# How to Develop a Culture of Coding for the Future: A Case Study of the megaGEMS Coding Academy

**George Zaccheus Sikazwe, University of the Incarnate Word**

George Z. Sikazwe is an undergraduate electrical engineering student at the University of the Incarnate Word in San Antonio, Texas. Mr. Sikazwe is passionate about applying engineered solutions to real-world problems. As a student research assistant in the Autonomous Vehicle Systems Research Laboratories his focus is in computational intelligence, specifically applications of deep learning onto hardware. For the GEMS (Girls in Engineering, Math, and Science) program he was the instructor of Coding Academy in which he was able to teach Python to high school students from various backgrounds.

**Stephanie Weiss-Lopez**

Stephanie Weiss-Lopez has overseen GEMS since 2020 as a Project Manager and Coordinator. Ms. Weiss-Lopez is a UIW alum with a degree in Meteorology, currently the AVS Laboratories Project Manager, and an MBA student at UIW. She has over 18 years of management and leadership experience and has been a member of the AVS labs since 2018. Ms. Weiss-Lopez has experience in personnel development, scientific research, and grant writing. During Ms. Weiss-Lopez's leadership GEMS implemented and distributed over 450 free STEAM kits during the COVID-19 pandemic. Ms. Weiss-Lopez's partnership with the PI expanded innovative programs such as megaGEMS Virtual Research camp, miniGEMS virtual after school clubs, miniGEMS virtual Spring Break camp, and the megaGEMS AEOP Apprenticeship.

**Dr. Diane L Peters P.E., Kettering University**

Dr. Peters is an Associate Professor of Mechanical Engineering at Kettering University.

**Dr. Michael Frye, University of the Incarnate Word**

Michael T. Frye, Ph.D. is a Professor of Engineering in the Department of Engineering at the University of the Incarnate Word, in San Antonio, TX. He is an Electrical Engineer who specialized in the field of nonlinear control theory.

©American Society for Engineering Education, 2024

# How to Develop a Culture of Coding for the Future: A Case Study of the megaGEMS Coding Academy

**Abstract**

Girls in Engineering, Mathematics, and Science (GEMS) is a free after-school club and summer camp for girls interested in exploring their career in various Science, Technology, Engineering, and Mathematics (STEM) fields. GEMS is the outreach program for the Autonomous Vehicle Systems Research and Education Laboratories. GEMS programs are designed to educate young women about STEM by providing hands-on experiential learning in robotics, programming, and research [1]. GEMS is divided into two main programs: miniGEMS for rising fifth through eighth-grade middle school students, and megaGEMS for rising ninth through twelfth-grade high school students [2]. miniGEMS focuses on robotic challenges and innovative STEM curricula. In contrast, megaGEMS focuses on independent research through two programs: Research Camp (RC), a 4-week program for ninth and tenth-grade students, and the Apprenticeship Program, an 8-week college-level research program for eleventh and twelfth-grade students. All GEMS programs prioritize serving Title I schools, rural, and students from low-income [3], [4] areas of San Antonio and Bexar County. All participants in GEMS explore and investigate hands-on lab experience in the science of autonomy through ground and air robotics, which helps them build the important skills essential to obtaining college-level degrees and readiness for workforce development [5]. GEMS aligns its foundation to address the lack of opportunities for marginalized groups such as race/ethnicity, gender, language, and socioeconomic status but not limited to. GEMS equitable and inclusive practices provide engineering and computer science opportunities to communities in need.

This paper will highlight Coding Academy, a feature of the megaGEMS program that looks to empower its students with the coding knowledge necessary to complete their faculty-guided research projects. Coding Academy supplies daily 1-hour coding lessons to all participants within the megaGEMS program [2]. Focusing specifically on teaching the fundamentals of the Python Programming Language. The function of Coding Academy under the GEMS program; however, is to supply early and effective exposure to coding and programming skills through student-led instruction, and project-based learning. As coding has become significantly important to the next generation of workforce this program provides beyond what is available in a typical classroom. With these methods in mind, the Coding Academy hopes to encourage analytical thinking, effective communication, and foster a problem-solving mindset in all its students which will extend from their studies into their professional lives and encourage pursing of STEM degrees in a 2 year or 4-year program [1], [5].

Coding Academy is managed by the Computational Intelligence Lab (CIL), part of the Autonomous Vehicle Systems Research and Education Laboratories, consisting of undergraduate student research assistants. The undergraduate students are made up of engineering and computer science majors from the university. These students are referred to the PI of the lab based on their level of professionalism in the classroom, self-efficacy, time management, and overall well-

rounded student. The undergraduate students are interviewed and then finally hired as student employees of the lab. In addition, the research assistants receive aid from the GEMS director. The curriculum of Coding Academy has traditionally centered around the basics of programming in Python, with emphasis on the development of solid fundamental programming skills [6], [7]. In the latest iteration of Coding Academy, the curriculum emphasized multiple-day projects and teamwork to capitalize on the student's ability to teach one another and help them keep information learned in these sessions. For example, the curriculum draws inspiration from popular studying methods, the Feynman technique, and spaced repetition as well as aligning with Texas educational standards for high school students.

Alongside highlighting Coding Academy, this paper will also explore the GEMS programs for females to investigate STEM pathways, the effectiveness of the teaching techniques, exploration of the importance of teaching coding to students, surveying the outcomes, and the continued work of the GEMS programs.

## Introduction

### *Background of GEMS*

GEMS (Girls in Engineering, Mathematics, and Science) is a free all-female STEAM (Science, Technology, Engineering, Art, and Mathematics) and Programming Summer Camps and Afterschool Robotic and STEAM clubs. All GEMS programs focus on educating young girls about the fields of STEAM and the careers in each field. GEMS was established in 2015 as the community outreach [5], of the Autonomous Vehicle System (AVS) Research and Education Laboratories (GNC, CIL, and GEMS) as a 1-week summer camp for middle school students but has grown to multiple year-round programs for middle school and high school aged females [2].

GEMS is divided into two programs: miniGEMS and megaGEMS. miniGEMS is for middle school girls and megaGEMS is for high school girls. GEMS recruits' students from Title I, underserved, and rural areas of Bexar County, Guadalupe County, and Medina County in south Texas. Title I schools are defined as a designation based on the number of low-income students who are at risk for school achievement. To be considered a Title 1 school, a minimum of 40% of the students must qualify for free or reduced lunch. GEMS currently partners with schools in San Antonio ISD, Judson ISD, Southwest ISD, and Southside ISD to host miniGEMS After-School STEAM and Robotics clubs.

Each summer camps are held at the University of the Incarnate Word (UIW) and hosted by the AVS Labs. UIW is recognized as a Hispanic-serving institution under federal guidelines [2] which promotes the GEMS community outreach. San Antonio's demographics include 17.7 % living in poverty compared to the 12.5% average of the United States and San Antonio's poverty rate ranks second among the five largest cities in Texas. San Antonio is comprised mostly of 64.2% Hispanic, 24.8% White, and 6.4% African American. The GEMS programs create

equitable and inclusive hands-on curricula that allow female students to spark their intellectual curiosity.

GEMS' *mission* is to inspire and empower young girls to be innovative with their future in the STEM/STEAM fields. GEMS covers diverse topics of education that the students would not normally be exposed to, supporting each other, developing teamwork skills, learning how to better the community with their knowledge, being creative, and developing self-efficacy [1], [4]. GEMS' *goal* is to increase the number of female students interested in STEM careers, especially in engineering and computer programming [5].

In the United States, women make up 14% of the engineering workforce (15% internationally) and in 2020, 24% of bachelor's degrees in engineering were earned by women, and women of color earned 10% of the total engineering degrees [8], [9]. Knowing these statistics GEMS' *objective* is to increase the number of female students from underrepresented communities [4] choosing STEM-related pathways in high school, STEM-related vocations, or STEM-related majors upon graduation from high school [5].

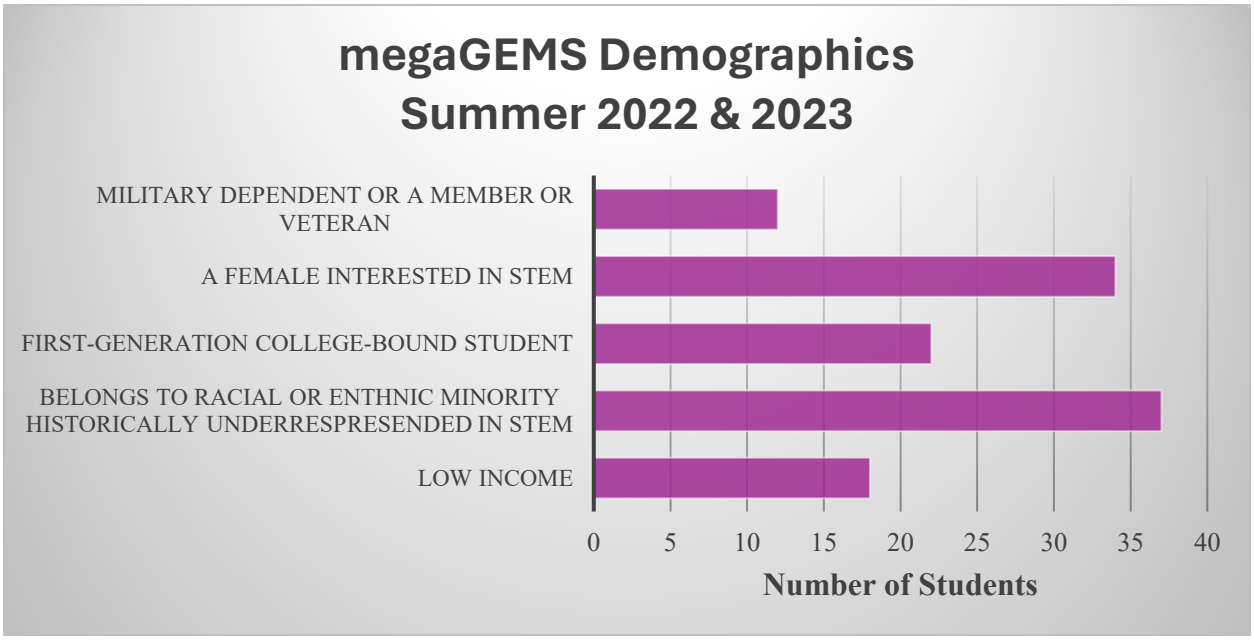



**Figure 1, Demographics of megaGEMS Students for the Summer of 2022 & 2023**

Additionally, as GEMS recruits from under-resourced [5], rural, and urban areas of San Antonio, and surrounding counties, the megaGEMS summer programs provide stipends which in turn increases the incentive to attend and help provide a small yet necessary income for many our students. Figure 1 depicts the demographics of the megaGEMS students for the summer of 2022 and 2023. megaGEMS Unite serves as a pipeline for students graduating from the miniGEMS middle school programs wishing to continue to explore their intellectual curiosity through hands-

on STEM research. Additionally, the students are then encouraged to apply for the 8-week megaGEMS High School Internship Program for juniors and seniors [2], [5] upon completion of the megaGEMS Unite program.

As all of GEMS' programs are funded through grants, GEMS is privileged to work with the AEOP Consortium. More specifically, GEMS has received funding from the Army Education Outreach Program High School Apprenticeship Program and through the Technology Student Association through grant submissions.

The Army Education Outreach Program (AEOP) offers a collaborative and cohesive portfolio of STEM programs that engage, inspire, and attract the next generation of STEM talent [10] administered through the AEOP consortium. The consortium consists of the Rochester Institute of Technology, the Technology Student Association (TSA) [5], [11], Battelle Memorial Institute, and various other organizations and partners. Each provides funding resources to create, and host programs to empower the next generation of the workforce with the tools and skills that are highly sought out. The AEOP focuses efforts on racial or ethnic minorities, low-income, first-generation [12], English as a second language, a female interested in STEM, and military dependent or a member or veteran [4], [5]. Additionally, GEMS recruits' students with similar demographics as seen in Figure 1 further noting the cohesive partnership.

The AEOP High School Apprenticeship Program (HSAP) is a career development initiative to conduct real-world research through internships and fellowships with a vision of "STEM-inspired change makers, problem solvers, and innovators" [13]. The mission is to provide an accessible pathway of STEM opportunities to attract, develop, and mentor the next generation of our nation's diverse talent through the U.S. Army Educational Outreach Program [13]. The AEOP high school program offers a Learning Hub and Speaker Series through an e-learning platform providing an added resource for students to expand their network and STEM interest during their internships. Essentially, providing a well-rounded foundation and support for all learning styles to experience, learn, and gain STEM knowledge, school pathways, and careers [5]. The HSAP program funds the megaGEMS 8-week Summer Research Program [2].

Unite, administered by TSA, is a nationwide summer program for talented high school students from groups historically underrepresented in STEM [5]. TSA offers various competitions and programs for middle school and high school students to explore fields of forensic science, biotechnology, structural engineering, and building solar-powered race cars [11]. The Unite program funds the megaGEMS 4-week Summer Research Program.

The AEOP consortium provides financial resources to fund GEMS summer high school programs for underrepresented and underserved students. The students can experience career opportunities, develop soft skills, and broaden their STEM skills while earning an education stipend and building a competitive Curriculum Vitae [10]. All students highlight their final

research in poster and presentation format at the End of the Summer Showcase and submit a research abstract to the AEOP to be published in the AEOP Research Journal.

**Demand for Coding Academy**

The need for Coding Academy lies within the very principles of the GEMS program, specifically in its goal of workforce development as well as improving social justice for female minorities. The National Center for Science and Engineering Statistics (NCSES) said that in 2021 "about two-thirds of those employed (65%) in STEM occupations were men and about one-third (35%) were women [14]." Coding Academy is essential for addressing the basis of this issue and empowering female students who will enter the workforce with strong skills and knowledge in computer sciences. Essentially showing the next generation of female students the feasibility of a career in STEM [4] and allows the students to approach learning STEM safely and encouragingly.

Coding Academy came to be through the request of GEMS participants. Students realized the importance of learning coding skills as they needed the skill to fully conduct their research projects. In 2021, the initial pilot program of teaching Python coding to high school programs was explored. The students received a similar curriculum that discussed foundational concepts through 1-hour teaching sessions. Since the inaugural program, the curriculum has been altered to align with Texas standards as well as adjusted to ensure all concepts can be covered throughout the duration of the program as well as challenge those who have attended the program previously.

**Curriculum**

The basis for the Coding Academy is the Python Programming Language. Python was selected as the language of choice for its ease of use, wide community support, and demand in the workforce as previously stated [6],[7].

Python is an interpreted beginner-friendly open-source programming language. The flow of this language is similar to how it is written in plain English. The linguistic similarities to English make the language easily readable, thus syntax becomes remarkably simple for users to understand. The Python programming language is also the basis for many introductory-level programming and computer science courses in institutions of higher learning [6], [7]. One such popularly discussed example is Harvard's CS50 Introduction to Computer Science. By establishing an early relationship with this language students become familiar with the basics of programming, from simple concepts like syntax to more advanced topics such as object orientation. This familiarity gives students a considerable advantage in both the classroom and the job market [15].

In addition to the programming usage of Python, the software is easily accessible. Because of the open-sourced nature of the language and its supporting community, many resources are available to the students for free or at a low cost [6], [7]. This enables all students a means of learning freely without hindrance of references or resources.

An important feature of the curriculum is the undergraduate instructor, who conveys "relatability" to the high school students. As stated previously, they are undergraduate students with similar interests and career paths as the high school students as well as similar backgrounds. Coding Academy is led by undergraduate Research Assistants from the Autonomous Vehicle Systems Laboratory. This is particularly important as they bring an interesting perspective from daily interactions with code. These instructors bring a wealth of on-the-job experience and fundamental theory which the students benefit from. This blend of practical and theoretical knowledge is beneficial especially when students seek to understand how code interacts with their research. Students learning from instructors who similarly interact with code helps to positively reinforce the lessons that the students learn in class.

With both quality instruction and a very beginner-friendly language the curriculum then centers itself around ensuring that students retain and apply knowledge given.

***megaGEMS Pedagogy***

To support this mission, the megaGEMS summer programs are to enhance learning in STEM topics that are aligned with Texas Education Agency (TEA) Texas Essential Knowledge and Skills (TEKS) [16] requirements for high school students. Students will understand the STEM fields and possible career pathways.

1. Students will be introduced to basic computer programming using the Python Programming Language,
2. Students will be introduced to Artificial Intelligence using Python,
3. Students, through the applied control of robots, will learn about why math and sciences are important,
4. Students and Parents will learn about the high school STEM endorsement and about the necessary courses to take in high school to be ready for STEM study in college, and
5. Students and Parents will learn how to apply to college and about several types of financial aid.

The curriculum of megaGEMS summer programs will incorporate project-based learning group activities and focus on robotics as well as computer programming [2]. Additionally, the students will learn to integrate sensors, such as GPS, so that their robot can make decisions and explore their environment. The Python Programming curriculum was introduced in the Summer of 2019 in the megaGEMS research camps where they learned to create video games. The course got an

incredibly positive review! The curriculum has been refined and aligns with TEKS standards [16], providing teachers and students with innovative relevant material. Python is being taught as it has been consistently ranked among the most popular programming languages and has already been used in Texas high school coding courses [6], [7]. The Python curriculum encourages students to learn fundamental concepts of coding through creative projects which in turn are relatable to their research [2]. The curriculum is designed to be taught throughout the research camp for one hour each day and build upon the previous days' concepts.

***Coding Academy Course Structure***

Each 1-hour session consists of lessons that develop basic skills in programming, as seen in Figure 2. Throughout the last session of Coding Academy students were able to cover syntax, data types (string, list/array, dictionary), classes and functions, and object-oriented programming basics [7]. The amount of curriculum covered throughout this course can be attributed to the nature of how it was instructed. The structure of the course features an interactive review at the beginning of each session to solidify lessons learned prior, followed by instructor-led examples of the usage of concepts covered, and then group/project work. In the first review at the beginning of each session, students were made to answer review questions collaboratively. For example, they are each assigned a data type and then called on to give an example and make the class guess what data type they have. Students benefitted from the repetition of concepts, and the ability to interact/connect with the lessons from previous sessions in a fun way which solidified confidence in the subject.

During the instructor-led portion of the session, students followed along with coding examples and newer concepts as they were introduced. This entailed having students write the code, and or modify older codes using newer concepts. These parts of the session laid the foundation for group work and projects. Students were responsible in groups of two to three for the development of codes related to some of the bigger lessons. For example, when covering functions students were to write a code for a restaurant menu in which users can select options and display their total at the end of ordering. The benefit of this practice was the students' interactions with each other [6]. With the ability to discuss and work in teams, the students were able to bridge gaps in understanding. When the students were surveyed, 95% of the students found the group work was helpful during the Coding Academy. As some students understood the project and concepts would help students for whom it was unclear. The teams also came with different approaches based on knowledge.

An interesting part of the group work portion of the class is that it mirrored the student's research project teams. Students who worked in teams together for their projects were paired with each other, expanding the extension of the coding fundamentals beyond the classroom. The culmination of which was the student's research projects. With the knowledge obtained in the Coding Academy sessions students were able to begin exploring integrations of code within their

summer research projects. Some of the student even decided to devote themselves to doing the coding parts of their projects exclusively as their confidence increased.

| | 6/12 MONDAY | 6/13 TUESDAY | 6/14 WEDNESDAY | 6/15 THURSDAY | 6/16 FRIDAY |
|---|---|---|---|---|---|
| 8:45 AM | Drop-off | Drop-off | Drop-off | Drop-off | Drop-off |
| 9:00 AM | Research Time | Drone Session | Revise Poster Outline | Research Time | UIW Garden |
| 9:30 AM | Research Time | Drone Session | Revise Poster Outline | Research Time | UIW Garden |
| 10:00 AM | Coding Academy | Coding Academy | Coding Academy | Coding Academy | Rest period/Research Time |
| 10:30 AM | Coding Academy | Coding Academy | Coding Academy | Coding Academy | Research Time |
| 11:00 AM | Research Time | Research Time | Research Time | One-on-one Conferences/Research Time | Research Time |
| 11:30 AM | Research Time | Research Time | Research Time | One-on-one Conferences/Research Time | Research Time |
| 12:00 PM | Lunch | Lunch | Lunch | Lunch | Lunch |
| 12:30 PM | Research Time/Drone Session | Go over Poster Outline | Research Time | Research Time | Weekly GEMS Meeting |
| 1:00 PM | Research Time/Drone Session | Create Poster Outline | Research Time | Research Time | Weekly GEMS Meeting |
| 1:30 PM | Research Time/Drone Session | Mega Meditation | Research Time | Drone Session | Weekly GEMS Meeting |
| 2:00 PM | Create Poster Outline | Mega Meditation (Until 2:45) | Revise Outline/Research Time | Drone Session | Research Time |
| 2:30 PM | Create Poster Outline (snack @ 2:45) | Work on Poster Outline (Snack at 2:45) | Revise Outline/Research Time (Snack at 2:45) | Drone Session (Snack at 2:45) | Research Time |
| 3:00 PM | Create Poster Outline | Work on Poster Outline | Revise Outline/Research Time | Work on Wkly Slide | Mega Meditation (snack @ 2:45) |
| 3:30 PM | Create Poster Outline | Work on Poster Outline | Revise Outline/Research Time | Work on Wkly Slide | Mega Meditation (snack @ 2:45) |
| 4:00 PM | Journal | Journal ( Poster Outline Due) | Journal ( Poster Outline Revision Due) | Journal (Wkly Slide Due) | Journal |
| 4:15 PM | Goodbye! | Goodbye! | Goodbye! | Goodbye! | Goodbye! |

**Figure 2, Example of Weekly Schedule**

***Implementing Python into research projects***

The megaGEMS high school summer research programs require each student to complete a high-caliber college-level project with a focus on air and ground robotics. The students are placed in small groups of 2-3 based on their interests in the provided ongoing research topics. As each member comes from a varying grade level, educational background, and/or interest this creates a cohesive measure to link the students. The final deliverable for each project is a scientific poster and oral presentation displayed at the End of Summer Symposium. The students in the 8-week research program are additionally required to write a 5-page scientific paper.

As the students begin their research the initial step is learning about the hardware and software they will be operating throughout the duration of their research. Coding Academy ties all the projects together as each of the areas of focus requires some coding to achieve the desired goals of the overall projects. For example, the students have various small unmanned aerial vehicles (sUAVs) that they use to determine object detection, and color detection, by implementing code that they find through research, or that they write specifically for the platform they are using.

This “trial and error” allows the groups to brainstorm with each other and then have an open discussion. Each “error” stimulates critical thinking for the students to solve issues that arise in the code they wrote or why a previously written code for another platform does not translate to a new platform.

Another example is seen in Figure 3A with students employing Python code to swarm DJI Tello drones. In this case, a swarm is defined as more than one drone flying together. The students in this group had one student who grasped the coding very well and successfully wrote a working code. This was a huge deal among the students as they then used pieces of her working code for their projects. Successes like this brought the students together and created an overall team among the various groups. This was pointed out by the students, showing how multiple departments of an organization work together to achieve their goals in business.

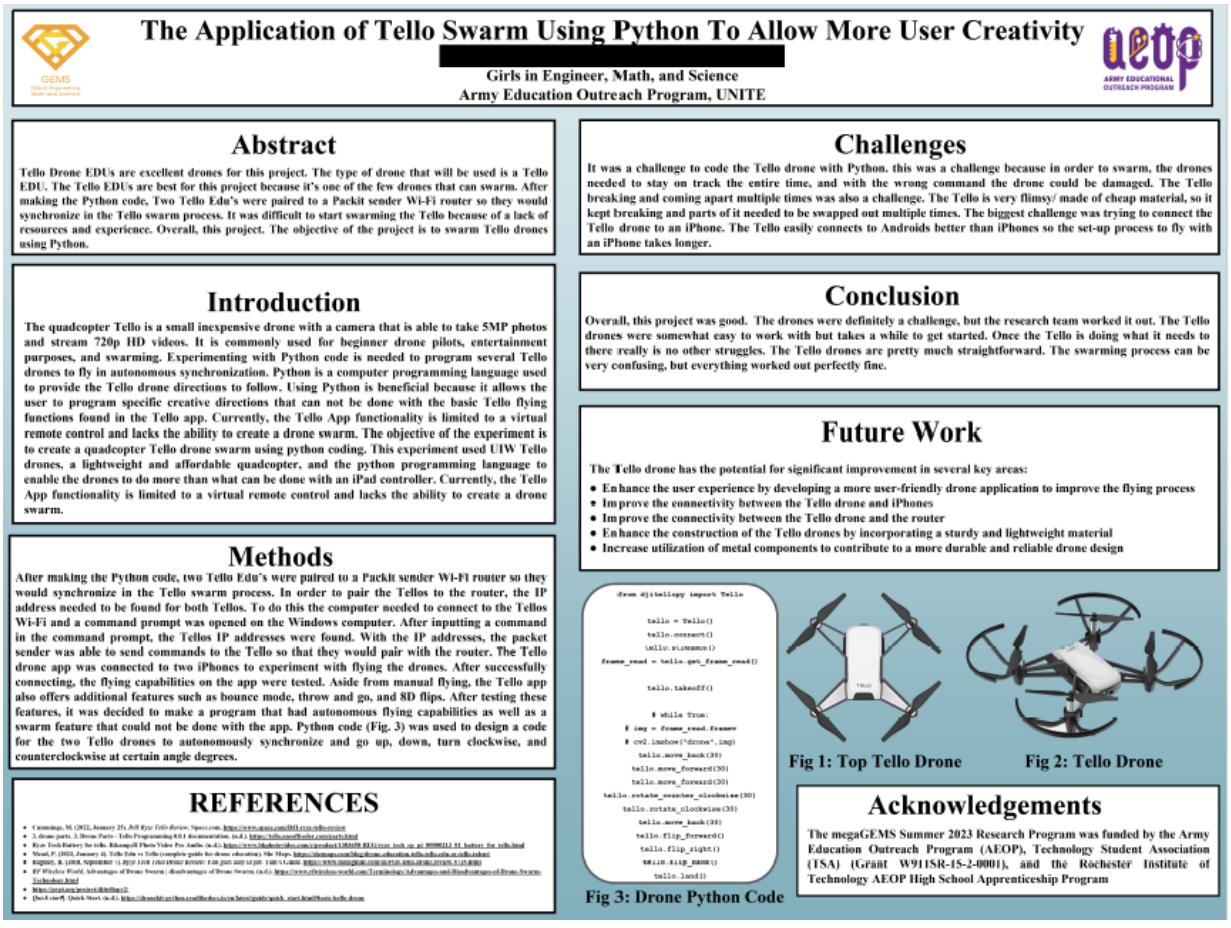



**Figure 3A, Example of Poster Presentations from students implementing Python Coding language to conduct their research**

Additionally, one group of students had previous background knowledge of JavaScript, an object-oriented computer programming language commonly used to create interactive effects within web browsers. Java is another popular language, well documented, has good community

backing, and with similar features to Python. Despite learning Python, this group of students wanted to challenge their Java skills to mimic the project of object detection and color detection previously mentioned. This unique situation had the groups compare coding languages and discuss how to translate code to achieve similar tasks.

Other research topics included implementing image filters in Python to improve the applications of an autonomous car seen in Figure 3B. and adding Python to a Donkey Car to determine functionalities and capabilities.

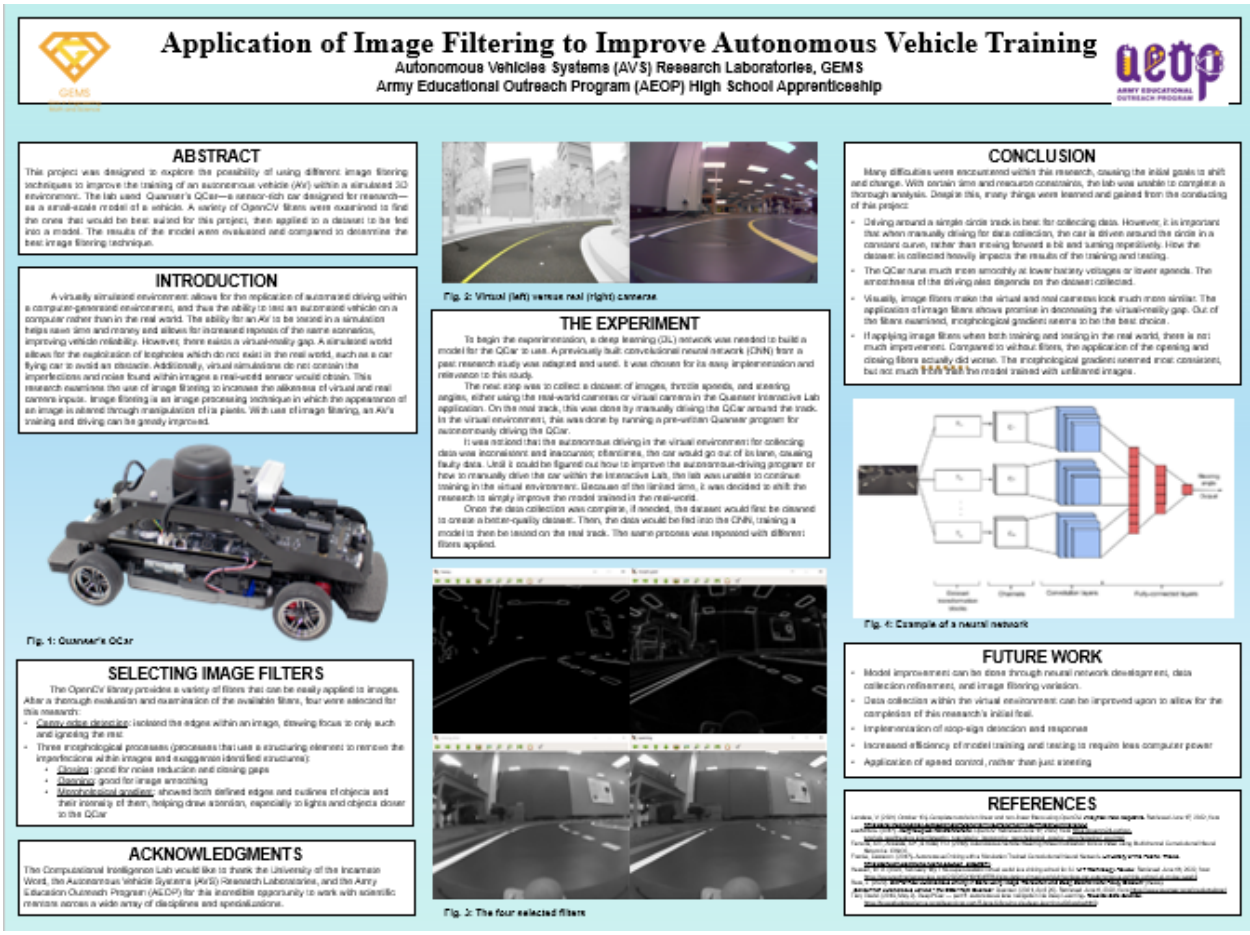



**Figure 3B, Example of Poster Presentations from students implementing Python Coding language to conduct their research**

## Surveying and Outcomes

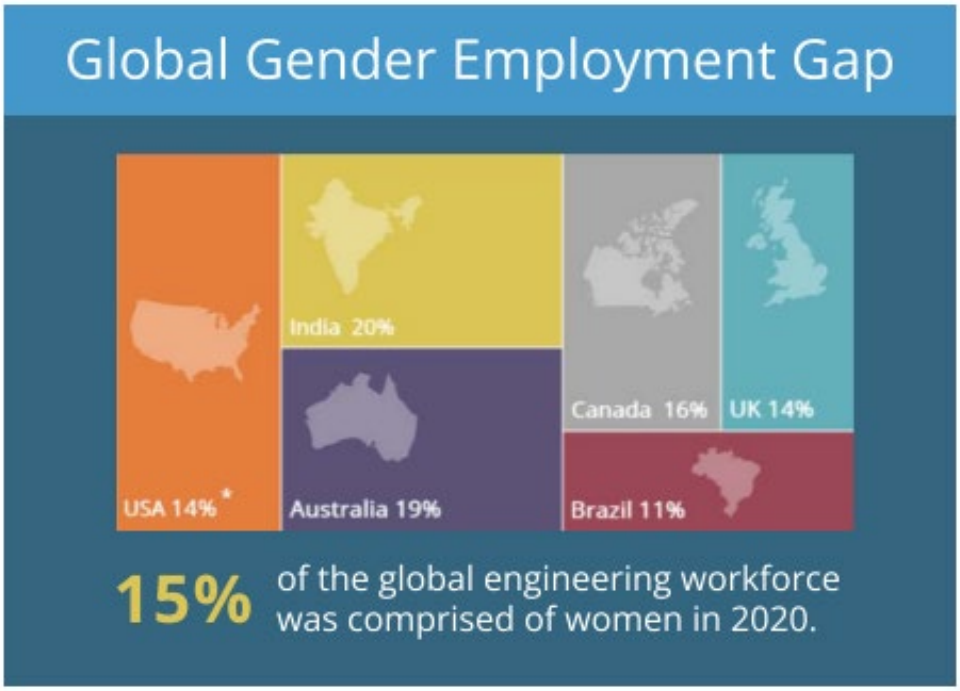
### *Workforce Development and GEMS*

Although GEMS serves primarily as a catalyst for STEM/STEAM exposure and preparation, another important function of the program is workforce development [5], [6], [7]. The students learn alongside their research how to develop a resume and cover letter, appropriate dress and

business mannerisms, and advice on how to pursue and continue an education and career across the STEM/STEAM fields. The importance of this practice lies in the ability to cultivate professionalism. The research camp attendees are exposed to professional practice and given a baseline for how a research experience works [1]. For example, research students are given an orientation on day one as well as a job description and expectations. This exemplifies how GEMS begins a "workplace-like environment" and lays the foundation of workplace culture. This allows the students to learn a new structure of communication that differs from that of a typical classroom. If a student is unable to attend, it is required for them specifically to contact the director through email notification of their absence versus their parents. Additionally, when high-level guests or presentations require "business attire," the students are asked to wear proper clothing. GEMS strives to prepare students for post-secondary school and workforce.

Given these needs and the importance of K–STEM preparation and the opportunities available to students who excel in STEM subjects, it is important to continue to focus on efforts that will increase the number and diversity of students interested in STEM and broaden opportunities for all students to succeed and thrive in STEM [3].

The image on the right shows the U.S. need for an increase in female engineers in the workforce as the global statistic is only 1% greater than the U.S. [9]. A study done by the University of Massachusetts Amherst stated that the United States will need to increase STEM degree completion for first-generation students by 34% annually to meet its goal of 1 million degrees over the next decade [12] further emphasizing the importance and need for programs like GEMS.




***Expected Results***

The expected results from the megaGEMS summer programs are to generate a collaborative and creative applied learning environment that will help research students build a solid foundation in

2 topics: (1) understanding how math and science relate to engineering and computer science, (2) understanding the importance of mathematics to science [1], [2], [5]. GEMS expects to provide hands-on experience to teach students STEM career pathways through basic computer programming using Python scripting languages.

The expected results from the megaGEMS summer programs teachers are: (1) introduce teaching skills that can support teachers in gaining hands-on experience in teaching block coding and Python scripting languages to control robots, (2) and provide a supportive professional development for teachers to network with other STEM teachers throughout San Antonio and (3) recruit students, help student management, and help with the research camp learning process. The expected results for the families of the students/campers are to teach about necessary STEM courses in high school that will benefit and prepare students for both college readiness and workforce development. Providing students and families with a foundation of knowledge and expectations going into high school and post-secondary school with maintain the pipeline into STEM careers [1], [2].

***Metrics***

Metrics are used initially introduced at the start of each program, during the application process, and continue throughout the camp to track the math/science maturation of the students. A pre-survey is administered to the students within their application. GEMS utilizes daily and final program surveys to assess the effectiveness of the program which are discussed further in subsection *Results from Student Surveys.*

***Students' progression***

> "The curriculum of Coding Academy is based upon concepts that build upon each other giving the students the tools they need to write working code for their research. Regardless of the student's level of coding knowledge, each student can learn new skills and/or refresh their skills. The interesting thing to note is that no matter what level the students have, each one struggles at different points throughout the summer, and by the end of the summer they all understand the material. Watching the students from day one of class to the last day of class, it is palpable to see the level of confidence gained by the students from the Coding Academy.
>
> On occasion the students would even ask to extend class beyond the hour so they can continue to work on their codes and complete daily projects. And when the students were able to code the wanted product, the mentors could see their excitement of their success with their eagerness to help others," said the GEMS Director Stephanie Weiss-Lopez.

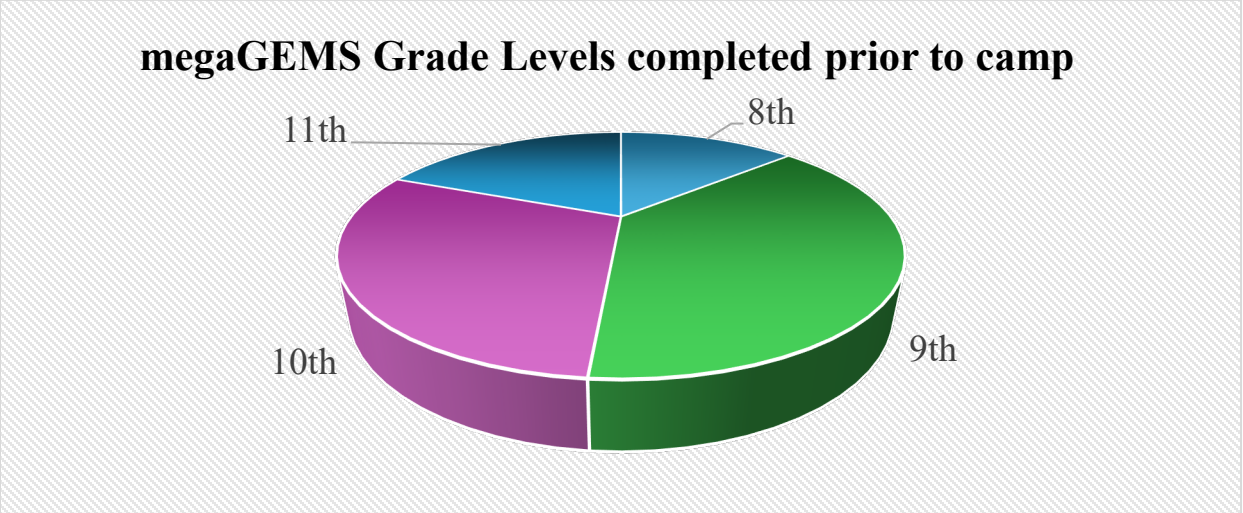



**Figure 4, megaGEMS Grade Levels completed prior to the start of summer programs**

The metric of student success is also understood from the perspective of the instructor. Students began the camp at various levels. Different grade levels, education levels, backgrounds in coursework, and even interest levels in STEM. Coding Academy provides a level playing field for each student to learn and acquire a new skill.

> "In Coding Academy, not only did students have different understandings concerning code, but they came from different grades and academic backgrounds (Figure 4). These differing backgrounds proved to be the basis upon which students' growth was observed. Seeing students who had no more common ground than the fact of attendance in the program grow to collaborate over a previously unfamiliar programming language was rewarding. This speaks a testament not only to the proficiency of students by the end of camp but to the nature of instruction and how it fostered interpersonal connections," said Coding Academy Instructor George Sikazwe.

***Results from Student Surveys***

The student surveys were conducted through a Google Form which allowed the students to read and answer each question at their own pace. The data was collected and analyzed by GEMS leadership.

**Figure 5, Common Responses from Student Surveys**

| What did you find most intriguing about Coding Academy? | What did you find the most challenging in Coding Academy? |
|---|---|
| "Challenged me and made me learn new things which I enjoyed" | " Syntax and methods specific to Python" |
| "The process of writing code was entertaining. Talking about what code does is also always fun" | "How specific the code needed to be. If you were to forget an indent or a colon the whole code would not work correctly, and you would need to go back and fix your mistake" |
| "I liked learning about coding. Coding is something I do enjoy, although I do not know much about it, and I would like to learn more about it, and the coding academy helped with that" | "The syntax, I always either spelled something wrong or forgot to space something" |
| "Making fun games out of code like tic tac toe" | "Solving the errors was difficult but we solved them together as a team, so if we failed, we did it together" |
| "The activities! I thought they were fun and thought-provoking!" | "Trying to figure out how to fix it" |
| "I think that while challenging, the concept of coding is really interesting in the sense that you can create something out of completely nothing" | " Understanding the code at first" |

For both summers of 2022 and 2023, the students were asked the same ten questions asking for feedback focusing specifically on Coding Academy. For this section, the analysis will focus on the common responses seen in Figure 5 from what the students considered the most intriguing and the most challenging about Coding Academy. The students consistently enjoyed the flexibility of coding. (i.e., game-making, coding activities) and “creating something out of nothing” was the most intriguing while the most challenging was syntax. Just like learning any new language, the students struggled to fix errors or to understand the code at first but as the syntax became familiar, they were able to write line after line of code.

Besides surveying the students for feedback on the varying aspects of the megaGEMS summer programs, a true testament is noticeable in student retention.

***Student Retention***

As previously mentioned, GEMS is divided into two programs: miniGEMS and megaGEMS. miniGEMS is for middle school girls and megaGEMS is for high school girls. GEMS has students who have been involved in GEMS programs dating back to 2017. In looking at the summers of 2022 and 2023, just under 25% of the students attended both summers (Figure 6) By the end of Summer 2023, four of the students had attended three years of miniGEMS and three years of megaGEMS.

Additionally, the megaGEMS Unite program began in summer of 2022 and provided the opportunity for a larger number of students for summer research programs.

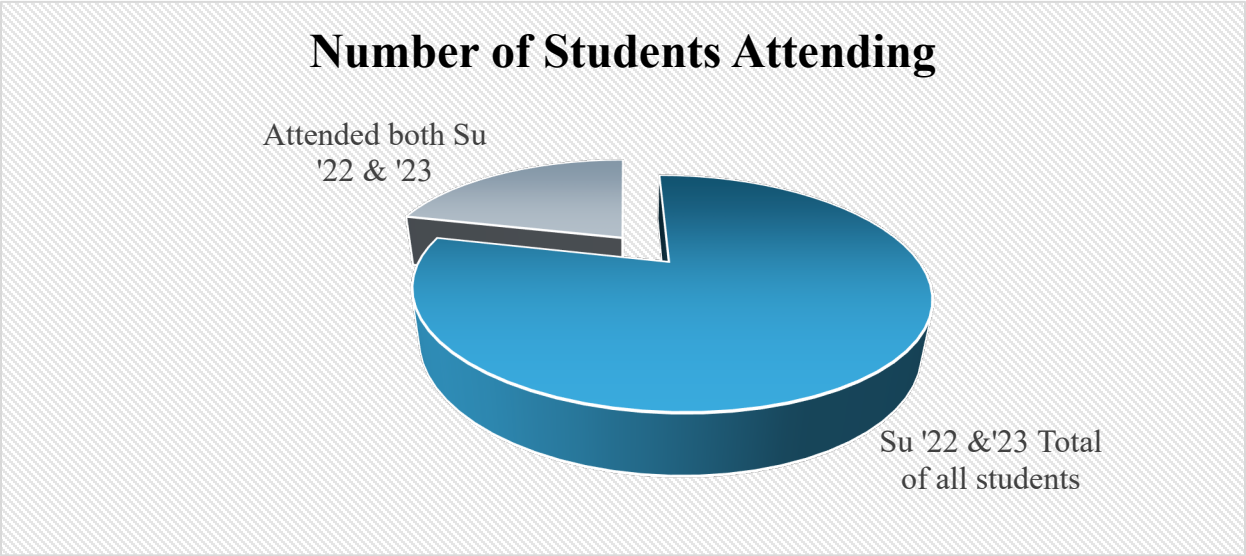



**Figure 6, Number of Students Attending GEMS High School Programs for the Summers of 2022 and 2023**

Students returning to conduct research having attended the previous year came back with a focus on their research typically wanting to either continue the work from the previous year or to alter the research towards a new direction. They came back ready to work and excited to see the outcomes of their research.

Obstacles that prevented students from returning were due to the students being involved in band/orchestra, sports, ROTC/ROTC leadership, and/or attending summer classes. GEMS leadership typically noticed that the students who attended GEMS also participated in multiple organizations and had a drive to learn and explore.

**Conclusion**

The Coding Academy looks to empower students with the fundamental programming knowledge and skills necessary for their academic and professional lives. With the core principles of the megaGEMS program in mind, students are instructed in ways that foster a collaborative and critical thinking environment. This collaboration and critical thinking are at the center of the Coding Academy curriculum wherein students are encouraged to take part in team-based projects, and reviews based on active recall. These lessons are built on top of their research project which they present at the end of camp.

The programming skills that students obtain from Coding Academy serve as a basis for STEM exposure. The majority of the megaGEMS students attribute the methods in which Coding Academy was instructed as encouraging them to consider learning and/or pursuing programming seriously. This can be explained through the number of projects that incorporate Python programming with the student's particular research interest, and the metrics from surveying presented above.

Overall, Coding Academy's implementation of engaging curriculum, and team collaboration proved to have a level of impact on each of its students. With this, it was successful in demonstrating the feasibility of developing analytical skills, and team collaboration through daily 1-hour coding lessons.

**Future Work**

***Evolving Curriculum***

The curriculum of Coding Academy features effective learning techniques but seeks to continuously improve upon itself. One such measure that it seeks to improve is adding new games and activities to invoke critical thinking and team building. Adding a new curriculum is critical to adjust the students attending year after year as well as remaining innovative.

Furthermore, adding activities, there are plans to translate lessons from Coding Academy into Saturday workshops. These short courses would help refresh students on material and/or build upon previous lessons from the summer curriculum. By supplying students with these extra lessons Coding Academy cultivates the learner and offers accessibility for students for whom summer classes, and or weekday lessons are not possible.

One question asked in the Coding Academy survey was if the students planned on learning other coding languages. Thirty-two percent of students said yes to learning another coding language and 55% said maybe. GEMS leadership is looking to create Coding Academy lessons that incorporate other languages, allowing the students to understand more high-level coding concepts and functionality. Another area Coding Academy seeks to improve upon is branching into more advanced topics and in-depth projects. The Python programming language has benefits in its clear readability, but it is a high-level language. This means the code created through it

offers a bit less control. Instruction of concepts like memory allocation, and exception handling are impeded because the language handles and allocates memory for the user. The lack of functionality places a barrier between students and important concepts.

In addition, it would be great to connect students for more in-depth projects for longer summer programs in the future for those who have a passion for coding. Considering the focus on fundamental programming skills, students progressed and in surveying confirmed the importance of projects. Coding Academy would succeed in enforcing the lessons learned through more in-depth projects that encompass multiple class sessions. During the last Coding Academy students worked on simpler in-class projects which they would finish in one session and review in another. Giving students more time to interact in their teams and work on larger projects would further ensure their capabilities to oversee larger coding tasks. In turn, better prepares them for the camp's research poster presentations. Incorporating the student's research projects into class sessions would also achieve this and allow for students to receive guidance if needed on their projects.

**Acknowledgments**

The megaGEMS high school summer programs are funded by various grants from the Army Education Outreach Program (AEOP): AEOP High School Apprenticeship Programs (HSAP) (Grant W911NF2010260), AEOP REAP through the Rochester Institute of Technology (RIT), and the AEOP Unite high school administered by the Technology Student Association (TSA) and member of the AEOP Consortium formed by the AEOP cooperative agreement award (W911SR-15-2-0001).

**REFERENCES**


[1] M. Schilling, & M. Pinnell, (n.d.). "The STEM gender gap: An evaluation of the efficacy of women in engineering camps" *Journal of STEM Education: Innovations and Research.* https://www.jstem.org/jstem/index.php/JSTEM/article/view/2346

[2] S. Weiss-Lopez, M. Frye, and O. Jones, "Overview of the megaGEMS AEOP Summer 2021 Research Apprenticeship Camp", *Proceedings of the 129th American Society of Engineering Education Annual Conference and Exposition*, Minneapolis, Minnesota, June 26 - 29, 2022 https://peer.asee.org/overview-of-the-megagems-aeop-summer-2021-research-apprenticeship-camp

[3] S. R. Burke, and A. (n.d.). *Science & Engineering Indicators*. NSF. https://ncses.nsf.gov/pubs/nsb20211

[4] R. Rincon, (Ed.). (2023, December). "A case study engineering leadership: Exploring Women in" https://swe.org/wp-content/uploads/2024/01/1-PIP-Study-Report_FINAL.pdf.pdf

[5] The Department of Defense Stem. (n.d.). https://dodstem-assets.dodstem.us/files/DoD_STEM_Strategic_Plan_2021.pdf

[6] J. Gipson, & K. Baird, (2023, April 12). "*What is Python? Python programming for beginners".* Ellipsis Education. https://ellipsiseducation.com/blog/what-is-python

[7] Jpotyraj. (2022, December 16). "*Why learn Python? Five reasons to start programming with Python"*. UT Austin Boot Camps. https://techbootcamps.utexas.edu/blog/why-learn-python-get-started-programming/

[8] *Centers for Disease Control and Prevention*. (n.d.). "International Women in Engineering Day". Centers for Disease Control and Prevention. https://blogs.cdc.gov/niosh-science-blog/2023/06/22/women-in-engineering-day/#:~:text=June%2023%2C%202023%20is%20International,workforce%20(15%25%20internationally)

[9] Swe Research Fast Facts - Society of Women Engineers. (n.d.-a). https://swe.org/wp-content/uploads/2021/05/SWE-Fast-Facts_FINAL2022.pdf

[10] Radu. (2023, December 12). "Unite". *AEOP*. https://www.usaeop.com/program/unite/

[11] “Technology student association”. *Technology Student Association*. (n.d.). https://tsaweb.org/

[12] G. Bettencourt; C. A. Manly; E. Kimball; and R. Wells, "STEM degree completion and first-generation college students. A cumulative disadvantage approach to the outcomes gap" (2020). *Review of Higher Education.* 35. Retrieved from https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1040&context=cfssr_publishedwork

[13] G. Judea, (2024, January 23). *High school internships*. AEOP. https://www.usaeop.com/program/high-school-internships/

[14] E. G. Deitz, and S. (n.d.). “Diversity and STEM: Women, Minorities and Persons with Disabilities Report The STEM Workforce”. *NSF*. https://ncses.nsf.gov/pubs/nsf23315/report/the-stem-workforce

[15] S. Thomas-Oxtoby, (2023, December 20). “Nearly 5 million people have taken this online course-here’s how it can kickstart your computer science career”. *Fortune Education*. https://fortune.com/education/articles/nearly-5-million-people-have-taken-this-online-course-heres-how-it-can-kickstart-your-computer-science-career

[16] Texas Education Agency. (2023, October 26). *Texas Essential Knowledge and Skills*. https://tea.texas.gov/academics/curriculum-standards/teks-review/texas-essential-knowledge-and-skills