Board 165: Evaluation of an Introductory Computational Thinking Summer Program for Middle School to Identify the Effects of Authentic Engineering Experiences (Work in Progress)

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Abstract

Experiences and opportunities in computer science allow students to build positive associations with STEM and STEM careers. There is a need to provide students with opportunities in computational and design thinking at a young age to increase interest and engagement in the computer science field. The Goldberg Gator Engineering Explorers (GGEE) is a donor-funded summer program designed to provide no-cost computer science-based experiences to underrepresented middle school students to support the K-12 pipeline. The 2022 GGEE program was held in six school districts across Florida and hosted over 110 students in 8 program sessions. The programs were four full-day or eight half-day sessions, depending on the district's summer schedule. The program engaged students in computer science through computational thinking, programming, design thinking, and real-world engineering experiences using micro:bit microcontrollers. K-12 lead teachers and undergraduate student mentors were trained and upskilled in the program materials to facilitate sessions and broaden their programming experience.

During the program, students completed activities to understand computational thinking, how computers work, the micro:bit, and the MakeCode programming environment. [1], [2] These activities introduced basic programming skills through simple projects that grew to students designing a rock paper scissors game and a light intensity meter to explore the relationship between distance and light intensity. Students then participated in two design-based challenges. A creative challenge: designing a micro:bit pet for a partner, and a technical challenge: creating a solution to an industry problem to expand and apply programming skills and engineering design.

The program assessment was designed to study the motivation and identity of students toward science and engineering. Assessment for technology has challenges, as some attributes of science and engineering may demotivate students. The GGEE program collected qualitative and quantitative data from student interviews, observations, surveys, and school district student data, and IRBs were obtained at the university and district levels. Students completed surveys before the camp started, at the end of each day, and at the end of the program. Students rated feelings about activities they completed – confidence, enjoyment, interest, and difficulty, identity as an engineer or scientist, application of the activities in school and future careers, and rating their coding ability. Students were interviewed to describe their camp experience, what they found challenging, what they learned, and why they decided to attend the camp. A longitudinal assessment will study the influence of the student's demographic data, summer program experience, motivation for computational thinking and design thinking on grades and course enrollment. Multiple regression analysis was used to determine the significant predictors of grades and course enrollment and if the summer program experience moderates the effect as predictors of grades and course type enrollment.

Introduction

As the landscape of computer science-related fields constantly changes, it can be challenging to construct a sustainable K-12 pipeline to careers that may not even exist yet. The Bureau of Labor Statistics Employment Projections reports 67% of new jobs in STEM are in computing, with only 11% of STEM graduates studying computer science reported by the National Center for Education Statistics IPEDS Completion Surveys. [3]–[5] Literature indicates programs that include programmable devices and involve inquiry and design-based practices early in education have positively affected math and science performance during the school year [6]–[8].

More research needs to be done on the impact of computer science and STEM summer programs on grades, class choices, and identity during the school year. Many programs do not study the longitudinal impact on students [9]. Understanding impacts could influence how summer programs are utilized, designed, and supported. It is of interest to investigate if summer programs that engage students in authentic science and engineering experiences have sustained impacts on grades and courses. [8]

Summer programs and other informal science education experiences engage students' attention in STEM fields while providing an experience responsive to student interest. [10]–[12]. The Goldberg Gator Engineering Explorers (GGEE) Summer Program was designed for underrepresented middle school students, rising 6th-9th graders, with varying levels of interest and experience. Students learn computational thinking and programming basics and explore and collaborate to construct solutions to multiple design-based challenges using micro:bits. The program studies short-term and long-term student data to investigate real-time changes in students' identity and motivation as they complete more challenging projects. Student data is arranged to be collected to investigate the impact of the summer program on student grades and enrollment.

Program development

A university donor wanted to support a computer science-based summer program requiring little coding experience and no participation costs. The program was anchored in engineering design to foster problem-solving, computational thinking, and programming skills to create solutions and increase confidence and identity as scientists and engineers. At the end of the program, students were allowed to take home their micro:bits [1] to continue coding.

The program was initially intended to be a weeklong, five-day program. Four-day and eight-day program variations were developed to meet school and district summer scheduling needs. A roadmap of the program, Figure 1, shows a high-level view of the GGEE summer program. The program began with an introduction to programming and computational thinking basics. Students constructed process maps to outline the inputs, steps, and outputs to build

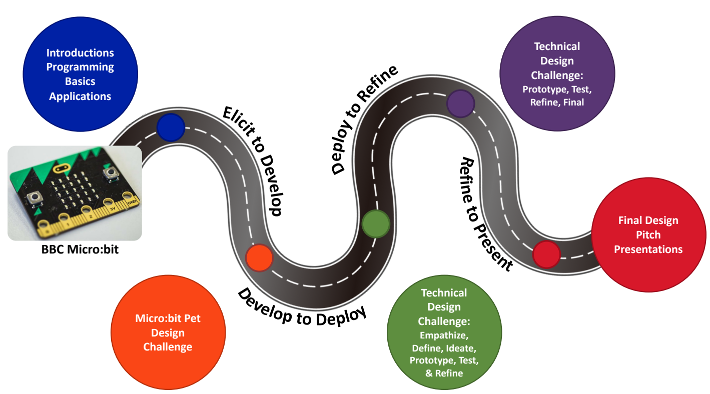

Figure 1: High-level program roadmap

micro:bit programs in MakeCode's block coding environment. [1], [2] Students applied coding basics; strings, icons, loops, and conditional logic statements; to program a game of rock, paper, scissors and to measure, collect, and analyze light-intensity data. The remainder of the program was centered around design-based challenges using the Stanford Design Thinking Model. [13] There was a creative challenge: designing a micro:bit pet for a partner and a technical challenge: creating a solution to an industry problem. Both challenges ended with presentations to the class and facilitators.

Pilot summer program

Recruitment of schools, districts, leaders, and students was completed after program design. Six districts across Florida hosted eight sessions held throughout June and July. All but one of the participating schools were classified as Title I. The donor covered all personnel costs, travel, technology, and meals. Prior grant teachers, along with undergraduate research students, were recruited to lead the sessions owing to experience with the grant's program design. Undergraduate students from a variety of backgrounds served as assistants to the primary facilitators, as well as mentors for the program participants. Student participants were recruited to the program through their local CTE and Science teachers and their school's Administration. Flyers and an online registration were shared with students and parents.

To comply with the high levels of compliance and regulation for youth programs, the team worked with the University of Florida Youth Compliance and participating districts to ensure facilitators were level 2 background screened, fingerprinted, and had correct badging requirements for each location. Parents completed waivers of liability and research consent documents on behalf of their children. District-level compliance paperwork was filed as required.

Lead teachers and undergraduate student mentors participated in a 4-week virtual training series to prepare for facilitation. Two-hour sessions were held once a week for four consecutive weeks in a synchronous and asynchronous model. Synchronous portions focused on high-level overviews of the program activities and provided space for lead teachers and mentors to collaborate. Asynchronous portions of the training program were opportunities for independent work and learning experiences to support students who may run into similar roadblocks. Office hours were held twice weekly to provide activity support and answer questions.

There was an average of 12 students per camp across the eight sessions, with the largest camp hosting 20 students and the smallest with 7 students in attendance. The GGEE Program collected student demographics for grade level (2022-2023 school year), gender, and race/ethnicity. More rising 8th-grade (30.9%) and 9th-grade (31.9%) students participated in the program compared to rising 6th (20.2%) and 7th (17%) graders, and there were significantly more male students (63.8%) than female students (25.5%). Student race and ethnicity demographics were as follows: 34.4% of students identified as Black or African American, 29.5% of students identified as White, 19.7% of students identified as Hispanic or Latino, and 16.4% of students identified as Asian.

Research study

The program focused on assessing the impact on a student's education and interest in computer science. The following research questions were posed: *Do demographics, summer program* *experience, and motivation in computational thinking and engineering design thinking impact student grades? Does the summer program experience moderate the effect of predictors on their grades?* The assessment was designed to study the motivation and identity of students toward science and engineering as program activities increased in difficulty.

Short-term research goals
Students completed anonymous online surveys before the start of the program, at the end of each day, and at the end of the camp. The "pre-camp" survey collected students' initial level of coding, demographics, and feelings towards coding and computer science. The "end-of-day" survey asked students to rate their feelings about the activities they completed using a 5-point Likert scale, Figure 2. Most students strongly agreed or somewhat agreed when asked about their confidence (92.91%), enjoyment (93.26%), interest (91.84%), and feeling of success (83.33%) at the end of the day. When asked if the activities were difficult, responses were almost evenly distributed. 64.5% of students responded somewhat or strongly agree when asked how much they felt like an engineer or scientist. 75.2% and 74.7% percent of students somewhat or strongly agreed that the activities were helpful for what they will be doing in school and for their future career goals, respectively, and 85.8% of students somewhat and strongly agreed that they would like to do more activities like those in the program. Surveys allowed the program to gauge interest in activities and if students felt appropriately challenged as scientists and engineers.

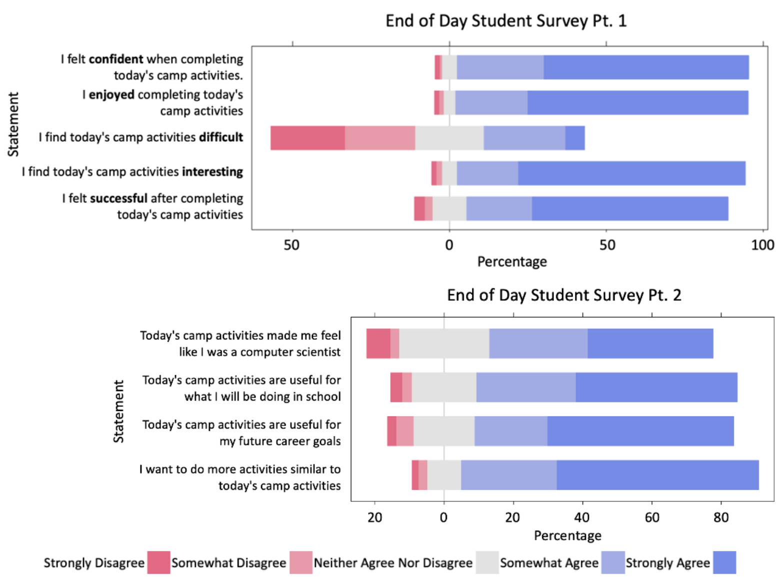

Figure 2: Survey results of students' feelings after daily camp activities, application of, and future use of their skills. (n=94 students, 282 responses, standard error = 9.7%)

At the end of the summer program, students completed an "end-of-camp" survey which included rating how students felt about their coding skills after completing the program on a scale from 0-3 (0 = None, 1= Basic, 2= Medium, 3 = High). Before the program, 40% of students reported medium and high levels of coding skills; by the end of the program, 92.3% of students reported as medium to high. The shift in how students perceived their coding skills after participating in the program shows that students felt more confident in their ability to code after working on programming different projects throughout the summer program.

Students were interviewed after the first day of the program. Students shared their camp experience, what they found challenging, what they had learned, and why they decided to do this during the interviews. Student interviews were de-identified, qualitatively analyzed, and assessed using sentiment analysis via text mining in R, Figure 3. [14] Sentiment analysis breaks student responses into individual words or "tokens." The words are then compared to a lexicon, such as the NRC library [15] used in this study. Keywords in the lexicon are given a specific sentiment value, and when words from a response match, they are given a sentiment classification. Sentiments to all interview questions were positive. When students were asked about their experiences completing the camp activities, their language contained many positive, joyful, and anticipation sentiments and low counts of words with negative connotations, such as sadness, fear, disgust, and anger, Figure 3A. When students were asked what had been challenging, Figure 3B, many words were categorized as positive, anticipation, and joy, with more words classified as negative from having to share about challenges and struggles to overcome.

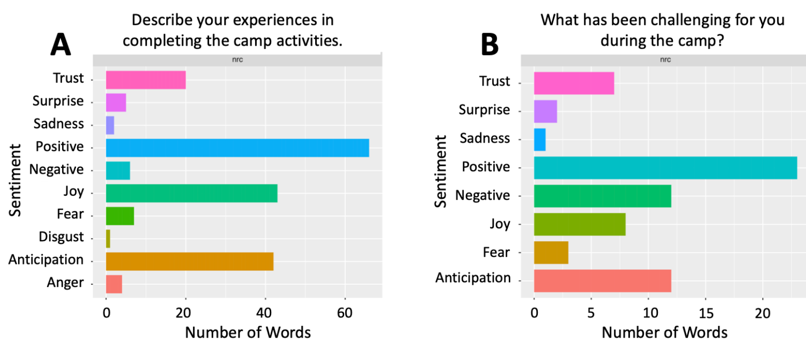

Figure 3: Sentiment analysis of student responses to respective interview questions. An NRC dictionary was applied to determine sentiment values for the words students used.

The preliminary evaluation of the end-of-day surveys and sentiment analysis of interview responses show students enjoyed the program design, and challenging experiences made them feel like authentic scientists and engineers. Most students felt confident and successful at the end of each day and enjoyed, were interested in, and were challenged by the activities. Students saw how to apply the program to their current and future work.

Future analysis includes a detailed evaluation of end-of-day survey data to understand the most impactful activities better. Assessing interview response word choice and frequency can provide more detail about how students felt, what challenged them, what they learned, and why they decided to participate in the program. Evaluating observation protocols will provide insight into the actions of students, facilitators, and mentors during activities.

Long-term research goals
A longitudinal assessment is in progress with two pilot districts. District-level IRBs were filed to obtain student grades and course enrollment data before and after participating in the summer program. A multiple regression analysis was used to identify significant predictors of grades. Grades and course enrollment were identified as indicators of changes that result from participation in the summer program, Figure 4. Short-term data are also indicators in the regression analysis to come. Data for the pilot year of the summer program will become available at the conclusion of the 2022-2023 school year. The GGEE team will work with school districts to collect and assess student grades and course enrollment changes that could be linked to participation in the 2022 GGEE summer program.

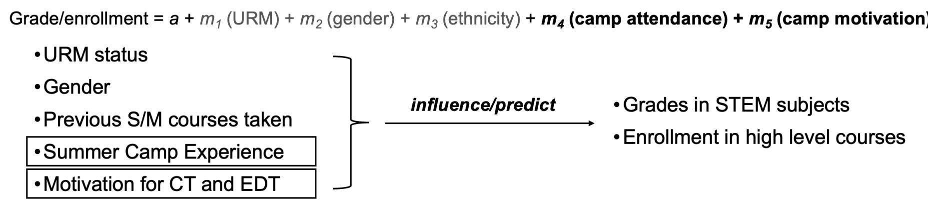

Figure 4: Multiple regression model for the longitudinal study of student grades in math and science and enrollment in high-level courses.

Following the pilot program

The following areas of refinement have been identified after reflection and feedback: recruitment of schools and districts should begin around September and October to allow time for schools to apply for funding. Training should include more hands-on opportunities to work through the activities together. Balance the ratio of male to female students in the program by working with student peers and female teachers for recruitment. Sustainably expand the program to more locations by cost-sharing with schools and training local teachers to run the programs. Sustain engagement with students through virtual after-school programs and the development of a year two advanced summer program for new and returning students.

Conclusions

The pilot year of the GGEE program successfully engaged over one hundred students across Florida in computational thinking, computer science, and engineering design through programming micro:bit microcontrollers.

Preliminary data show that students felt they had authentic experiences as engineers and scientists. From "end-of-day" surveys, students enjoyed, were interested in activities, and felt confident and successful in their work, even when activities were difficult. There was a positive shift in confidence in coding ability. Students were interviewed to gain insight into their experiences and what they found challenging. Further evaluation of the surveys, interviews, and observations is needed to identify impactful activities and activities that need refining. After the 2022-2023 school year, the GGEE program will receive its first set of longitudinal student grades and course enrollment data to investigate if participation in the summer program influences a student's academic trajectory.

To sustain and expand the GGEE Summer Program, virtual after-school programs were designed and deployed to meet students at different levels to introduce or continue to program the micro:bits. The summer program is becoming more sustainable by cost-sharing with school districts and training local teachers to lead the summer programs. The GGEE Summer Program looks forward to expanding and hosting more summer programs in 2023 across Florida.

Acknowledgments

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