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K-12 Student STEM Identity Development through Participation in Goldberg Gator Engineering Explorers Summer Programs (RTP)

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Abstract

The Goldberg Gator Engineering Explorers (GGEE) Summer and Afterschool Programs are informal learning programs designed to provide opportunities for middle school students to build skills in programming, computational thinking, and engineering design by bringing camp experiences to students in their communities. The programs are designed to be engaging while providing enough scaffolding to support the development of conceptual knowledge, skills, and confidence throughout the program. This paper discusses the impacts of the GGEE program on student science, technology, engineering, and mathematics (STEM) identity before, during, and after participation in the 2024 summer programs.

This study aims to investigate the impacts of the GGEE summer program on the development of STEM identity in middle school student participants. To measure the impacts on the development of STEM identity, three validated survey tools were modified to fit the needs and perspectives of the summer programs: the single-item STEM Professional Identity Overlap (STEM-PIO-1) measure, Role Identity Surveys in STEM (RIS-STEM), and Student Attitudes toward STEM (S-STEM). These tools focused on different aspects of STEM identity formation: 1) overall STEM identity formation by measuring how much students feel like they overlap with a scientist or engineer, 2) role identity in STEM constructed from interest, competence, and recognition, and 3) attitudes towards STEM regarding 21st-century skills. Students were also asked to rate their coding skills before and after participation in the summer program to support the measure of competence in STEM identity.

As a result of participating in the summer programs, student participants experienced an increased level of STEM identity. There was a 107% increase in the percentage of students pre-to-post who felt their identity overlapped closely with a scientist or engineer. Student STEM identity measured through role-identity and 21st-century skills also experienced increases in students strongly agreeing or feeling the most confident across all survey questions. The marked shifts in students toward an increased STEM identity indicate that the GGEE summer programs have positive impacts on developing STEM identity in students.

Keywords: STEM identity, K-12 students, informal learning, summer camps, underrepresented groups

1.0 Introduction

1.1 Background

Identity is often defined as a "core sense of self," who a person is, and who that person could be [1], [2]. In the context of STEM, this is how someone views themselves or is recognized by others as a "STEM person." This STEM sense of self can be observed using multiple lenses, such as a holistic view of yourself as a STEM person [1-6], role identities, seeing oneself as a scientist or engineer, and social identities, self-concept generated from the group of people around you [2], and attitudes, self-efficacy, and expectancy-value beliefs in a subject [7], [8].

K-12 student learners have been shown to start building STEM identities as early as elementary school. At this critical time, students begin to see themselves as a science or STEM person and develop attitudes and interests toward futures and careers in STEM [2], [3]. It is important to support STEM identity and self-efficacy in students, and informal programs can help provide additional opportunities for learning. Summer and afterschool programs offer K-12 students the opportunity to continue developing their STEM attitudes and interests while fostering STEM self-efficacy and career aspirations [5], [9-13]. These programs often lend themselves to smaller group sizes, curricula that are more focused on specific topics, and are more adaptable to a learner's needs and interests [5], [13].

1.2 Summer Program Overview

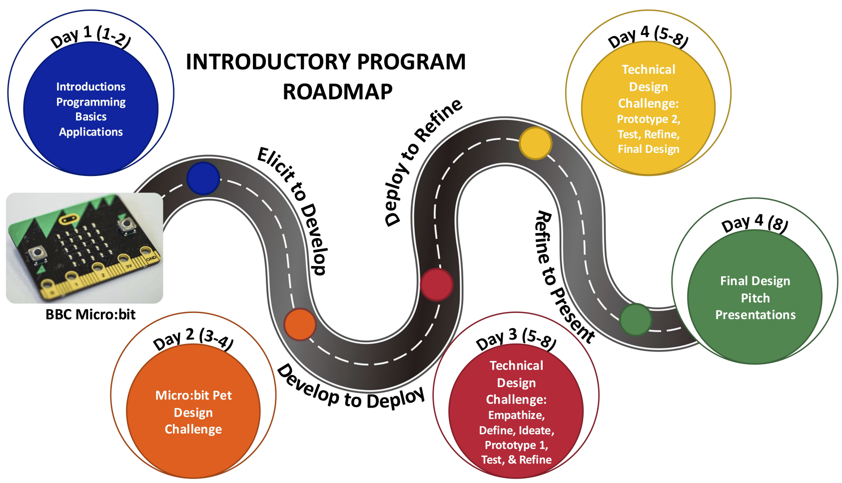

Figure 1: The introductory program roadmap for the GGEE summer programs.

The Goldberg Gator Engineering Explorers (GGEE) summer programs are one to two-week long 40-hour summer camps designed and managed by the Engaged Quality Instruction through Professional Development (EQuIPD) grant at the University of Florida to engage middle school students by providing high-quality programs situated in their home communities. The programs are offered at no cost to the parent(s) or guardian(s). The curriculum for the summer programs was developed in 2021 and piloted in the summer of 2022. The program is designed using a beginner-friendly block coding language to program a simple micro:bit microcontroller paired with scaffolded engineering design activities [14], [15]. The GGEE team followed the EQuIPD inquiry model stages to scaffold conceptual understanding of STEM concepts in the program curriculum. [16] The inquiry model is composed of 4 stages where activities are designed to *Elicit* prior knowledge and conceptual understanding, *Develop* a conceptual model and understanding of new concepts, *Deploy* one's understanding to test the boundaries of understanding and *Refine* to reflect and modify your understanding of a concept. The design of the camp activities pairs the inquiry model development stages with the Stanford Design Thinking Process to build a conceptual understanding of programming and computational thinking skills while prompting to identify user needs, iterate designs, and receive feedback [17]. The programs are structured into three main activities: 1) programming basics, 2) micro:bit pet, an individual programming and engineering design activity, and 3) technical design challenge, a team-based programming and engineering design activity. As the activities progress, there is a gradual release of responsibility as students work together to develop solutions to real-world problems. A roadmap of the program structure is provided in Figure 1 to outline the duration of each camp activity for 4-day programs and 8-day programs in parentheses.

The summer programs result from coordination between schools, districts, and youth organizations across Florida and the GGEE team at the University of Florida. In 2024, there were 26 camp sessions held across 13 Florida counties: Brevard, Charlotte, Hernando, Marion, Miami-Dade, Orange, Palm Beach, Pinellas, Putnam, Santa Rosa, Sarasota, Sumter, Suwannee, Figure 2A. This was an increase from 22 sessions in 2023 and 8 in 2022. These programs were held at schools, district offices, Boys and Girls Clubs, and youth program spaces. Teacher facilitators led programs from the host locations and were accompanied by one to two local undergraduate engineering student mentors from the University of Florida. To prepare the 23 teacher facilitators and 22 undergraduate students for the programs, they participated in 10-12 hours of curriculum and program facilitation training. To abide by youth compliance regulations, all undergraduate student mentors and teachers hired through the University of Florida underwent youth protection training, a level-2 DCF background screening, fingerprinting, and completed an affidavit of good moral character. Teachers outside of the university from partnering schools and youth organizations had their own background screening through their organizations.

There were 322 middle school students who participated in the 2024 GGEE summer programs. This is a continued increase in the number of student participants, Figure 2B, from previous years, with 319 student participants in 2023 and 135 students during the 2022 pilot year. Promotion of the summer programs and distribution of registration flyers to interested students and parents is managed by the partnering schools and youth organizations and is typically done directly with the students by teachers or through established electronic communication systems used by the organization.

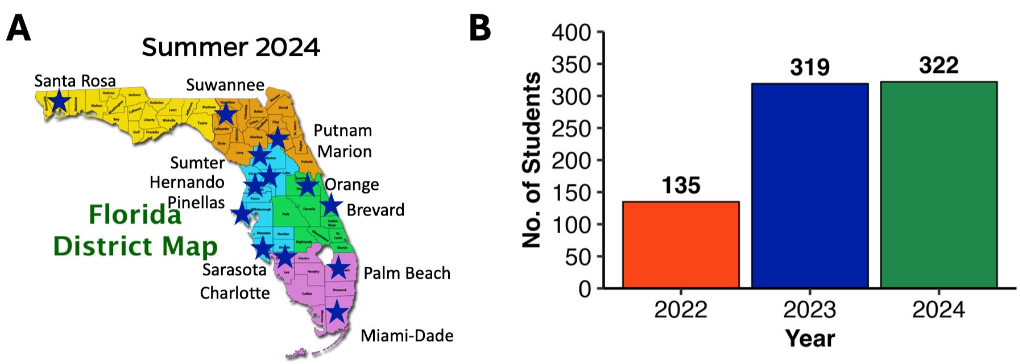

Figure 2: A) Map of Florida counties denoting 2024 GGEE summer program locations. B) The number of enrolled students from 2022 to 2024.

2.0 Purpose & Study Aims

The overarching goal of the GGEE summer program was to provide an opportunity for middle school children to gain experience with computer science through real-world applications, learn to solve real-world problems using computational thinking practices, engage in practices that mirror the real-world work of scientists and engineers, build mentoring relationships, and be empowered to pursue careers in computer science. The camps are brought directly to communities to create more opportunities for students to attend high-quality, free, and local summer STEM programs.

The work reported in this paper is part of a larger research study investigating the impacts of participation in the GGEE summer program on STEM identity, teacher self-efficacy, and mentoring relationships in student participants, undergraduate student mentors, and teacher facilitators. This study is focused on the impacts of informal STEM learning programs on student participants' STEM identity.

This study aims to investigate the impacts of a STEM summer program on the development of students':

1. *STEM identity as a scientist or engineer*
2. *Role-identity in STEM in terms of interest, competence, and recognition*
3. *Attitudes toward STEM through 21st-century learning skills*

3.0 Methodology

This study was approved by the University of Florida's Institutional Review Board (IRB202102451). There were 186 student participants who attended summer programs across the state between June 3rd and August 1st, 2024. The parent(s) or guardian(s) of the student participants acknowledged that they would like their child to participate in the study by completing a research consent document. At the start of each program, student participants whose parents opted them into research were also given the opportunity to assent to their participation in the program.

3.1 Data Collection

Data was collected from students using multiple surveys distributed at different time points after key activities. The pre-survey was completed by student participants at the start of the summer program, after the camp introductions and student assent process. The pre-survey needed to be delivered before students partook in any summer program activities. Students completed two end-of-day surveys upon completing the camp day after each large activity - programming basics and micro:bit pet. The post-survey was distributed to students upon completing the summer program, concluding with the technical design challenge activity. The surveys were aligned with the completion of camp activities to ensure that the same number of time points were collected for both 4-day and 8-day camp formats. All surveys were designed using the online survey tool Qualtrics and delivered electronically to students over the summer program's learning management system, Microsoft Teams.

3.2 Data Analysis

Data collected in the pre- and post-surveys were tabulated and averaged in Microsoft Excel to calculate the percentage of participant responses. The resulting Excel file was imported into the RStudio integrated development environment (IDE) [18] and visualized using the open-source programming language R [19].

4.0 Results and Discussion

4.1 Student Demographics

At the start of the surveys, general student demographics were collected: age, grade level, and race and ethnicity. There were 186 student participants who provided their grade level and age in the pre-survey.

Age and Grade Level

The summer programs were advertised to incoming 6th-grade to outgoing 8th-grade students at their schools or youth programs. The distribution of students per grade level, Figure 3A, is as follows: 33.9% 6th grade, 30.6% 7th grade, 23.7% 8th grade, 8.1% 9th grade, and 3.8% 10th grade. The distribution of student participant age at the time of the summer program, Figure 3B, was as follows: 4.8% were 10 years old, 31.7% were 11, 30.1% were 12, 21.5% were 13, 8.1% were 14, and 2.7% were 15, and 1.1% did not respond to the survey.

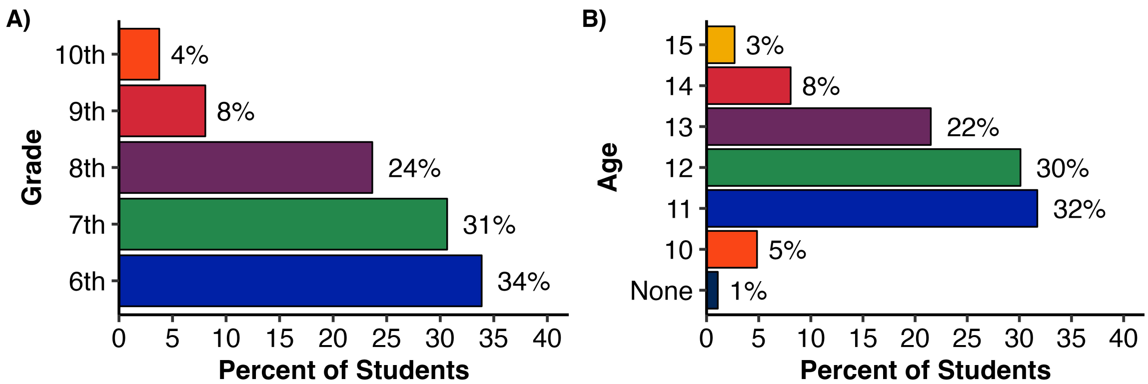

Figure 3: Distribution of student participant's A) grade level (n=186) and B) age (n=186).

More than 88% of the students who participated in the research study were between grades 6-8, and 83% were between the ages of 11-13 at the time of the pre-survey. The grade bands and age ranges align with the program's target audience. Students who indicated 9th or 10th grade were likely to indicate the grade they were moving into or, in some cases, were registered for the program with a younger sibling.

Gender

Student participants selected the gender they most closely identify with. Out of 186 pre-survey responses, 24.7% of the student participants identified as Female, 73.7% identified as Male, and 2% preferred not to say or their gender was not listed. The gender demographics are displayed in comparison to the total US population and the population of the STEM workforce, Table 1.

Research shows that girls' interest in STEM declines in the middle school years, which is also where the gender gap starts to form [22]. Continuing to make STEM approachable for female students supports the development of STEM identity in an often male-dominated field at an early age. Currently, the GGEE summer programs have a distribution of participants that aligns with the 36.8 million people in the U.S.'s STEM workforce (34.6% Female and 65.4% Male) and more closely matches the gender demographic breakdown of solely Science and Engineering occupations (26.7% Female and 73.3% Male) [21], [23].

Table 1. Student participant demographics compared to U.S. national STEM data.

Category	Participants	Total Population [20]	STEM Workers [21]
Gender (n=186)			
Female	24.7%	49.5%	34.6%
Male	73.7%	50.5%	65.4%
Prefer Not To Say/Not Listed	1.6%	-	-
Race (n=183)			
American Indian or Alaska Native	0.5%	1.3%	0.3%
Asian	1.1%	6.4%	9.5%
Black or African American	14.8%	13.7%	8.2%
White	63.4%	75.2%	62.9%
Other Race Alone or in Combination	6.0%	3.3%	4.3%
No Race Selected	14.2%	-	-
Ethnicity (n=183)			
Hispanic or Latino	26.8%	19.8%	14.8%

Race and Ethnicity

Student participants provided racial and ethnic information. They selected all of the options that applied to them from the following list: American Indian or Alaska Native, Asian, Black or African American, Hispanic or Latin(x), Native Hawaiian or other Pacific Islander, White. There were 183 students who provided their racial and ethnic information, summarized in Table 1. It is important to note that Hispanic or Latin(x) was not offered as a separate ethnicity in this survey. Therefore there were 26 participants, 14.2%, who solely selected Hispanic or Latin(x) and did not identify an accompanying race.

When the summer camp population is compared to the racial and ethnic distribution of the STEM workforce, we find a similar percentage of people who are white, ~60%, in both spaces. Overall, the population of participants in the program had a larger percentage of minority students compared to the STEM workforce in the U.S [21], [23].

4.2 STEM Identity Measures

STEM Professional Identity Overlap (STEM-PIO-1)

Throughout the summer program, students identified how much they perceive they overlap with a scientist or engineer. The single-item STEM Professional Identity Overlap measure (STEM-PIO-1) was adapted to help further understand the overarching development of STEM identity throughout student's participation in the summer program [1]. The students referenced a 7-point graphic tool, Figure 4, composed of 2 circles that gradually overlap more and more from A to G, to represent how much they felt like a scientist or engineer at that moment.

Participants were given this question at four time points during the camp program: 1) at the start of the program (pre-survey, n=185), 2) at the end of the first activity cluster (programming basics, n=140), 3) after the second activity (micro:bit pet, n=139), and 4) at the end of the camp after the third and final activity (technical design challenge, n=138). These time points align with the program activities outlined in the program roadmap detailed in Figure 1.

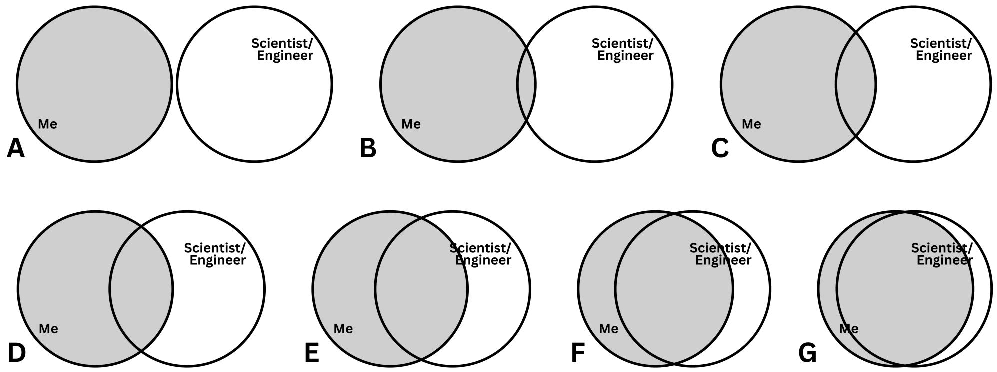

Figure 4: The 7-point graphic tool students used to indicate how much they feel like a scientist or engineer.

When looking at the percentages of students reporting how much they overlap as an engineer or scientist, Figure 5, we see a few trends within students choosing the lowest amount of overlap, option A, the middle option D, and the highest amount of overlap, option G. *Low Overlap Option A*: at the start of the program, 9.7% of students surveyed selected the lowest level overlap. As the program progressed, the percentage of the student population identifying with option A decreased to 1.4% after programming basics, 2.9% after the micro:bit pet, and ending at 2.2% upon the conclusion of the program. *Middle Overlap Option D*: the percentage of students identifying with the middle level of overlap remained around 20% for the first three activity time points. It reduced to 13% at the final time point. *High Overlap Option G:* the percentage of students identifying with the option containing the highest level of overlap between themselves and a scientist or engineer nearly doubled by the end of the program. At the program's start, 16.8% of students selected G, and 20% of students selected that option after the programming basics activity. After the micro:bit pet engineering design activity, there was a 2% decrease. This is likely due to the introduction of a comprehensive engineering design activity that requires using an engineering design cycle that may be new and more challenging for students. By the end of the camp, 34.8% of students felt their identity highly overlapped with that of a scientist or engineer.

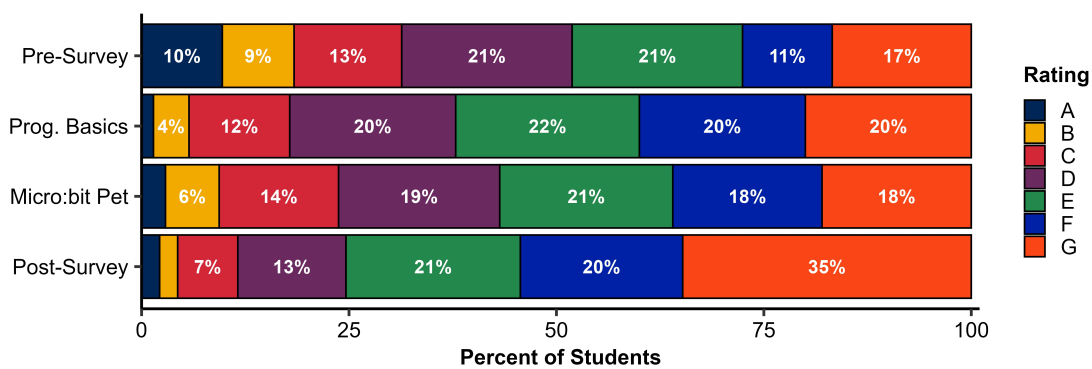

Figure 5: Changes in students' perception of feeling like a scientist or engineer across the duration of the summer program (n_{pre} = 185, n_{Basics} = 140, n_{MBPet} = 139, & n_{post} = 138).

The gradual increase toward identifying with a higher sense of being a scientist or engineer suggests that the camp positively impacted the student population's sense of STEM identity from a high-level point of view, as shown in Figure 5, where the highest two levels of feeling like a scientist or engineer increased from 28% of students to 55% of students from pre- to post-survey.

Role Identity Survey
To investigate the impacts of summer program participation on role identity in STEM, students were encouraged to complete questions dedicated to the Role Identity Survey – STEM (RIS-STEM) tool [2], [6]. The survey questions are tailored to assessing students' perceptions of themselves in three facets of STEM role identity: Interest – desire or curiosity, Competence – ability or performance, and Recognition – self-recognition and recognition by others as a STEM person.

Role Identity Survey: Interest
To measure the student participant's interest in STEM, shown in Figure 6, students rated how much they agreed with the following questions using this 4-point Likert scale: Strongly Disagree, Disagree, Agree, Strongly Agree.

A. *I like to figure out how things work*
B. *I enjoy learning about STEM*
C. *Doing STEM is fun*
D. *I like the challenge of STEM activities*

When looking at results for each question, there is an even distribution of the percentage of students who selected agree or strongly agree in the pre-survey (n=183) and post-survey (n=137) for all questions; this ranges between 85% and 96% of the student participants. However, within each question, there is an increase in the percentage of students who strongly agree from pre- to post-survey. These trends could be due to students beginning the program interested in STEM and continuing to grow their interest and enthusiasm for STEM while participating in the summer program.

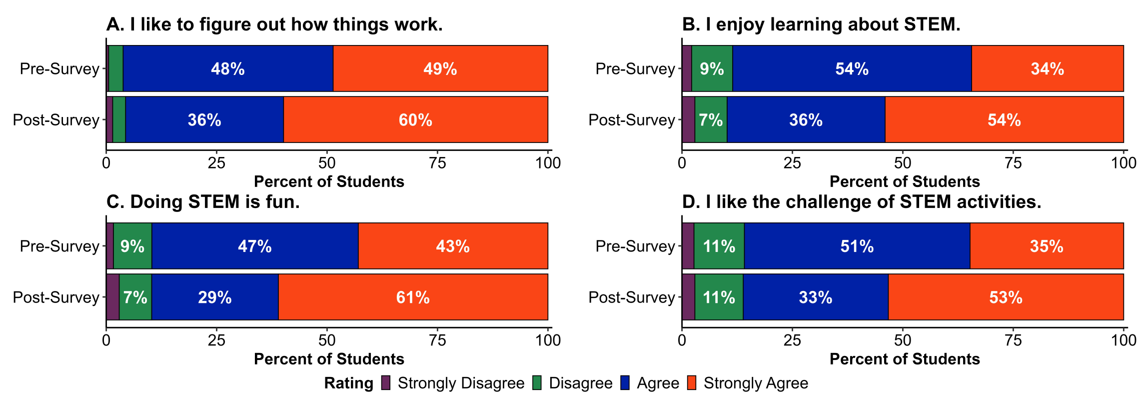

Figure 6: Student participant's interest in STEM activities before and after the summer program using the RIS-STEM survey tool (n_{pre} = 183, n_{post} = 137).

Role Identity Survey: Competence
To measure the student participant's competence or ability in STEM, students rated how much they agreed with the following questions using this 4-point Likert scale: Strongly Disagree, Disagree, Agree, Strongly Agree.

A. *I am confident that I can understand STEM activities*
B. *I like to design solutions to problems during STEM design challenges*
C. *I can apply STEM ideas to solve challenges*

For the three questions asked, we see a similar trend where the majority percentage of students agree or strongly agree at both pre- and post-survey time points, paired with an increase in the percentage of students who strongly agree with the sentiment by the end of the summer camp, Figure 7. These results indicate that students arrived at the summer program confident in completing STEM activities and likely left the program feeling more competent and capable in STEM.

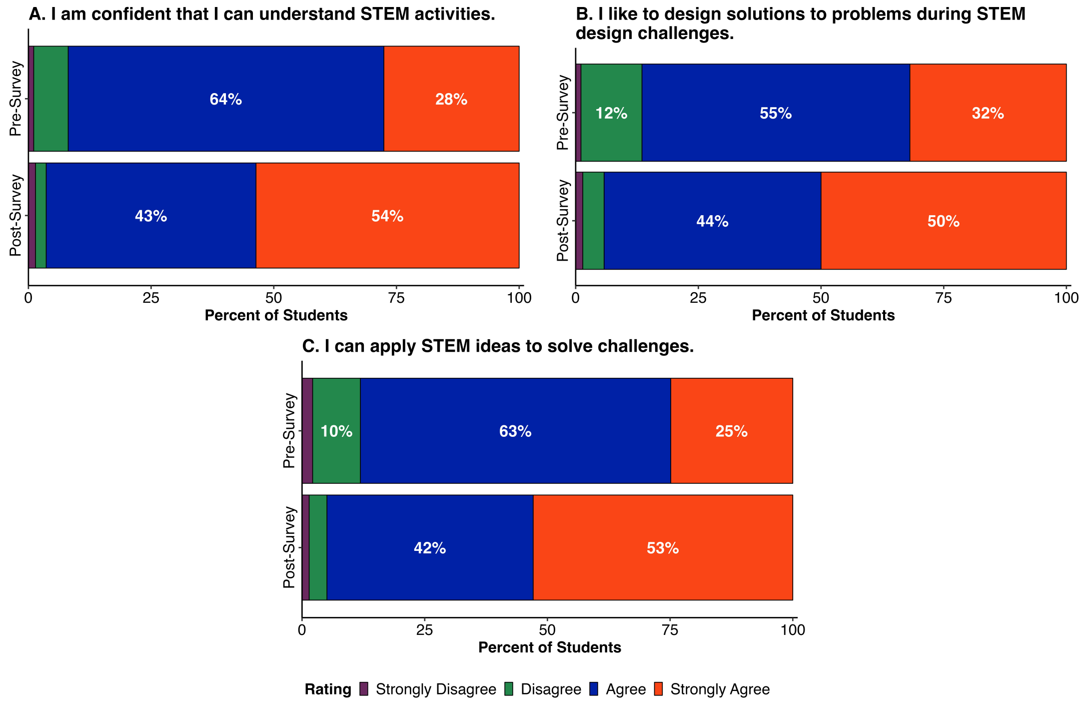

Figure 7: Student participants' competence in STEM activities before and after the summer program using the RIS-STEM survey tool (n_{pre} = 185, n_{post} = 138).

Competence through Coding Skills

To demonstrate competence in coding skills, the students rated their coding skill level at the start and end of the summer program using the following 4-point Likert scale: None, Basic, Medium, and High. At the start of the program, in the pre-survey (n=185), 29.3% of the students rated their skills as None, 38.0% as Basic, 27.2% as Medium, and 5.4% as High. By the end of the program, in the post-survey (n=139), 1.4% rated their skills as None, 7.9% as Basic, 61.2% as Medium, and 29.5% rated their coding skills as High.

This evaluation of students' perceived level of coding skills before and after participation in the summer program is displayed in Figure 8. In the pre-survey, 67% of the students indicated that their coding skill level was either none or basic. By the end of the program, the percentage of none and basic ratings decreased substantially to 9.4%. The percentage of students who indicated a medium level more than doubled from 27% to 61%, and the percentage of students rating their skills as high increased nearly six-fold from 5.4% of surveyed students to 29.5%. The profound shift in ratings to a higher skill level demonstrates that students could develop or increase their existing coding competencies by participating in the summer program.

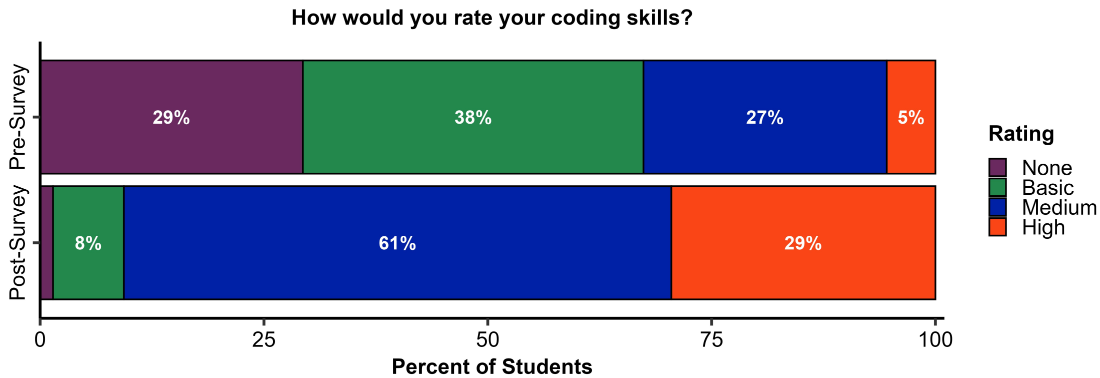

Figure 8: Students' rating of their coding skills before and after the camp (n_{pre} = 184 & n_{post} = 139)

Role Identity Survey: Recognition

To measure the student participant's recognition of themselves as a STEM person, students rated how much they agreed with the following questions using this 4-point Likert scale: Strongly Disagree, Disagree, Agree, Strongly Agree. These questions were designed to capture recognition from two perspectives: self-recognition (A-D) and the perception of being recognized by others as a STEM person (E-F).

A. *It is likely that STEM will be part of my job someday*
B. *When I grow up, I want to work in STEM*
C. *I see myself as a STEM person*
D. *I feel like a STEM person when I apply STEM ideas to my life*
E. *My teachers sees me as a STEM person*
F. *Other people see me as a STEM person*

The results of the recognition survey questions are displayed in Figure 9. Before the camp (n=184), the percentage of students who responded strongly agree to each of the STEM recognition prompts ranged from 17% to 28% of the student participants surveyed. By the end of the summer program (n=137), the percentage of students increased for each question. Overall, there was a positive shift in the percentage of students who strongly agreed to being recognized as a STEM person. In the case of questions D and E, there were substantial increases in the percentage of students choosing strongly agree from pre- to post-surveys, D: 23.9% to 42.3% of students and E: 18.5% to 42% of students, respectively, indicating they saw themselves as a STEM person, and they felt recognized by the teacher as a person who does STEM.

At the end the camp, there was a shift toward agree and strongly agree, indicating that more students viewed themselves as a STEM person and how they believe they are perceived by others, like their teachers and peers. This suggests that participating in the camp boosted their connection with STEM and made them feel more recognized and supported in their STEM identity.

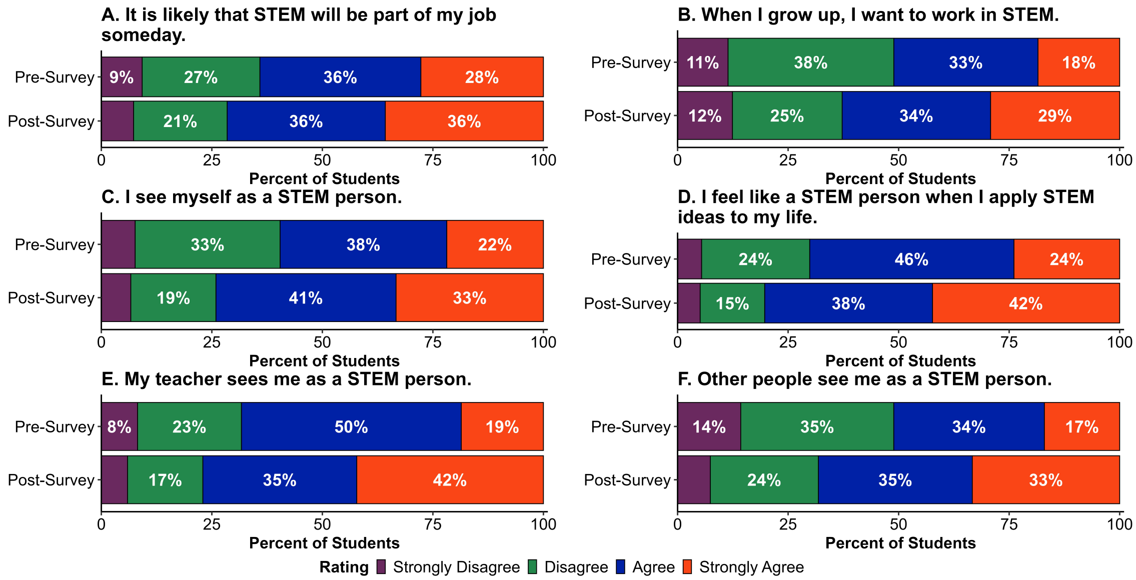

Figure 9: Student participants' recognition of themselves as a STEM person before and after the summer program using the RIS-STEM survey tool (n_{pre} = 184, n_{post} = 137).

MISO S-STEM – 21st-Century Learning

The final measure used to measure the development of STEM identity in students was designed to capture students' attitudes and self-efficacy in STEM by assessing various 21st-century learning skills. These questions were modified for the context of the summer program from the validated MISO S-STEM survey, which studied and measured student's attitudes toward Science, Technology, Engineering, and Mathematics [7], [8]. Students used a 4-point Likert scale, Confident at All, A Little Confident, Confident, Very Confident, to describe their confidence level related to working with others. The questions were as follows:

A. *I can lead others to accomplish a goal*
B. *I can encourage others to do their best*
C. *I can respect the difference of my peers*
D. *I can help my peers*
E. *I can listen to other people's ideas*
F. *I can work well with students from different backgrounds.*

The results displayed in Figure 10 highlight the impact of the summer program on the students' professional skills and confidence in leadership, collaboration, and teamwork. Initially (n=181), many students displayed moderate assurance in their ability to lead, encourage, and support their peers. Up to 60% of students selected confident or very confident in their pre-survey responses. The post-survey (n=137) illustrates increased levels of confidence, particularly increases in students rating themselves as very confident in the areas of A. leading others toward accomplishing a goal (pre 20%, post 42% of students), C. respecting differences (pre 37%, post 51% of students), and D. helping peers (pre 38%, post 52% of students). These increases suggest the camp created an environment that boosted the confidence of students in various 21st-century skills required to be successful in STEM.

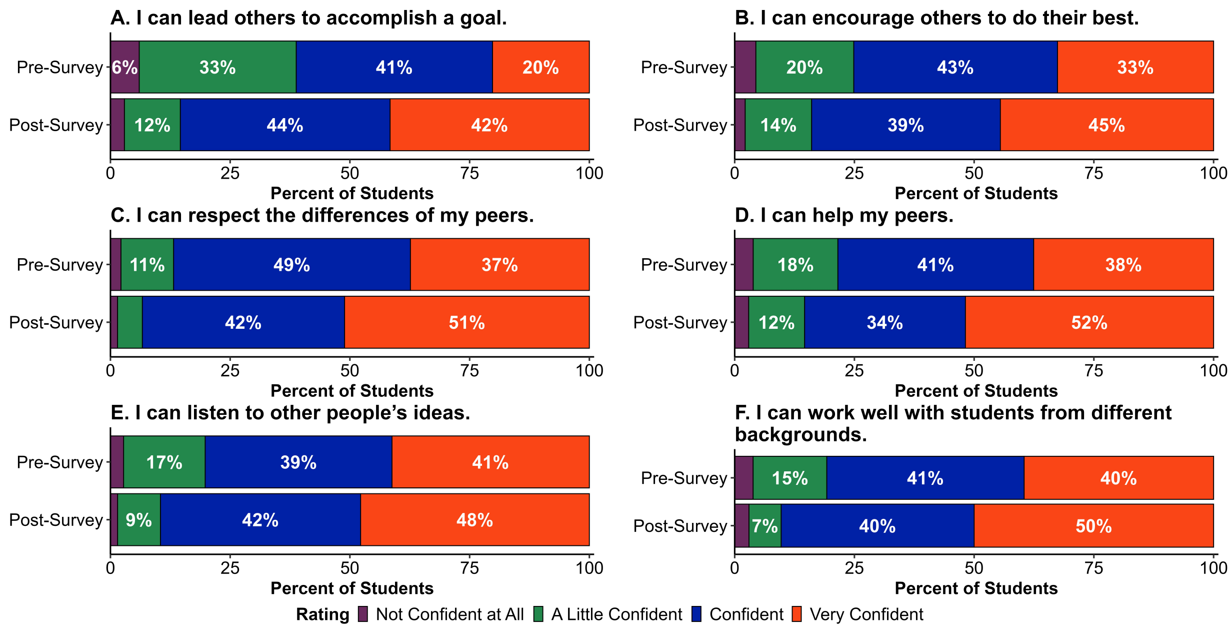

Figure 10: Pre- and post-survey responses of students' confidence rating given the following prompts related to 21st-century skills (n_{pre} = 181, n_{post} = 137).

4.4 Limitations

The study was limited in analysis due to the variation in the number of student responses to each survey at each of the time points. Student participants remained anonymous throughout the data collection, and no unique ID or code was provided to students to allow for blinded participant matching.

5.0 Conclusions and Future Work

The 2024 GGEE summer programs reached 322 middle school students during 26 camp sessions held in 13 different counties across Florida. Summer programs were held in informal settings outside of traditional school time at school sites and youth organization locations.

This study was focused on the impacts of STEM summer programs on the development of students' STEM identity. The GGEE research team found that there was overall growth in STEM identity after students participated in the summer programs. Survey tools were used to measure the increases in 1) overall STEM identity as a scientist or engineer using a graphic tool for students to identify the level of overlap they have with a scientist or engineer, 2) Identity in STEM from the perspectives of interest, competence, and recognition, and 3) Attitudes toward STEM through 21st-century learning skills.

The single-item STEM Professional Identity Overlap measure (STEM-PIO-1) captured the overall development of students' STEM identity from participating in the summer program. The percentage of students selecting the graphic option with the highest level of overlap between them and a scientist or engineer increased by 107% (pre-survey 16.8% of students, post-survey 34.8% of students). The Role Identity Surveys (RIS-STEM) captured increases in all 13 survey questions asked about student identity in each of the contexts: interest, competence, and recognition. In all three areas, the survey results indicate that the students who participated in the program arrived with some level of identity with roles in STEM, and that identity continued to grow stronger in the student population after participating in the summer program. The last STEM identity metric focused on students' attitudes toward STEM through the development of 21st-century professional skills. There were increases ranging from 17% to 110% in the percentage of student participants who felt "very confident" in using professional skills, such as leading others toward a goal, respecting differences, and helping peers in STEM settings. Together, these different measures show that summer programs effectively build STEM identity, attitudes, self-efficacy, and 21st-century skills in students through informal learning programs.

The GGEE research team is completing a thematic analysis of the interview transcripts from participating students to supplement and provide additional context on the impacts of the summer programs assessed through the surveys. The GGEE program is also tracking longitudinal data of students to see their STEM course trajectory after the camp to see if the camp experience has any impact on their academic career towards STEM.

6.0 Acknowledgements

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