Investigating Student Perceptions of a Digital Health Summer Program

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Introduction

Early exposure to hands-on learning in Science, Technology, Engineering, and Mathematics (STEM) plays a critical role in shaping students' academic interests and long-term career trajectories [1]. As demand for professionals in engineering, computing, and healthcare continues to grow, interdisciplinary fields such as digital health have emerged at the convergence of these domains. Digital health relies on core technical components such as microprocessors, sensors, data science, and artificial intelligence to drive innovation in healthcare delivery, diagnostics, and monitoring. Preparing a future workforce capable of operating at this intersection requires early and authentic exposure to these technologies.

Summer programs that integrate technical instruction with real-world applications represent a promising strategy for fostering STEM engagement. In response to this need, Rice University developed a three-week experiential learning program designed to introduce high school and community college students to digital circuitry, computer science, and engineering through healthcare-focused applications. The overarching goal of the program is to address the growing demand for advanced technical training in integrating microelectronics and biotechnology within the digital health sector. The purpose of this study is to examine student perceptions of the program's effectiveness in supporting learning and skill development. This study is guided by the following research question:

To what extent does participation in the Digital Health program influence students' perceived learning outcomes and measured gains in technical coding skills?

Literature Review

Experiential Learning Theory

This study is grounded in Kolb's Experiential Learning Theory, which posits that knowledge is created through experience and that meaningful learning occurs through a cyclical process of concrete experience, reflection, conceptualization, and active experimentation [2]. Experiential learning has become a crucial instructional approach in STEM education, and a substantial body of literature has examined how these learning experiences can be effectively designed, implemented, and evaluated [3]. Experiential learning is particularly valuable in STEM contexts because it provides students with opportunities to engage in practical, contextualized problem-solving beyond traditional classroom instruction [4]. In this summer program, students engaged in experiential learning through continuous interaction with university faculty and graduate student mentors. Participants were immersed in authentic tasks such as conducting needs assessments, developing prototypes, and articulating value propositions for digital health solutions.

As higher education increasingly emphasizes employability and workforce readiness, experiential learning has become essential for bridging the gap between academic instruction and industry expectations. [5] highlights the importance of aligning educational experiences with professional practice, making experiential learning particularly well-suited for programs preparing students for STEM fields.

Integration of Experiential Learning in Engineering Education

The transition from academic settings to the STEM workforce has received increased attention in recent years, particularly amid declining student preparedness in foundational subjects. A report from the National Science Foundation noted a significant decline in U.S. student mathematics performance between 2019 and 2022, raising concerns about future STEM workforce readiness [6]. These trends underscore the need for more robust, authentic learning experiences that better prepare students for STEM careers.

Despite the growing importance of digital health, current K–12 and community college curricula often provide limited exposure to foundational engineering and computing concepts. For example, in Texas, formal instruction in electrical circuits is introduced in fifth grade and later revisited in a second-semester high school physics course. As a result, many students enter higher education with limited experience in circuit design, programming, data science, or machine learning. Current workforce demands necessitate earlier exposure, particularly at the high school [7] and community college levels [8]. Strengthening partnerships among K–12 schools, community colleges, universities, medical centers, and industry stakeholders is therefore critical to providing students with the experiential learning opportunities needed to succeed in the evolving STEM workforce.

Assessment of Technical Coding Skills

Assessing learning outcomes is an essential component of evaluating STEM outreach programs. As coding has become an integral element of STEM education, a variety of programmable platforms, such as Arduino, have been widely adopted across educational levels [9]. The Arduino platform is an open-source hardware and software environment that enables students to design and implement interactive electronic projects, and its accessibility and versatility make it well-suited for teaching foundational programming and electronics concepts [10], [11]. Previous studies have demonstrated the effectiveness of Arduino-based instruction in enhancing student engagement and coding proficiency in educational settings [12]. Consequently, validated assessment instruments such as the Arduino-Based Assessment of Coding (AABC) have been developed to objectively measure coding skill development among new learners [9].

Methods

Research Design

This study used a two-part design to examine (1) changes in participants' coding skills and (2) student perceptions of the Digital Health program's effectiveness, including program satisfaction, content knowledge, and educational impact. To assess perceptions of program effectiveness, students completed a post-program survey that captured their experiences and perceived learning outcomes. To measure changes in technical skills, participants completed an AABC-validated coding assessment instrument at the beginning and end of the program.

Program Design and Participants

The program took place in July 2025 at Rice University and served two cohorts totaling 29 students (15 in the high school cohort and 14 in the community college cohort) from the Greater Houston Area. Students were recruited through partnerships with local schools and community colleges, as well as through program outreach efforts. Eligibility criteria for the program included enrollment in high school or a community college and an interest in STEM-related fields. All students selected for the program were invited to participate in this research study. The three-week curriculum combined technical instruction, hands-on Arduino projects, faculty talks, and campus experiences. Some of the technical skill development included:

- Basic C programming
- Python programming
- Machine learning and computer vision
- Printed circuit board (PCB) design
- Foundational electrical circuit concepts
- Topics in neuroengineering and the history of computing, including wearable health technologies

During the three-week program, the students worked in pairs to identify a health need and developed a technological solution using their programming and hardware skills. They also toured key campus facilities at Rice University, including the Clean Room and the Oshman Engineering Design Kitchen (OEDK). Students participated in professional development sessions and learned to create research posters while applying best practices in visual communication. The program concluded with a Digital Health Symposium, where student pairs presented their health-focused prototypes and research posters to an audience of faculty, staff, students, family members, and teachers. Therefore, the program intentionally aligned with Kolb's experiential learning theory by integrating applied design, structured, reflection, conceptual learning, and real-world presentation opportunities.

Data Collection

Students completed surveys at two points during the program: at the beginning and at the end. On the first day, participants completed only the pre-program Arduino-Based Assessment of Coding (AABC) instrument, which assessed baseline coding skills. The AABC consists of 15 items designed to assess foundational Arduino programming and coding concepts. Each item is worth one point, resulting in a maximum possible score of 15. The instrument has been previously validated for use with novice learners and has demonstrated reliability in assessing introductory coding skills.

On the final day of the program, students completed the post-program AABC instrument and an additional post-program feedback survey. Post-program AABC allowed us to measure gains in coding skills from pre- to post-program. The post-program feedback survey, which included 13 quantitative items on a Likert-type scale and two open-ended questions, was designed to assess overall satisfaction, the perceived effectiveness of the program, and the influence on academic and career interests.

Data Analysis

Pre- and post-program AABC scores were analyzed using a paired-samples t-test to determine whether statistically significant changes in coding proficiency occurred over the course of the program. Statistical significance was set at $p < .05$. Quantitative feedback survey data were analyzed using descriptive statistics to summarize student satisfaction and perceptions of program effectiveness, while qualitative responses were examined to provide a more detailed understanding of students' feedback.

Results

Coding Skills

To assess changes in coding proficiency, pre- and post-program scores on the Arduino-Based Assessment of Coding (AABC) [13] were compared using a paired-samples t-test. The results are shown in Table 1. Results indicated a statistically significant improvement in coding skills over the duration of the program. Mean AABC scores increased from 4.48 (SD = 3.09) on the pre-test to 8.59 (SD = 3.20) on the post-test. This difference was statistically significant, $t(28) = 5.87$, $p < .001$, indicating substantial gains in students' proficiency with Arduino programming. These findings suggest that the hands-on instructional approach was effective in promoting measurable technical skill development within the program's time frame.

Table 1: Paired T-Test Results, n=29

	Mean	Standard Deviation	t(df)	p-value	Mean Difference	Cohen's d (effect size)
Pre	4.48	3.09				
Post	8.59	3.20				
Difference	4.10	3.76	5.87(28)	< 0.001	4.10	1.09

Program Satisfaction

Survey responses indicated overwhelmingly positive perceptions of the program. In Cohort One, 11 of 15 students reported being "Fully Satisfied," and in Cohort Two, 13 of 14 students selected the same response. The 13 students in both cohorts also reported that they would "Definitely" recommend the program to others. All respondents either "Strongly" or "Somewhat" agreed that instructors were effective demonstrators who stimulated interest in the material, and 93% all participants "Strongly Agreed" that instructors were responsive and helpful. These results reflect both high instructional quality and strong student–instructor relationships.

Content Knowledge and Educational Impact

Participants reported that the program influenced their academic and career interests. Eight students indicated increased interest in pursuing computer science, eleven reported increased interest in engineering, and four in both fields. When asked to self-report their skills prior to the start of the program on a five-point scale (ranging from poor, fair, satisfactory, very good, to excellent), all students rated their content knowledge as satisfactory or below. However, when asked to complete the same assessment at the end of the program, responses shifted, with 70% of students reporting their skills as very good or excellent. This pattern suggests growth not only in technical competence but also in confidence.

Open Ended Feedback

Qualitative feedback reinforced the quantitative findings. Students frequently identified hands-on coding, circuitry, and Arduino-based projects as the most valuable components of the program. Many highlighted the real-world application of their work and the opportunity to engage in authentic research experiences. For example, when asked about their favorite part of the program, a student in Cohort 2 reflected, *"Learning how to program hardware that actually functioned in the real world . Making something that has a real-world application."* Instructor support, particularly in troubleshooting final projects, was also widely praised. For example, a student from Cohort 2 expressed, *"Constant help when I needed assisting with my projects was very good."* Representative comments included reflections on exposure to real scientific research, programming hardware with real-world functionality, and creating applied solutions such as the TinyScreen smartwatch project. A student in Cohort 1 mentioned, *"[The Digital Health Program] exposed me to what someone in a science filed would be doing (doing research) and gave me opportunities that I normally wouldn't have."*

When asked how the program could be improved, students most commonly suggested extending the program length to allow for more in-depth instruction and advanced projects. Some participants recommended providing a stronger foundational introduction to coding for beginners, while others suggested greater gender balance among mentors. Overall, feedback emphasized a desire for expanded learning time and additional instructional scaffolding rather than fundamental program changes.

Discussion

The results suggest that the program was effective in enhancing technical skills that could potentially lead to fostering interest in STEM careers. Integrating health applications likely increased the program's relevance for students, and the findings support experiential learning as a valuable model for STEM outreach and education. This study found that high student satisfaction and significant improvements in coding skills suggest that short-term, immersive programs can positively influence both learning and student attitudes. Notably, the increase in AABC scores shows that hands-on, project-based instruction can build measurable skills even in just three weeks. For example, a study conducted by researchers at Geroge Mason University [14] found that a one-day robotics workshop using a bioinspired blimp platform resulted in statistically significant pre- to post-assessment gains among middle school students, demonstrating measurable improvements in STEM knowledge. These findings align with the results of the present study, reinforcing that even short-term, project-based instruction can foster meaningful skill development.

These results align closely with Kolb's Experiential Learning Theory, which emphasizes learning through active engagement, reflection, and application. Hands-on Arduino and circuitry activities provided students with concrete learning experiences, while discussions and problem-solving fostered reflection and understanding. Also, applying these concepts to real-world health scenarios allowed students to actively experiment. This approach likely contributed to the increases in confidence and perceived competence reported by participants.

In recent years, coding has become an essential component of education at all levels, leading to the emergence of programmable platforms such as Arduino. These tools provide students with hands-on opportunities to develop and strengthen their coding skills. However, the literature reveals a lack of studies examining how assessment instruments, such as the AABC tool, can be used to evaluate students' coding abilities [9]. This study addresses that gap by using the AABC tool to assess the coding skills of students who completed a program specifically designed to develop coding competencies. By doing so, it contributes to the growing body of research on the use of available coding assessment tools in educational settings. The results showed a significant increase in participants' AABC scores, which indicates improved efficiency in Arduino programming. These findings align with existing literature suggesting that Arduino-based activities can motivate students to engage more deeply in learning [15] and support learning to code through playful, hands-on experiences [16].

Despite these positive outcomes, several limitations should be considered. The study's sample size was relatively small and drawn from two cohorts of a single program, which may limit the generalizability of the findings. Additionally, student perceptions were measured using self-reported survey data, which may be subject to response bias. In addition, self-selection bias may be present, as students who chose to participate in the program may already have had a higher level of interest in STEM or stronger technical skills. The short duration of the program also limits the ability to assess long-term impacts on academic persistence or career outcomes. Future research should explore longitudinal designs, include comparison groups, and examine how similar programs can be scaled or adapted for different student populations.

Conclusion

This study examined student perceptions and learning outcomes from the Digital Health program, a STEM-focused experiential learning initiative for high school and community college students. Findings indicate that the program effectively enhanced coding proficiency, boosted confidence in technical abilities, and fostered interest in STEM careers. Participants reported high levels of satisfaction and highlighted the value of hands-on learning, real-world health applications, and a supportive instructional environment.

Feedback from both cohorts demonstrates that the program successfully engages students, develops technical skills, and inspires continued pursuit of STEM fields, particularly computer science and engineering. Students consistently praised the quality of instruction and the program's emphasis on applied, meaningful projects. Self-reported skill growth was strong, and many participants indicated that the experience influenced their academic and career interests.

While overall responses were overwhelmingly positive, some students suggested providing more foundational coding instruction for beginners and allowing additional time to explore advanced projects. These insights highlight opportunities to further enhance the program, while reinforcing the effectiveness of interdisciplinary, experiential summer programs in strengthening the STEM pipeline and preparing students for future academic and professional pathways.

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