BOARD # 69: Improving Student Retention Using Research Mentors

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Abstract

The Advancing Retention via Research Opportunities for Workforce Development in STEM (ARROWS) Project aims to boost minority women's participation in scientific and technological occupations. The ARROWS pipeline is an institutional initiative award that introduces academically outstanding female high school and undergraduate students to majors and jobs in science, technology, engineering, and mathematics (STEM). This project includes an annual summer research effort that aims to attract and develop the next generation of female scientists, mathematicians, and technologists. When combined with partner programs such as Developing Advanced Research Through STEM (DARTS) and STEM Pathways for Success, these projects create a three-stage student success pipeline: (1) secondary education exposure, (2) college-level engagement, and (3) transition to graduate school or the technical workforce. We foster students' enthusiasm for STEM by providing immersive summer research experiences that improve competency in four national needs: artificial intelligence (AI) and machine learning (ML), robotics/autonomy, cybersecurity, and data analytics, with a focus on hybrid learning environments [12]. Our mission is to address the ongoing difficulty of helping traditionally underprivileged and underrepresented student populations in STEM, such as women, minorities, and economically disadvantaged students [10]. As the world's biggest Historically Black College and University (HBCU), North Carolina A&T [11] is uniquely positioned academically, regionally, and culturally to accommodate these emerging demographics.

Introduction

Retention of students in Science, Technology, Engineering, and Math (STEM) professions has long been a problem, especially among minority and female students. According to studies, structural impediments such as a lack of mentorship, limited access to research opportunities, and budgetary restrictions disproportionately affect these populations [1], [2]. To address these discrepancies, the ARROWS program at North Carolina A&T State University has taken a holistic strategy that focuses on mentorship, hands-on research, and a supportive academic atmosphere.

Mentorship, defined as experienced persons guiding mentees through academic and professional problems, has been demonstrated to dramatically increase retention rates [3]. For example, it promotes self-efficacy (confidence in one's own potential to succeed) while also assisting students in developing a strong identity within their chosen STEM areas. Further, mentorship has been associated with higher self-efficacy, stronger STEM identities, and better professional development [4], [5]. Self-efficacy is a student's belief in their capacity to overcome hurdles and achieve goals, which is essential for perseverance in difficult STEM subjects. Similarly, creating a STEM identity entail viewing oneself as a legitimate part of the scientific community—a process aided by positive mentorship connections [6].

Hands-on research opportunities improve retention by exposing students to real-world applications of STEM topics. Evidence suggests that such encounters not only enrich understanding but also boost motivation and commitment to STEM careers [7].
Finally, building an inclusive academic atmosphere ensures that students feel appreciated and encouraged, which is critical for overcoming feelings of isolation common among

underrepresented groups [8]. This report investigates how ARROWS activities—structured mentorship, immersive research involvement, and institutional support—help minority STEM students achieve better retention outcomes.

As a core retention strategy, mentorship is an essential part of the ARROWS curriculum. The initiative connects participants with dedicated faculty mentors who give tailored help on both academic obstacles and personal development. To date, 15 faculty members from the College of Science and Technology (CST) have won mini-grants to enhance their research capacity while also serving as mentors. They play an important role in building students' confidence, instilling a sense of belonging, and assisting them in navigating difficult study topics. Faculty mentors have regular one-on-one interactions with students, providing tailored feedback and encouragement. They also walk students through the complexities of research projects, assisting them in developing critical thinking skills and building confidence in their abilities. This structured mentorship framework not only keeps students interested but also encourages them to seek higher degrees or professions in STEM.

Literature Review

Retention in STEM disciplines has long posed challenges for higher education institutions, particularly among underrepresented populations. Numerous studies highlight how structural barriers, including inadequate access to mentorship, financial hardship, and a lack of representation, disproportionately affect women, minority students, and those from low-income backgrounds [1], [8]. NASEM [2] emphasized that to increase diversity in STEM meaningfully, institutions must address not only academic challenges but also psychosocial factors such as students' sense of belonging, identity, and self-efficacy. Mentorship has been identified as one of the most effective strategies for improving STEM retention. Johnson [3] demonstrated that mentorship increases self-efficacy—defined as an individual’s belief in their ability to succeed—and helps students form a positive STEM identity, both of which are strong predictors of academic persistence. Similarly, [4] found that students who participate in structured mentorship programs are more likely to remain in STEM majors and pursue advanced degrees. These mentorship relationships provide students with guidance, role models, emotional support, and access to professional networks, thereby reducing the feelings of isolation that often discourage underrepresented students from persisting in STEM fields [6]. Equally important are hands-on research experiences, which allow students to apply classroom knowledge to real-world problems, thus reinforcing their understanding and increasing their motivation. A meta-analysis by [7] found that undergraduate research participation is significantly associated with higher retention rates, enhanced academic performance, and greater commitment to STEM careers. By engaging students in active problem-solving and critical thinking, research experiences cultivate a sense of ownership and accomplishment, which are crucial for sustained interest and success in STEM [5]. Despite these known benefits, the literature reveals notable gaps. Many existing studies are limited to short-term outcomes and lack rigorous methodologies, such as control groups or longitudinal tracking [9], [2]. Furthermore, most research focuses on interventions at predominantly white institutions or within a single educational stage, often neglecting the cumulative effects of multi-stage, pipeline-based approaches, especially at HBCUs. The ARROWS and DARTS programs offer a unique opportunity to fill these gaps by examining the long-term impact of a holistic, culturally relevant, and equity-centered model implemented at a minority-serving institution.

By situating this study within the existing body of literature and addressing its limitations, this research seeks to advance a practical understanding of what works in retaining underrepresented

students in STEM. Specifically, it will explore how mentorship and research experiences influence students' development of self-efficacy, STEM identity, and belonging and how these factors, in turn, affect retention, graduation, and workforce entry. These insights will provide valuable guidance for institutions and policymakers committed to building a more inclusive and representative STEM ecosystem.

Identification of Need

Although there is a high priority placed on science, technology, engineering, and math (STEM) education across the country, a shortage still exists among girls and women who pursue STEM degrees and careers [7]. In North Carolina specifically, the 2019 Condition of College & Career Readiness Report showed that 19,569 North Carolina graduates (18 percent) indicated having an interest in STEM majors and/or careers [9]. However, we continue to see females fall behind males in STEM-related attainment. This is true both for graduates generally and for graduates interested in STEM. Additionally, the achievement gap between females and males is wider among graduates interested in STEM than among all graduates—4 percentage points wider for the Math and Science Benchmarks and 3 percentage points wider for the STEM Benchmark [8].

The underrepresentation of young women in STEM education negatively affects their future career paths and results in countless missed opportunities for achievement and discovery in those fields. The implications are even larger for young women of color and for those who are economically disadvantaged. These disparities exist due to wide gaps in science, technology, engineering, and mathematics representation and access. Female and male students perform equally well on standardized tests in math and science; however, females tend to earn higher grades than their male peers during high school [10]. But in education and workplaces, gender equity in STEM is still elusive. A study conducted by the American Association of University Women (AAUW) concluded that pre-college recruitment is critical to build young women's involvement and confidence in STEM and establishes the value of mentoring and a supportive environment for diverse women [3]. The report points to social and environmental barriers, including gender bias, stereotypes, and the climate of engineering and science courses that continuously hinder women's progress in STEM. It is imperative that we position women to be successful within this economy as society grows its digital economy. This includes creating opportunities and access for young women to learn about STEM and career pathways as well as encouraging them to join the STEM workforce.

Objective of the Study

The specific objectives of this study are to:

i. Recruit female high school students in the areas of robotics/autonomy, cybersecurity, artificial intelligence (AI), machine learning (ML), and data analytics by working in concert with NC A&T Partnering Institutions.
ii. Support students through hybrid learning environments to innovatively harness student engagement by allowing students to improve competence in robotics/autonomy, cybersecurity AI, ML, and data analytics through mentorship, professional workshops, and presentations while stimulating enthusiasm and interest in STEM-related research and discovery.
iii. Connect students to opportunities through leadership conferences, presentations, and networking for them to obtain STEM careers and internships as well as develop interests in attending college/grad school and pursue majors in STEM.

ARROWS Operation

The Advancing Retention through Research Opportunities for Workforce Development in STEM (ARROWS) project aligns perfectly with the Minority Science and Engineering Improvement Program's aim to increase the flow of minority women into scientific and technological careers. The ARROWS initiative brings together several program activities to collaborate toward improving recruitment, retention, career preparation, and job placement for these underserved populations. When coordinated, this will create an ARROWS pipeline that advances young women from high school to university and then into the STEM workforce or graduate school. The ARROWS project targets four areas of national need: artificial intelligence (AI) and machine learning (ML), robotics/autonomy, cybersecurity, and data analytics. It is an expansion of our proven Recruit-Support-Connect (RSC) program that increased enrollment, retention, and STEM degrees awarded to women in North Carolina A&T State University's College of Science and Technology in 2011-2015 [6]. Mirroring and building on the structure of the successful RSC project, the ARROWS project is a three-stage student success pipeline model that 1) "Recruits" academically talented high school using partnerships with several Minority Serving Institutions (MSIs) to stimulate interest in STEM; 2) "Supports" recruited high school and undergraduate students with summer research experiences and mentoring at North Carolina A&T State University using hybrid learning environments; and 3) "Connects" students to STEM undergraduate and graduate programs as well as STEM careers and fellowship opportunities via annual research symposiums (Figure 1) to further influence retention in STEM fields.

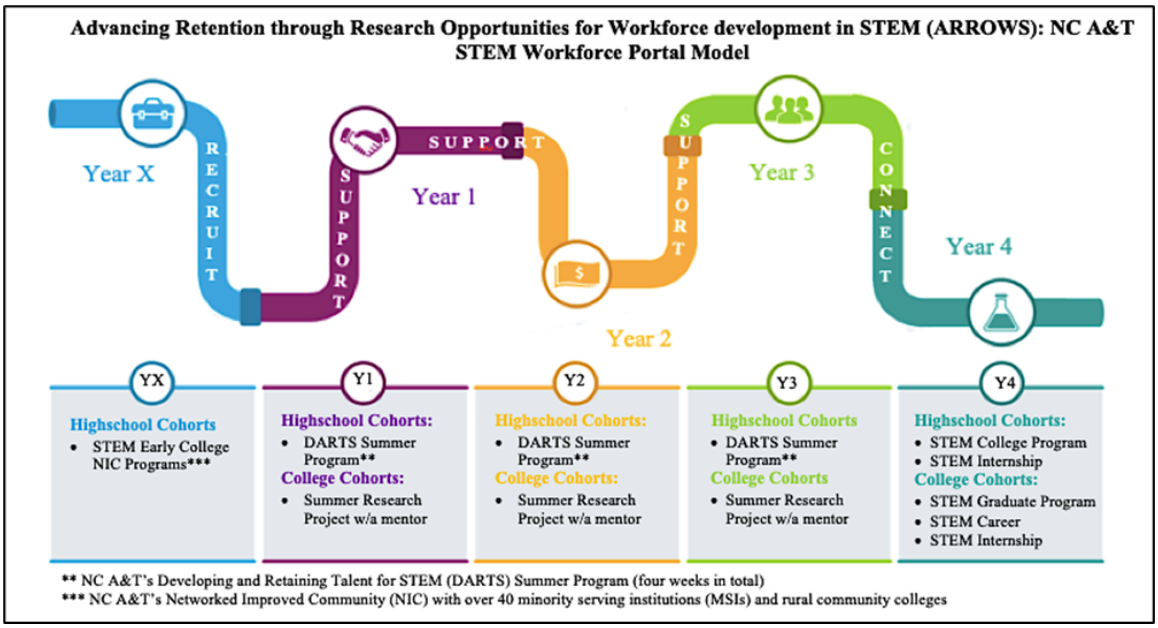

Figure [1]: NC A&T STEM Workforce Pipeline

Figure 1 presents the NC A&T STEM Workforce Pipeline. In year X, students are recruited from STEM Early College and NIC programs (Networked Improved Community). Through years 1 to 3, participants in both high school and college cohorts receive support via the DARTS Summer Program and mentored research projects. By year 4, students transition into internships, graduate programs, and STEM careers, ensuring a well-rounded and sustained development toward the STEM workforce. This initiative uniquely serves underrepresented and rural communities through its expansive NIC network and strategic academic partnerships.

Engagement Through Research Activities

ARROWS promotes immersive research activities as a crucial factor in student retention. Participants are introduced to cutting-edge issues that correlate with national workforce goals, such as artificial intelligence, robots, cybersecurity, and data analytics. By integrating classroom learning to real-world applications, the curriculum demonstrates the importance and value of STEM education. Evidence suggests that participating in research activities improves retention by establishing a sense of ownership and pride in one's effort [5]. Many students consider these events to be watershed moments, reaffirming their decision to pursue a career in STEM. The annual summer research initiative is a cornerstone of this effort, allowing high school and undergraduate students to conduct hands-on research projects under professor supervision. High school students involved in the DARTS (Developing Advanced Research Through STEM) program share their discoveries at the ARROWS Symposium, which highlights their efforts and encourages a sense of accomplishment and success. Participating in research projects allows undergraduates and graduate students to publish findings and present at academic conferences, reinforcing their dedication to STEM careers.

ARROWS Symposium: A Showcase of Achievement

By fostering a sense of accomplishment and appreciating students' contributions to the scientific community, presenting research has been shown to increase retention [7]. Many attendees view the symposium as a pivotal experience, where they are able to fully grasp their potential and the tangible results of their hard work. On July 26, 2024, the ARROWS program had its annual symposium at North Carolina A&T State University. In addition to honoring research advancements, this occasion encouraged teamwork, stimulated creativity, and involved instructors and students from a variety of STEM fields.

The symposium was carefully planned to provide a vibrant, inclusive setting where attendees may showcase their work, network, and share ideas. It included a wide range of events, such as interactive workshops, high school project exhibits, keynote addresses, and student poster presentations. Together, these components demonstrated the program's capacity to inspire and retain students while demonstrating the depth and scope of current scientific, technological, engineering, and mathematical research.

The chance for students at all levels—high school, undergraduate, and doctoral—to present their research was one of the symposium's most notable features. The event, which included 50 high school children, 32 undergraduates, and 10 doctorate candidates, emphasized the value of developing talent at all educational levels. Exposure to advanced themes and approaches was beneficial for high school pupils in particular, since it gave them a preview of what their academic paths would entail. In the meantime, graduate and undergraduate students improved their presentation abilities, got helpful criticism, and made connections with mentors who could help them in their future pursuits.

Looking ahead, the 2024 symposium's success lays a solid basis for further iterations. Based on participant input, organizers are already contemplating improvements including adding more interactive sessions, reaching out to marginalized groups, and using technology to enable remote participation. The symposium will continue to be a shining example of STEM education and engagement by developing and adapting throughout time.

Symposium Activities

Undergraduate, graduate, and even high school students had the chance to present their innovative research on cutting-edge topics like artificial intelligence (AI), cybersecurity, robotics, and the Internet of Things (IoT) through the symposium's exciting lineup of student poster presentations. These talks promoted a culture of intellectual conversation among attendees in addition to showcasing the creative work being done by the upcoming generation of researchers. The breadth and complexity of the projects, which included anything from developing secure systems that might survive contemporary cyberthreats to investigating machine learning methods for practical applications, especially pleased the attendees. It was particularly notable that high school students were included in this academic context because it demonstrated the symposium's dedication to developing young talent and motivating upcoming innovators.

Numerous activities were included in the symposium with the goals of involving attendees, showcasing cutting-edge research, and encouraging teamwork. The event's focal point was the student poster presentations, which were among its most powerful elements. The ingenuity, commitment, and technical proficiency of students ranging from high school to doctoral candidates were showcased in these presentations.

Here are a few glimpses of student posters to give you an idea of the caliber and diversity of the work that was presented during the symposium. The innovative research that was presented, which covered subjects including robots, artificial intelligence (AI), cybersecurity, and the Internet of Things (IoT), is encapsulated in these images.

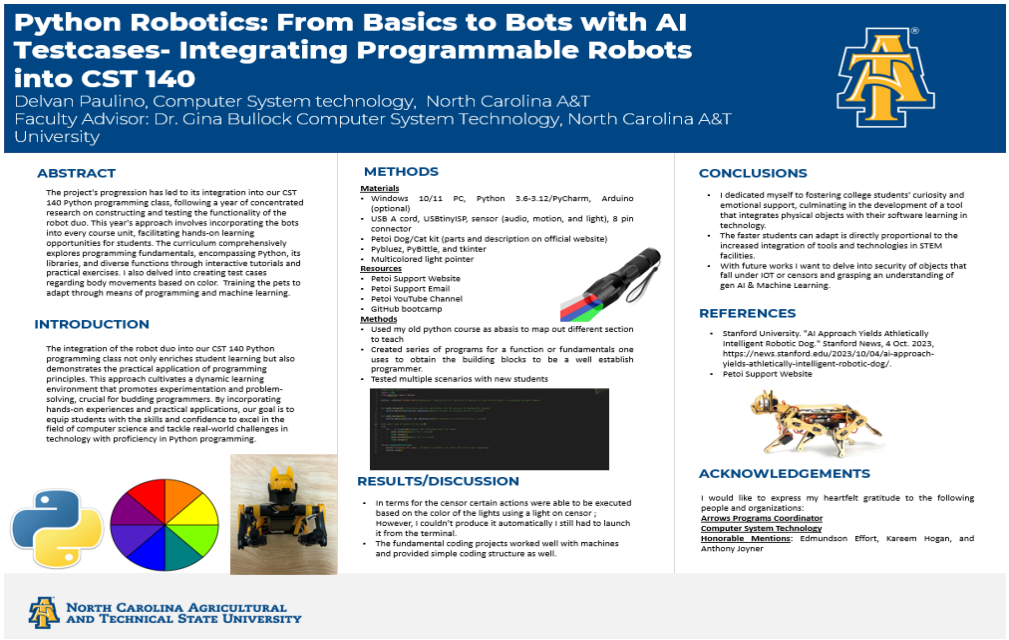

Figure [2]: From Basics to Bots with AI Testcases- Integrating Programmable Robots (Delvan Paulino, undergraduate researcher)

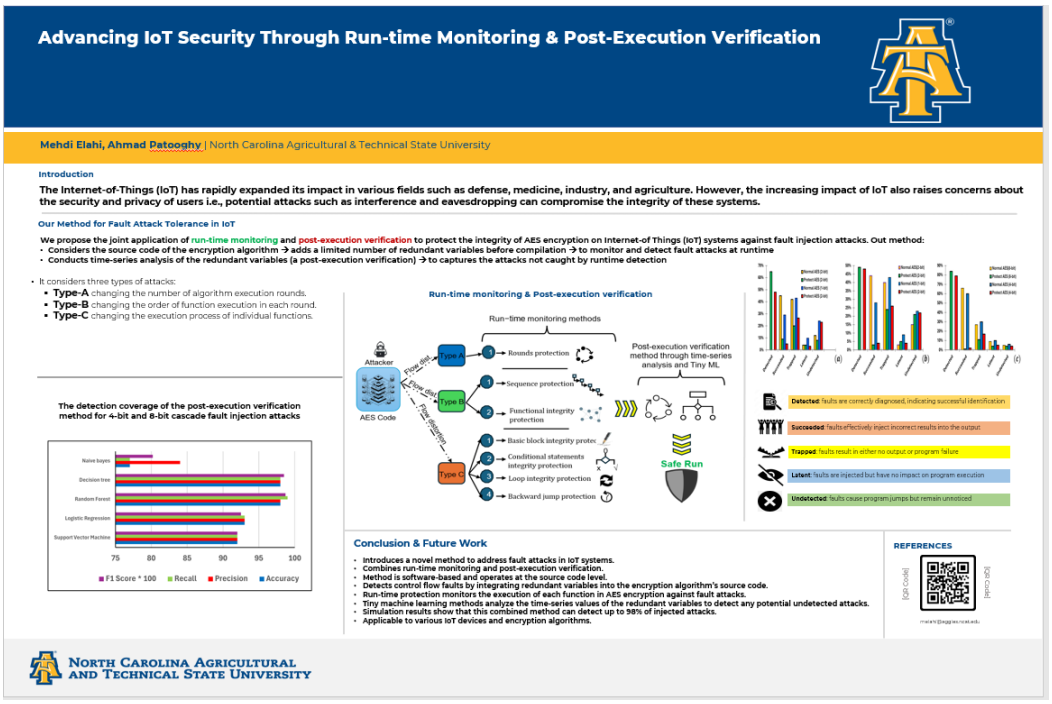

Figure [3]: Advancing IoT Security Through Run-time Monitoring & Post Execution Verification (Mehdi Elahi, graduate researcher)

Apart from the poster presentations, the symposium offered priceless networking opportunities that helped students, scholars, and business professionals connect. Through these exchanges, participants were able to form deep connections that may lead to future partnerships, possibilities for mentorship, and professional growth. Professionals from the industry discussed new developments and difficulties in their domains, and students were exposed directly to possible directions for using their research in real-world situations. Numerous attendees conveyed gratitude for the relaxed yet effective ambiance of the networking events, which promoted candid communication and interdisciplinary cooperation.

A thorough post-event survey was carried out in order to evaluate the event's impact and pinpoint areas that needed improvement. Attendees unanimously praised the symposium's structure, relevancy, and overall influence, according to the survey findings, which clearly showed how successful it was. Remarkably, 88% of the students who responded gave the event organization an "excellent" rating, praising the careful preparation that made sure everyone had a smooth experience. Important elements, including the organized timetable, handy location, and quick registration process were regularly cited as noteworthy characteristics. According to a participant, "The event ran like clockwork—everything was easy to navigate, and I never felt rushed or disoriented."

The symposium did a fantastic job of covering topics that were both relevant and powerful. Of those present, half thought the ideas were "quite relevant" to their current work or studies, and the other half thought they were "extremely relevant." The event's capacity to appeal to a broad spectrum of interests while keeping a laser-like focus on current concerns influencing the technology landscape is reflected in this balancing. For example, individuals working at the nexus of technology and society found great resonance in conversations about AI ethics and IoT

security, while those interested in automation and engineering applications were excited by robotics demos.

Another significant advantage of the symposium was networking, as 63% of participants said the opportunities were "very effective." Participants stressed the importance of interacting with mentors and peers who were as passionate about innovation and discovery as they were. A number of participants reported making contacts that resulted in prompt follow-up discussions on collaborative projects, internships, or research collaborations. According to one participant, "I left the symposium feeling inspired and connected, with concrete ideas for how to move my work forward thanks to the people I met there."

Because 63% of attendees indicated that they were "very satisfied" with the symposium, overall satisfaction percentages further demonstrated its effectiveness. Remarkably, all attendees expressed a desire to attend subsequent symposiums, demonstrating the symposium's enduring influence and popularity. This widespread excitement says a lot about how well the event fosters a sense of belonging and community among attendees, irrespective of their experience level or background.

Future symposia will be improved and refined in response to the feedback received from the survey. The organizers are already taking into account recommendations to broaden the range of subjects covered, include more participatory components like practical workshops, and enhance chances for interdisciplinary cooperation. Building on the successes of this year, the symposium is well-positioned to remain an essential forum for encouraging creativity, advancing learning, and propelling advancement in the rapidly changing domains of science and technology.

Attendee Feedback

The feedback from attendees was very positive, with qualitative replies highlighting the symposium's significant impact on both a personal and professional level. The vast range of study subjects and presentations was not only stimulating but also incredibly motivating to the participants. One participant said, "The various research topics and talks were inspiring," highlighting the event's ability to pique interest and cultivate a greater understanding of multidisciplinary work. In a statement, another participant said, "Seeing all the research happening in the CST department made me want to get more involved." Several others agreed, stating that the symposium inspired them to seek new prospects in their profession and rekindled their enthusiasm for scholarly inquiry.

Attendees commended the symposium's easy organizing and friendly atmosphere in addition to its engaging material. Many emphasized the event's capacity to establish an environment in which contacts could be made with ease and ideas could flow freely. In the words of one participant, "It was a well-organized and engaging event." This pleasant experience was further enhanced by the interactive aspect of the seminars, the presenters' accessibility, and the careful scheduling of the sessions. Everyone, from seasoned academics to undergraduates just starting their academic careers, felt respected and included thanks to the organizers' emphasis on inclusivity, which was well received by attendees.

The symposium also provided a forum for fruitful discussion and cooperation. Many participants mentioned how the networking possibilities let them meet specialists and peers they might not have otherwise met. Fruitful conversations regarding possible partnerships, pooled resources,

and upcoming initiatives resulted from these exchanges. These discussions were among the most beneficial things that many people learned from the symposium, which further reinforced its function as a hub for creativity and community development.

Beyond its immediate consequences, the symposium inspired participants to critically examine their own contributions to respective areas, leaving a lasting imprint. While several attendees indicated interest in attending or even planning similar events in the future, others revealed intentions to integrate lessons from the event into their ongoing study. Overall, the symposium was a great success, in that it succeeded in promoting intellectual development, involvement, and a sense of community among academics.

Suggestion for Improvement

Constructive criticism was provided by attendees with the goal of expanding the symposium's influence and audience. A common recommendation was to broaden the audience to include more professionals in the field, which might greatly enhance professional networking prospects. Participants underlined the importance of networking with experts who are actively influencing STEM-related companies. Deeper conversations regarding practical applications of research and collaborations between academics and practice might be facilitated by bringing a wider spectrum of industry leaders, including engineers, data scientists, cybersecurity experts, and AI developers. These exchanges may be helpful to students and early-career researchers as they investigate career options, comprehend industry expectations, and perhaps land internships or jobs.

Participants suggested expanding the audience and using an expo-style structure for further gatherings. With this strategy, the symposium might host more sessions, giving researchers and innovators a wider stage on which to exhibit their work. In an expo-style design, presenters can connect directly with visitors in a less formal environment through interactive booths or stations. In addition to promoting lively discussions, this type of structure lets attendees go at their own speed and concentrate on the subjects that most interest them. Additionally, it opens doors for interactive demonstrations, live experiments, or prototype presentations, all of which can help a variety of audiences better understand and be interested in complex research concepts.

By enabling more students to participate and exhibit their work, especially those from marginalized groups or smaller universities, the expo-style format could further improve inclusivity. By ensuring that a greater range of voices and viewpoints are included, broadening the breadth of presentations would enhance the symposium's intellectual diversity.

In the end, these suggested improvements support the symposium's main objectives of encouraging creativity, advancing learning, and creating relationships. The event can continue to develop into a leading forum for recognizing outstanding research and advancing STEM fields by growing its audience and adopting new formats.

DARTS Program Activities

To evaluate the program's effectiveness, survey data was collected from 31 participants both before and after their participation in the program. This report presents the findings of the analysis, highlighting the program's impact on participants' knowledge, confidence, and interest in STEM topics and careers.

The DARTS program had a significant impact on students' engagement and learning in STEM fields. Before participating in the program, only 20% of students reported familiarity with key STEM topics such as machine learning and the Internet of Things. However, post-program assessments indicated a substantial rise in foundational STEM knowledge, with 80% of participants demonstrating familiarity—reflecting a 60% increase. Confidence in technical abilities also showed notable growth. Prior to the program, 33% of students felt "moderately confident" or higher in their technical skills. By the end of the program, this number increased to 71%, representing a 38% improvement in confidence related to technical competencies.

Participation in team-based activities contributed to improved collaborative skills. Initially, only 27% of students felt "very comfortable" working in teams. Following the program, this number grew to 64%, indicating a 37% increase in teamwork confidence and engagement. The program also played a crucial role in expanding students' awareness of STEM career opportunities. Before participation, 40% of students expressed knowledge of STEM-related careers. By the end of the program, this figure rose to 90%, demonstrating a 50% increase in career awareness. This improvement can be attributed to program elements such as guest speaker sessions and symposium participation.

Students' interest in STEM disciplines deepened over the course of the program. Before the program, 45% of participants reported being "moderately interested" in STEM topics such as machine learning and robotics. This interest level increased to 75% post-program, marking a 30% rise in enthusiasm for STEM-related subjects. In addition to increased knowledge and confidence, the program encouraged students to adopt positive STEM-related habits. Post-program results showed a 44% increase in STEM engagement behaviors, with 82% of students reporting more frequent use of online resources, participation in extracurricular activities, and engagement with technology-related content.

The survey results, as demonstrated in Figure 2, highlight the success of the DARTS program in improving STEM knowledge, confidence, and engagement. The notable increases in technical skill confidence and STEM career awareness underscore the effectiveness of the program's hands-on, career-focused approach. These findings reinforce the value of structured STEM initiatives in fostering long-term interest and proficiency in STEM fields.

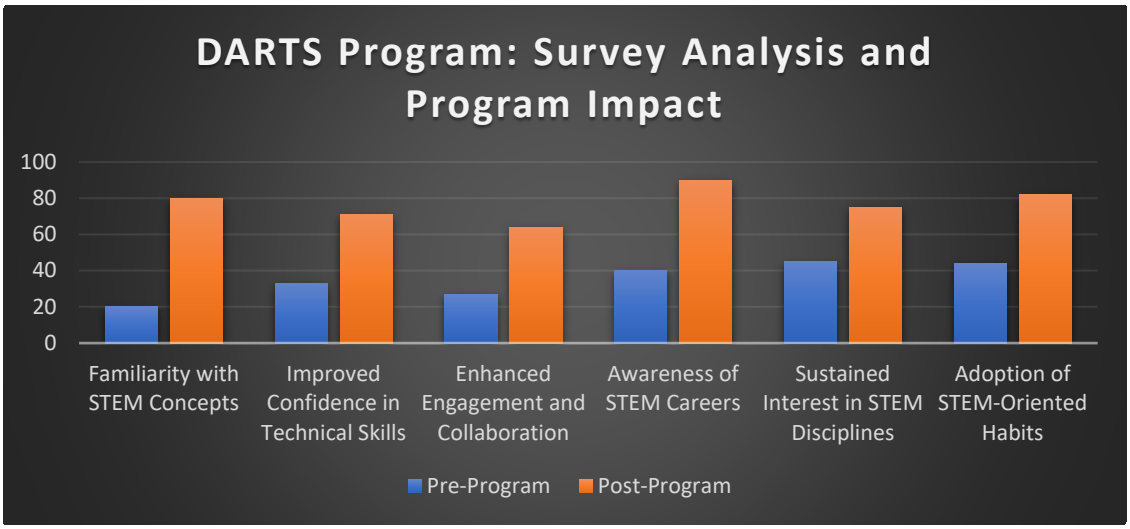

Figure [4]: DARTS Survey

To further enhance program development, several recommendations can be considered. Broadening career exposure by expanding industry speaker sessions would provide students with a deeper understanding of various career pathways and professional opportunities in STEM fields. Increasing hands-on activities through additional project-based learning experiences could further develop technical skills, allowing students to apply their knowledge in practical, real-world scenarios. Additionally, implementing long-term tracking by conducting annual alumni surveys would help evaluate the program's lasting impact, providing valuable insights into its effectiveness and areas for improvement. These recommendations aim to strengthen the program's ability to prepare students for future STEM careers and ensure continuous growth and relevance.

Support for underserved populations

For historically underrepresented groups in STEM, such as women, underrepresented minorities, and students from low-income families, retention poses unique difficulties. Systemic obstacles that these groups frequently face include lack of representation in academic and professional settings, restricted access to resources, and financial limitations. These barriers may result in disproportionately high dropout rates, which would further entrench inequality in the STEM field. These systemic injustices may deter gifted people from pursuing or continuing in STEM areas if specific remedies are not implemented.

By creating an inclusive atmosphere and offering customized support catered to the need of underprivileged students, ARROWS tackles these problems. Stipends and support for research activities are provided to economically disadvantaged students, relieving financial strain and allowing them to concentrate on their academic and career objectives [10]. Undergraduate and high school students also gain from possibilities for practical research, academic support networks, and mentorship programs. Mentors help students overcome obstacles, and financing gives them the freedom to experiment with creative ideas without worrying about money. Through the removal of obstacles to participation and the provision of customized resources, ARROWS guarantees that every student has an equal chance to thrive in STEM.

ARROWS creates a sense of community and belonging among participants from a variety of backgrounds by planning events such as networking sessions and symposium. Early exposure to STEM through outreach programs piques youngsters' interest and establishes the groundwork for continued involvement. Through these initiatives, ARROWS not only helps current students but also advances new ideas and creative solutions, which benefits the larger scientific community.

Institutional Commitment and Cultural Alignment

As the foundation and driving force behind ARROWS's success, North Carolina A&T State University is essential to the organization's support and advancement of its purpose. The institution's strong regional and cultural ties to its target audience—especially women, underrepresented minorities, and students from low-income families—help it draw in, involve, and keep participants who might otherwise encounter obstacles when trying to access STEM education. In typical HBCU fashion, North Carolina A&T upholds a tradition of empowering underprivileged groups by providing an environment where students are encouraged, respected, and visible. The program's impact is increased by the strong synergy that results from the university's identity and ARROWS' objectives being in line.

By cultivating a campus culture that values diversity, innovation, and academic performance, ARROWS builds upon this solid foundation. The program helps to ensure that students are not just accepted but are also prepared to succeed in STEM disciplines by implementing focused activities. For example, networking opportunities, mentorship programs, and workshops assist students in gaining confidence in their capabilities and developing critical thinking abilities. By enabling faculty members to pursue advanced research through mini-grants, which frequently involve student involvement, institutional financing supports these efforts even more. A dynamic feedback loop is produced by this combined emphasis on faculty development and student mentoring, whereby academics further their own research endeavours while mentoring the upcoming generation of researchers, leading to growth and success for both parties.

North Carolina A&T's and ARROWS's learning environment create a vibrant academic community that is advantageous to all parties involved. Students are given access to life-changing materials, guidance, and practical experiences that equip them for prosperous STEM careers. In turn, faculty members can develop their research portfolios, foster talent, and help create a more diverse scientific environment. Beyond individual accomplishments, this cooperative environment fosters institutional achievement and retention, guaranteeing that teachers and students stay inspired and involved throughout their careers. North Carolina A&T is a prime example of how colleges may act as catalysts for innovation and equity in STEM education by utilizing its distinct advantages and coordinating them with ARROWS' mission.

Long-term effects on retention and success

Student retention has been shown to be significantly improved by the ARROWS program, especially for groups who have historically been underrepresented in STEM disciplines. Participants frequently express greater levels of academic satisfaction, attributing their improved participation to the program's inclusive approach and encouraging atmosphere. Many students also say that ARROWS's mentorship, tools, and chances have given them a newfound feeling of resolve to finish their STEM degrees. In addition to addressing pressing issues like budgetary limitations and academic readiness, the program's methodical approach cultivates a stronger feeling of community within the STEM field. Students are empowered to overcome challenges that could otherwise result in attrition because to this combination of emotional support and practical assistance.

Additionally, the research and mentorship opportunities offered by ARROWS are essential in giving students the networks, abilities, and self-assurance they need for long-term success. Students acquire important technical knowledge and problem-solving skills through practical research projects, preparing them for both academic success and professional jobs. Faculty and business mentors offer direction and motivation, assisting students in navigating challenging academic paths and imagining themselves as future leaders in STEM domains. As participants learn to regard themselves as competent members of the scientific community, these experiences play a crucial role in boosting self-efficacy. It is anticipated that the combined effects of these interventions would eventually result in notable rises in graduation rates as well as better preparedness for going on to further education or the STEM profession.

ARROWS is a model for other universities looking to improve STEM retention by addressing the particular needs of underrepresented populations, including women, underrepresented ethnicities, and economically disadvantaged students. Its all-encompassing strategy, which

combines targeted outreach, institutional support, research funding, and mentorship, provides a model for building fair and long-lasting pipelines in STEM education. According to preliminary data, ARROWS is broadening the STEM landscape and enhancing individual outcomes while also promoting more extensive systemic change. The future of STEM may change as additional institutions implement comparable frameworks, guaranteeing that talent from all backgrounds is identified, developed, and enabled to propel innovation and advancement.

Conclusion

Improving student retention in STEM requires a comprehensive, multimodal strategy that effectively addresses academic, social, and economic challenges. Many students, particularly those from underrepresented backgrounds, face barriers that hinder their ability to persist in STEM fields. These challenges can include a lack of role models, limited access to research opportunities, financial constraints, and difficulty navigating rigorous coursework. To combat these obstacles, programs such as ARROWS have implemented a holistic approach that integrates mentorship, hands-on research experiences, and institutional support to create a more inclusive and supportive learning environment. By fostering meaningful relationships between students and faculty mentors, ARROWS helps students build confidence, develop a sense of belonging, and gain exposure to real-world applications of STEM concepts. Through research participation, students are actively engaged in problem-solving and critical thinking, further strengthening their skills and deepening their interest in STEM disciplines. Additionally, institutional resources such as academic advising, tutoring, and career development services contribute to a structured support system that enhances student success. The innovative activities and personalized support offered through ARROWS have demonstrated a significant positive impact on the retention and achievement of underrepresented students in STEM fields, reinforcing the importance of targeted interventions in addressing retention disparities.

Similarly, the DARTS program has had a measurable and meaningful impact on participating high school students, with substantial improvements in STEM knowledge, confidence, and engagement. By providing students with hands-on learning experiences, mentorship, and exposure to career opportunities, DARTS plays a crucial role in increasing STEM participation among underrepresented groups. The program not only helps students develop technical skills but also cultivates essential soft skills such as teamwork, problem-solving, and effective communication—key attributes for success in both academic and professional settings. Furthermore, DARTS emphasizes the importance of sustained interest in STEM by introducing students to role models, industry professionals, and real-world applications of STEM disciplines. The program serves as a strong model for fostering long-term academic and professional success, demonstrating how early intervention and comprehensive support can shape students' future educational and career pathways. The successes of ARROWS and DARTS highlight the transformative potential of structured, well-designed STEM programs in creating equitable opportunities for all students and ensuring a diverse and thriving STEM workforce.

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