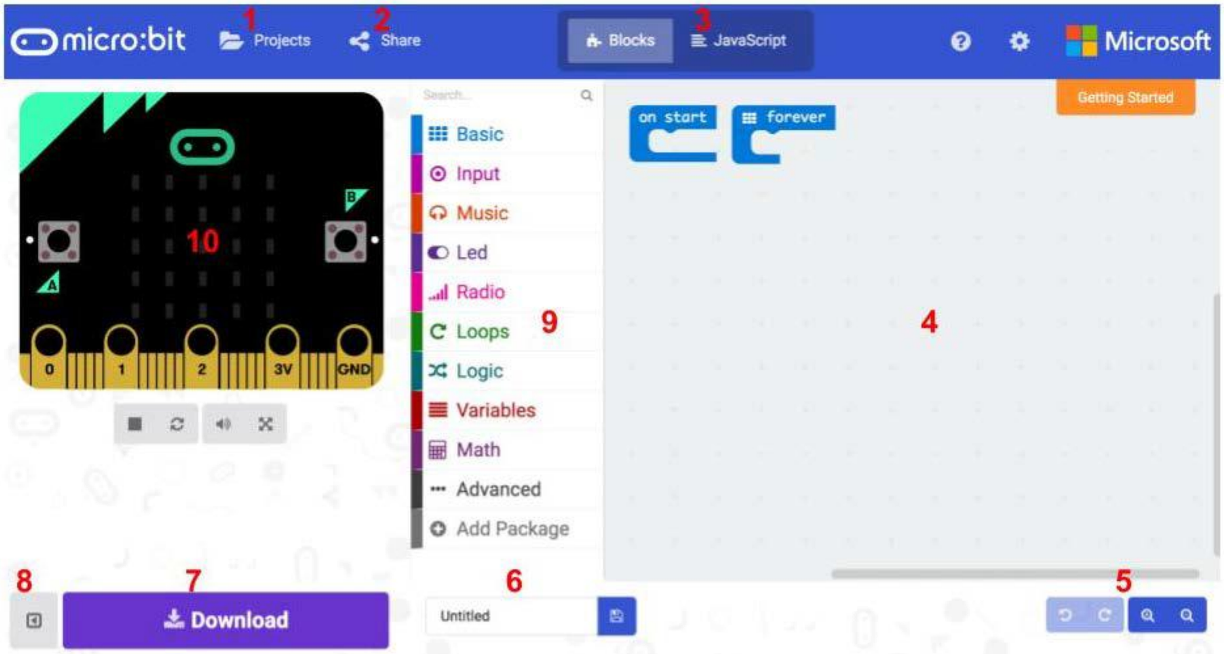

Figure 1: Makecode simulator

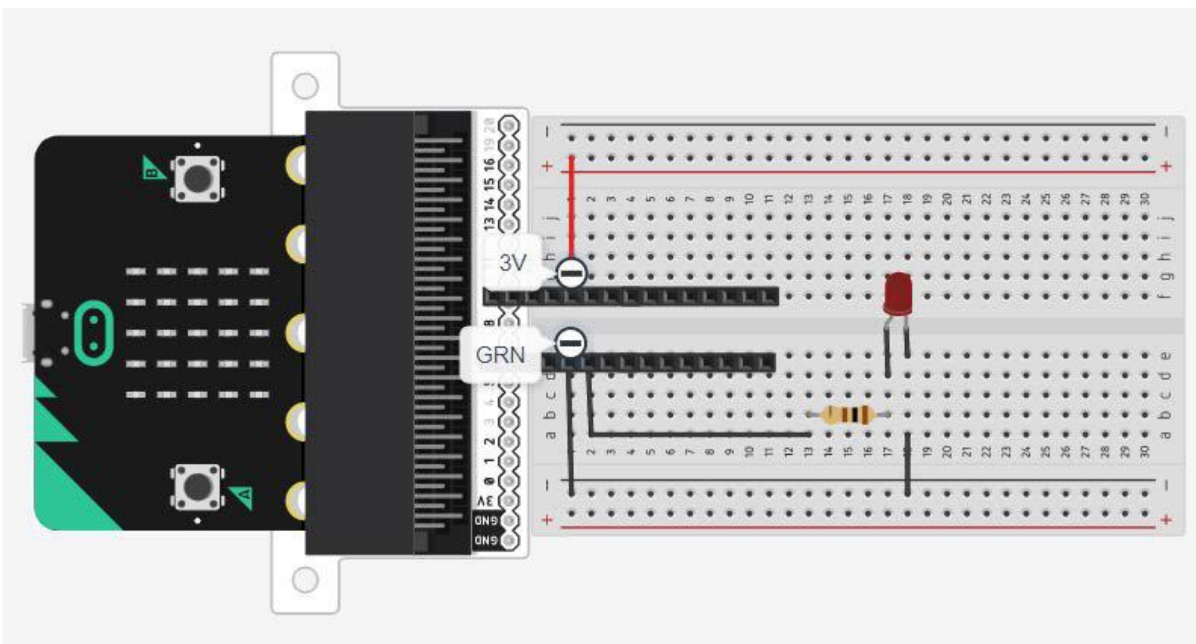

Figure 2: Micro:bit interface prototype

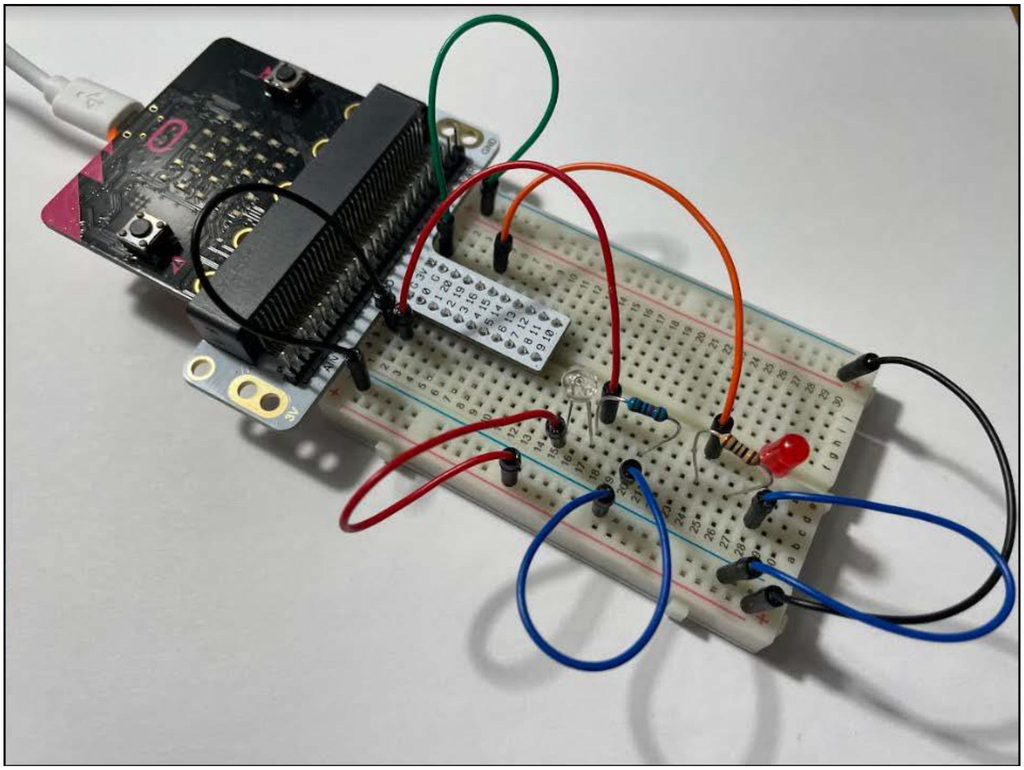

Figure 3: Final Prototype using motion sensor

Table 1: Instructional Modules/Time

MODULES	TIME
WORKSHOP: 1	
Introduction to Cybersecurity: • Introduction to CIA-Triad • Introduction to cryptography • Introduction to cybersecurity tools (password-cracking and network monitoring)	2.0 Hours
BREAK	0.25 Hours
Introduction to Programming Fundamentals: • Introduction to Micro:bit • Introduction to block-based programming • Introduction to text-based programming • Introduction to variables, conditional statements, iteration structures, etc. Introduction to Micro:bit IDE and Makecode IDE	3.0 Hours

During the second and third workshops, the Raspberry Pi [11] and IoT sensors [12] were introduced to students, but the initial configuration of the Pi was completed previously to expedite the learning experience during the workshops. However, each student successfully completed the configuration to interface the IoT sensors with the Pi. Students learned during these sessions how to program the Pi and IoT sensors using text-based programming; students used Leafpad, a simple Linux text editor, due to the diverse educational backgrounds of the participants. The students were given a discussion of the basic concepts of various sensors, such as LED, motion and ultrasonic sensors, and LED matrix display. In addition, the students were taught how to debug (troubleshoot and fix) their programs to run effectively. Figures 4, 5, and 6 show the activities in which students interface the Raspberry Pi with the IoT sensors.

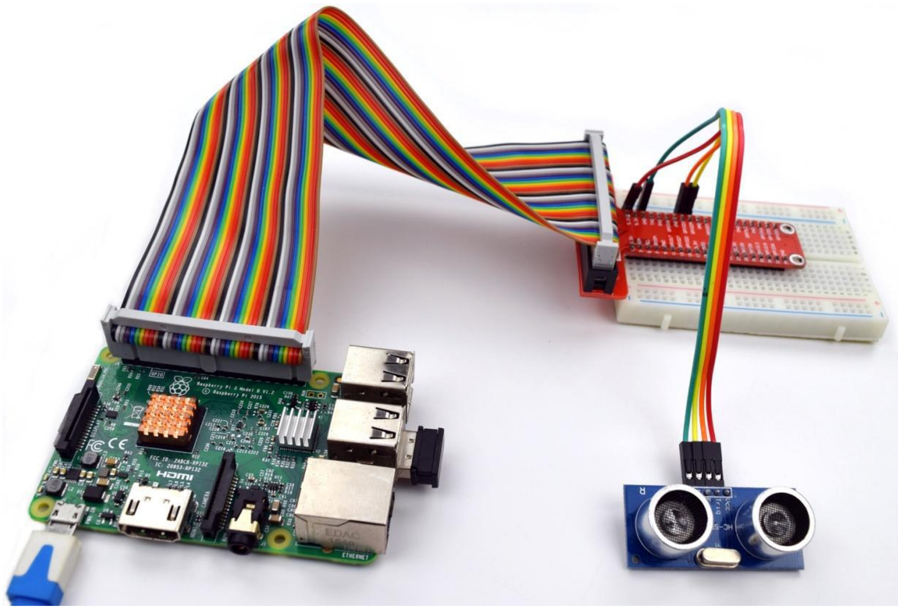

Figure 4: Raspberry Pi interfacing with an ultrasonic sensor prototype

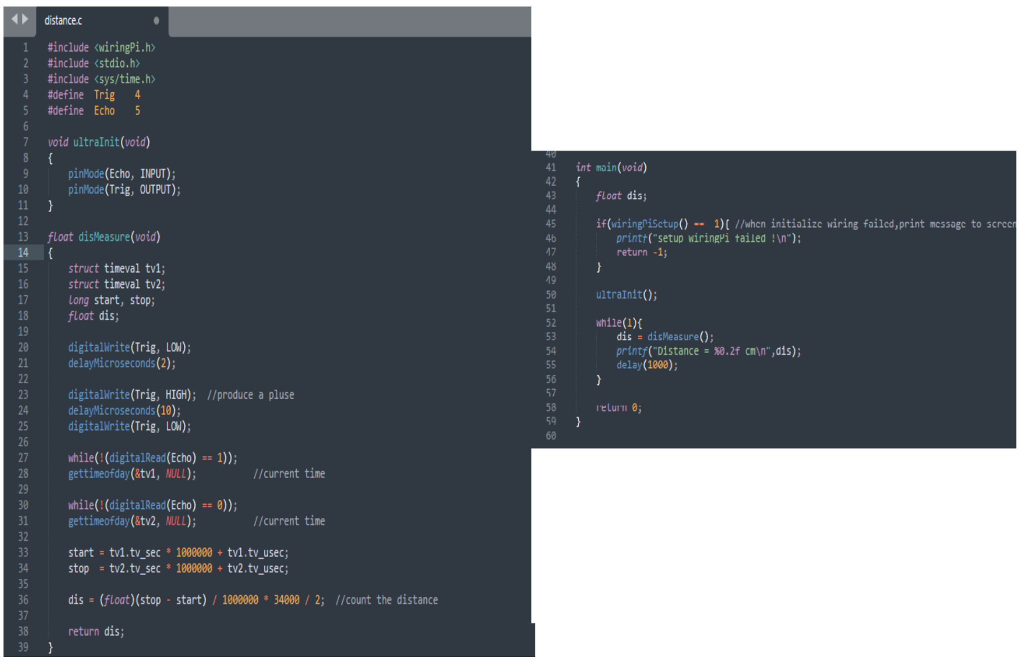

Figure 5: Ultrasonic program to measure distance

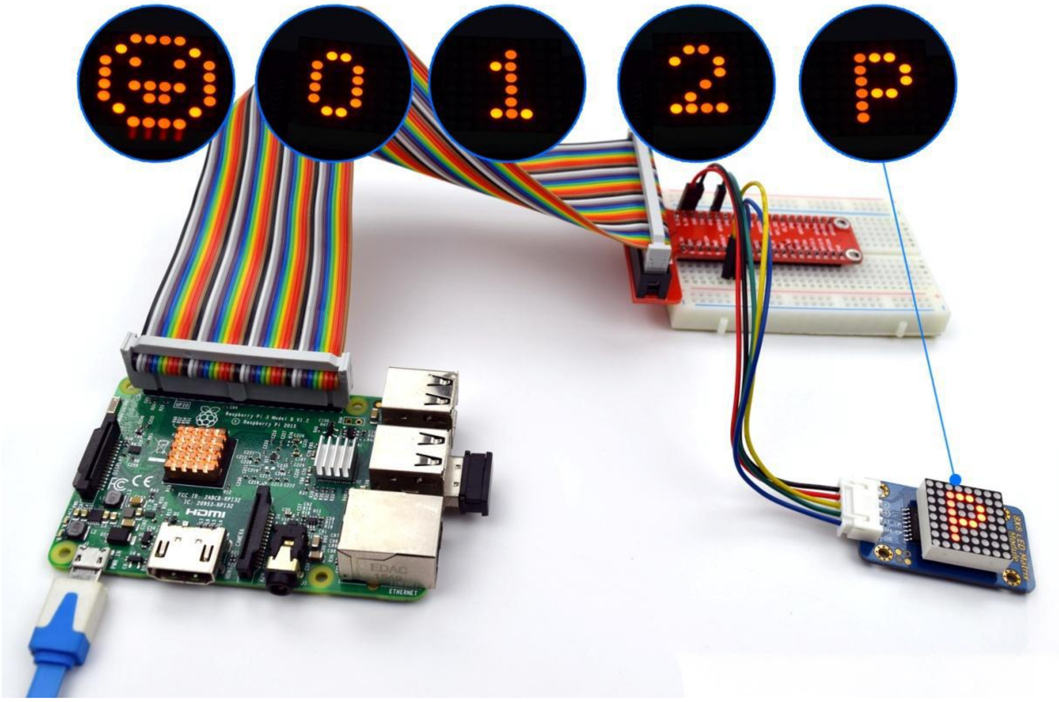

Figure 6: LED matrix display prototype

The main objective of these activities was for students to understand how sensors interface with the Raspberry Pi microcontroller to detect motion, measure distance by converting the echo return time to obtain the distance in centimeters or inches and display a message on the LED matrix display. The breakdown of the module learned and time is shown in Table 2.

Table 2: Instructional Modules/Time

MODULES	TIME
WORKSHOP: 2	
Introduction to Raspberry PI and IoT Sensors: • Introduction to Pi configuration • Introduction to prototype building Introduction to text-based programming: • Introduction to Leafpad text editor • Introduction to programming fundamentals (variables, conditional statements, and iteration structures)	2.0 Hours
BREAK	0.25 Hours
Introduction to Programming Fundamentals: • Introduction to LED • Introduction to variables, conditional statements, iteration structures, etc.	3.0 Hours
WORKSHOP: 3	
• Introduction to motion and ultrasonic sensors	2.5 Hours
BREAK	0.25 Hours
• Introduction to LCD matrix display	2.5 Hours

In the last two workshops, students engaged with a Smart Home IoT sensor kit [13] and Arduino microcontroller [14]. Furthermore, to enhance their understanding, participants were introduced to various sensors included in the Smart Home sensor kit, such as RFID, servo, smoke detector, and temperature sensors. A discussion highlighted the purpose and applications of these technologies in today's environment. During these hands-on activities, students collaborated in pairs to assemble and program the IoT sensors to interface with the Arduino board. In addition, students implemented a single program to interface multiple sensors, including LED, motion, ultrasonic, and LCD; all these sensors were used during the course of the workshop sessions.

Unfortunately, due to the diverse students' educational backgrounds, an Android app to control the sensors from a mobile device was not fully implemented. However, the students were introduced to Android Studio IDE [15], which allowed them to design and create their user interface (UI) through a drag-and-drop control object functionality. Figures 7 and 8 show the activities in which students interfaced the Arduino microcontroller with the IoT sensors and the students' UI design in Android Studio.

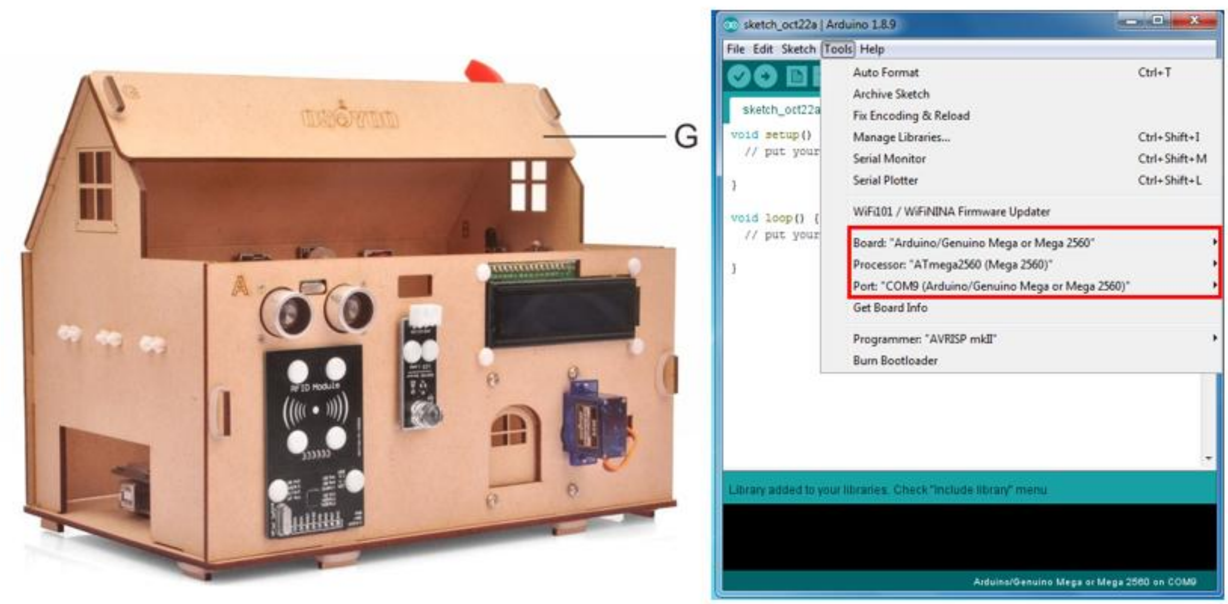

Figure 7: Smart Home Sensor kit assembly and Arduino IDE configuration

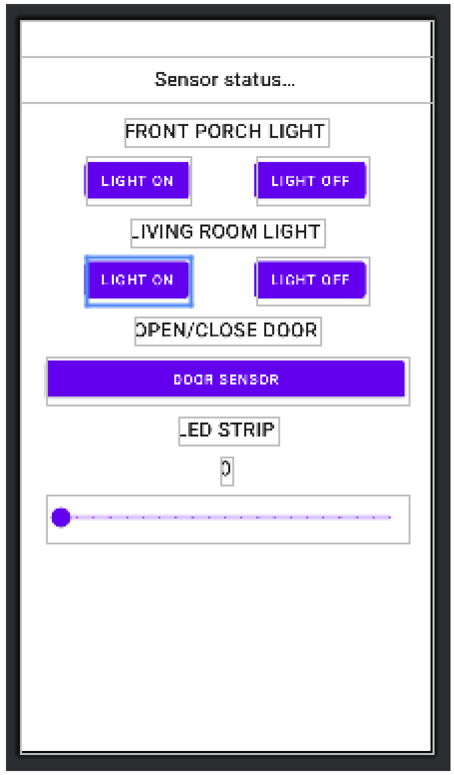

Figure 8: Android app UI design

The main objective of these activities was to help students understand how sensors interface with the Arduino microcontroller to detect motion and simulate opening doors using servo motors. In addition, students were introduced to various sensors used in today's Smart homes. Each group had the opportunity to test their final Smart Home prototype and ensure it was fully functional before starting working on the Android application. The breakdown of the module learned and time is shown in Table 3.

Table 3: Instructional Modules/Time

MODULES	TIME
WORKSHOP: 4	
Introduction to Arduino and IoT Sensors: • Smart Home assembly	2.0 Hours
BREAK	0.25ours
• Introduction to Arduino IDE and board configuration to interface sensors.	3.0 Hours
WORKSHOP: 5	
• Arduino IDE and board configuration to interface sensors.	3.0 Hours
BREAK	0.25 Hours
• Introduction to Android Studio to create a simple app	2.0 Hours

Metrics, Evaluation, and Future Research

The current paper does not include a research method, using quantitative metrics, and a theoretical framework to evaluate the effectiveness and impact of the workshops. This oversight is primarily because the authors were not directly involved in the collaboration between The University of Texas at San Antonio and Savannah State University. To address this gap, future iterations will incorporate comprehensive participant surveys designed to measure various aspects of the workshop experience. These surveys will assess knowledge gain by comparing pre- and post-workshop evaluations, allowing us to quantify improvements in understanding key concepts in computer science and cybersecurity.

In addition to knowledge assessment, the surveys will gauge participants' interest levels before and after the workshops, providing insights into how the program may influence their perceptions of these fields. We will also investigate barriers that students face when considering degrees in computer science or cybersecurity, even as a minor. Identifying obstacles such as lack of confidence, awareness, or resources will be crucial in tailoring the workshops to meet participants' needs.

Understanding the motivations behind participants' enrollment—especially given the significant time commitment required—will also be essential for refining future workshops. Questions will explore why students chose to participate, what they hope to gain, and how these workshops align with their academic and career aspirations.

Future research should focus on examining participants' reasons for signing up and assessing any shifts in their interest or capabilities related to pursuing STEM education. Specifically, we will track changes in their attitudes toward computer science, cybersecurity, and engineering, as well as any increased engagement in related coursework or extracurricular activities. By gathering and analyzing this data, we aim to create a more effective and impactful workshop series that inspires and supports students on their educational journeys in STEM fields.

Conclusion

The series of workshops designed to engage underrepresented minority and female students in computer science and cybersecurity has proven to be significantly beneficial in enhancing diversity in STEM fields. By integrating hands-on experiences with fundamental programming and cybersecurity concepts, the workshops successfully satisfied participants from diverse academic backgrounds, fostering a supportive learning environment.

The implementation of practical activities using tools like Raspberry Pi, Micro:bit, Arduino, and IoT sensors not only facilitated the acquisition of technical skills but also encouraged collaboration among students. Despite challenges posed by different levels of prior knowledge and educational backgrounds, the determination and enthusiasm exhibited by the participants was amazing. All participants expressed a new level of interest in the computing field after completion of the workshops.

This initiative demonstrates the importance of early intervention in STEM education [3], particularly for URM and female students, highlighting the need for continuing investment in inclusive educational practices. By sharing the insights gained from these workshops, we aim to continue adopting similar approaches, thus contributing to a more diverse and skilled workforce in the fields of computer science and cybersecurity.

Acknowledgment

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