Flexible Internship-Research-Education (FIRE) Model: A Multisector, Multi-Team System Collaboration for Graduate Student Success

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ABSTRACT

Studies have established the value of experiential learning opportunities in higher education for undergraduate STEM student success. Specifically, they are associated with improved outcomes such as sustained interest in STEM fields, the pursuit of graduate degrees, career placement, and creation of start-ups. While these relationships are well-studied in undergraduate populations, there is a dearth of studies exploring the impacts of these experiences on engineering master's students.

Often, engineering students are "tracked" into post-graduation pathways based on the types of experiential learning opportunities in which they engage as undergraduates. Traditional master's programs treat research experiences and internships as mutually exclusive options with linear pathways to doctoral programs and careers in academia or research labs (public or private) for the former; or practice in industry, government, or consulting for the latter. Our Flexible Internship-Research-Education (FIRE) model for scholar development was designed to offer multiple integrated and dynamic pathways that evolve as student interests evolve. Scholars may choose research and/or design-based experiences and work in teams that cross traditional boundaries.

Supported by the National Science Foundation, our team created a project, which aims to implement and evaluate the impact of the FIRE model on master's students' success. This project is a partnership among four universities (with a fifth conducting educational research under a subaward to the lead institution) plus a federal agency workforce partner. The FIRE model integrates evidence-based strategies that provide career and educational development support for master's students in engineering programs.

This work-in-progress paper presents an overview of experiences with elements of the FIRE model to date. It includes case study qualitative data from the multisector, multi-team system that manages this project, as well as preliminary findings about student experiences. The results may help institutions and employers identify strategies for initiating and/or improving academic-workforce partnerships toward STEM career success for master's students.

INTRODUCTION

Over the past decade, higher education has experienced extensive growth in science, technology, engineering, and mathematics (STEM) master's degree conferrals [1]. The recent shift in STEM master's degrees is influenced by professional industries demanding improvements in STEM workforce training. For example, individuals with STEM master's degrees are more likely to experience long-term economic sustainability and career advancement [2], [3].

Master's degrees provide individuals with specialized knowledge for their future STEM careers through advanced coursework and experiential learning. Experiential learning opportunities provide individuals with skillsets necessary for applying classroom knowledge to real-world problems in academic and workforce settings. Research-based experiential learning opportunities train STEM master's students to manage research projects, gain disciplinary knowledge, and publish scholarly articles [4], [5]. Practice-based experiential learning opportunities train STEM master's students on workplace norms, and product management and development [6]. Collectively, experiential learning opportunities not only provide students the opportunity to apply and grow their technical knowledge as they learn by doing, but they also strengthen students' critical thinking, problem solving, creativity, management, and other professional skills and capabilities [7], [8].

The benefits associated with STEM master's degree attainment are limited for some individuals. Master's degrees are costly, making it hard for individuals who come from economically disadvantaged backgrounds to access graduate training [9]. Further, because engineering and other STEM master's degrees tend to offer either research (via theses) or practice (via projects) pathways, many master's students may not experience a diverse array of experiential learning opportunities that could clarify their future STEM career pursuits. Thus, there exists the need for more flexible opportunities in graduate programs offering STEM master's degrees.

Funded by the National Science Foundation (NSF), the Improving Access to Career and Educational Development for Talented, Low-Income Students through the Flexible Internships-Research-Education Model (I-ACED) project was designed to increase the number of domestic low-income academically talented students with demonstrated financial need obtaining STEM master's degrees and entering the U.S. STEM workforce. The team implementing the project is a multi-sector, multi-team system (MTS) composed of individuals from four institutions and one workforce partner. The I-ACED project was developed around the Flexible Internship Research Education (FIRE) model, which was conceptualized by the second author to leverage evidence-based strategies for educational development and student academic and career success. Traditional master's programs treat research experiences and internships as mutually exclusive options with linear pathways to doctoral programs and careers in academia or research labs (public or private) for the former; or practice in industry, government, or consulting for the latter. FIRE offers multiple integrated and dynamic pathways that evolve as student interests evolve (Figure 1). Scholars may choose research and/or design-based experiences and work in teams that cross traditional boundaries.

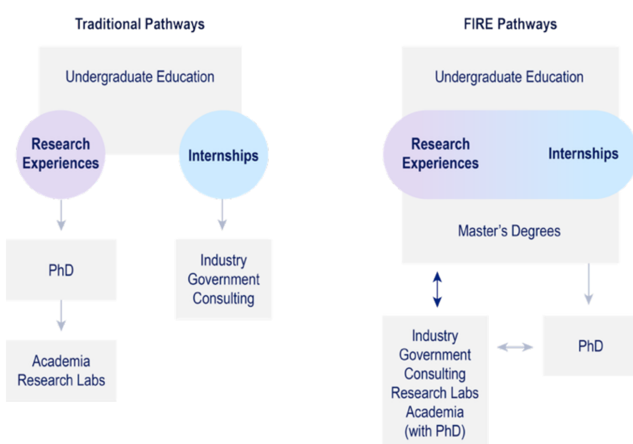

Figure 1. Traditional Education-Experiential Learning-Career Pathways versus FIRE

Recently, the National Academies of Science, Engineering and Medicine (NASEM) have called for more information on how to best facilitate multi-institutional collaborations for student success [10]. Therefore, the first research aim of this work-in-progress paper is to explore how I-ACED team members make sense of their experiences supporting scholars in the program. Additionally, there is limited information on the unique benefits of offering STEM master's students the opportunity to pursue multiple types of experiential learning opportunities in academia, industry, and government and the impact on their post-graduation intentions and pursuits. Therefore, our second research aim is to examine how I-ACED scholars make sense of these diverse experiences. Based on these aims, the following research questions guide this study:

1. How do I-ACED team members conceptualize their roles in supporting STEM master's student success, operationalized by career development?
2. What are the experiences of I-ACED scholars who have participated in experiential learning opportunities?

This study has several implications for STEM higher education. First, this paper expands literature on academic-workforce partnerships by demonstrating effective career socialization for STEM students [11, 12], with a focus on STEM master's students. Additionally, this paper contributes to team science literature by offering considerations on how multi-sector multi-team systems in engineering education can partner across difference [13,14].

METHODS

We used a case study methodology to answer the research questions. Case studies are useful when researchers desire a comprehensive overview of a phenomenon of interest [14], [15]. The case in this project is the I-ACED project. The I-ACED project involves team members embedded in academia and the STEM workforce who are responsible for guiding STEM master's students through their degree programs and into their professional STEM careers. The partners include four universities - three Carnegie R2 public Historically Black Colleges and Universities (HBCUs) and one Carnegie R1 private, highly selective admissions institution - and one federal agency. A fifth university leads the research component of the project but has no students engaged in the program.

Participants

This study includes both I-ACED scholars and members of the MTS (i.e., faculty and staff from all partnering organizations) who are executing the project. I-ACED scholars are individuals who are pursuing STEM master's degrees (primarily engineering and computer science) at one of four partner universities. Each scholar is considered academically talented and identifies as a domestic low-income student (per NSF funding requirements). While in I-ACED, each scholar is expected to complete their graduate program's academic requirements as well as pursue additional experiential learning opportunities like research and/or design-based internships that will prepare them for their future STEM careers. Many of these experiential learning opportunities occur outside of the I-ACED MTS ecosystem. Scholars participated in internships at national governmental agencies and in engineering, financial services, and healthcare industries. Additionally, scholars participated in research opportunities in university laboratory settings across the United States.

The I-ACED MTS includes six teams (Figure 2): Project Administration and Management (PAM), Educational and Behavioral Research (EBR), Career and Educational Development (CED), Faculty and Practitioner Mentoring (FPM), Cohort Development and Engagement (CDE), and Scholar Recruitment and Retention (SRR). The teams include faculty and staff members from each partner organization (represented by the different shapes in the diagram). For this paper, we focus on the CED and CDE teams based on their roles in shaping scholar experiences. The CED team is responsible for planning, scheduling, and implementing activities regarding career and educational development for the scholars. The CDE team works on planning, scheduling and implementing cohort-building activities for the scholars.

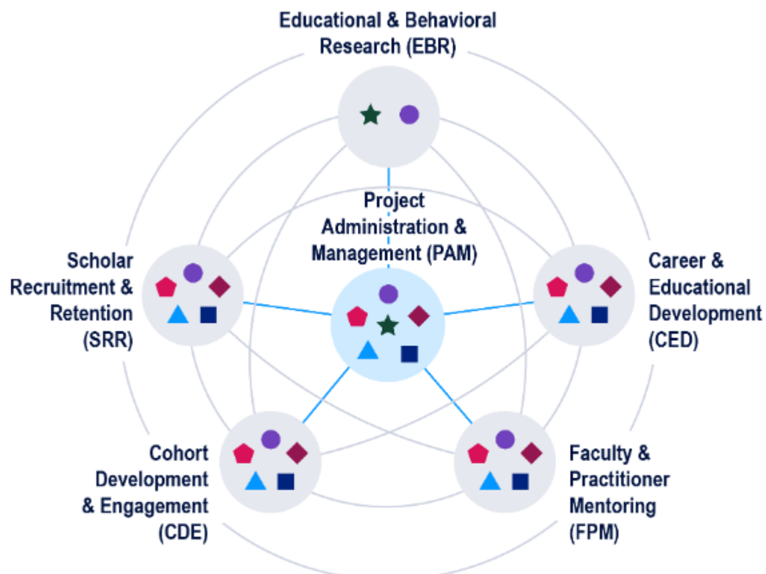

Figure 2. I-ACED MTS Structure

Data Collection

The data presented comes from a larger research project examining how our MTS collaboration supports the academic and professional development of I-ACED scholars. Based on their in-depth nature, case study methodologies require leveraging data from multiple data sources [17]. This paper uses data collected in Fall 2025 from both the project's team members and scholars via surveys.

Scholar Survey. The scholar survey included questions about their engagement in experiential learning opportunities. They were asked to report if they participated in an internship and/or research experience. For each experience they were then asked questions about the activities in which they engaged; their responsibilities; and the knowledge, skills, or abilities gained to help their future STEM careers. Of the 44 scholars who were in I-ACED in Fall 2025, 14 participated in the study (~32% response rate).

Team Member Survey. The project team members received a reflection questionnaire asking about their experiences with the project during the past year. Participants were asked to identify all the teams on which they served (many served on two or three teams) and to identify the primary team with which they engaged. They were then asked to share perceptions of their primary team's role in supporting I-ACED scholars and to name specific ways in which they accomplished this. Additional questionnaire items are beyond the scope of this paper and are not described here. Of the 20 participants who completed the survey across various teams, 18 individuals completed the survey items about role clarity and experiential learning opportunities. For this paper, we focused on the CED and CDE teams, who worked directly with the academic and professional development of I-ACED scholars. Four of the participants were members of the CED team and three were members of the CDE team (n=7).

Data Analysis

For the qualitative data from both the scholar survey and the team member reflection questionnaire, we employed a deductive coding approach based on the exploratory nature of the project [18]. First, we reviewed all the surveys to familiarize ourselves with the data. Then, one member of the research team exported the survey responses from Qualtrics into Excel for coding purposes. Next, we openly coded the data using the research questions as a conceptual frame. Lastly, we grouped the codes to develop a set of themes among scholar and team member experiences.

The scholar survey also included quantitative items asking the extent to which their experiential learning opportunities helped them develop key professional skills and technical capabilities, including:

- Creative thinking and problem solving
- Project management
- Teamwork and collaboration
- Communication skills
- Technical skills required in their field
- Leadership abilities

The responses were reported on a four-point Likert scale (a lot, somewhat, a little, not at all). Because of the small number of respondents, statistical analysis was not possible; here we report response frequencies to provide added context for the qualitative responses.

FINDINGS

MTS Team Member Responses

We questioned how I-ACED team members conceptualize their roles in supporting STEM master's student success, operationalized by career development. Responses revealed the extent to which CDE and CED team members understood their roles and the ways in which they used their roles to support students.

Clear Understanding of Team's Role. Most project team members understand their role in supporting students' career success, particularly as related to experiential learning. Most participants could explain their role in supporting I-ACED scholars. For example, a member of the CED team stated:

> *We focus on students' academic development and experiential learning, such as hosting graduate school seminars based on students' interests, resume and interview support, technical tours, collaborative projects*.

Additionally, a member of the CDE team responded:

> *Our Cohort [Development] and Engagement Team is the backbone of the I-ACED Scholars program… By fostering a sense of belonging, supporting academic persistence, and opening doors to industry and research engagement, we ensure scholars have the social and professional capital to thrive and graduate successfully.*

Lack of Clarity of Team's Role. We found that clarity varied by team. All members of the CDE team were able to explain their responsibilities, whereas half of the CED team members struggled to describe theirs. One was due to lack of engagement: *"I would do my best not to respond yet be cooperative since my engagement has been limited."* The other seemingly believed the role was synonymous with the team's name and simply entered *"Career and Educational Development."*

Connecting Scholars to Experiential Learning Opportunities. Several participants reported supporting scholars with career networking and professional development. Regarding career networking, multiple I-ACED project team members reported *"coordinating with <redacted I-ACED workforce partner> and providing internships"* for scholars. Another discussed helping I-ACED scholars learn about *"career paths beyond graduate school"* and hosting informational workshops on engineering fellowships for master's and doctoral students. Additionally, multiple participants supported scholars through professional development opportunities including *"resume and interview workshops,"* and hosting events where *"students could share career information and encouragement with their cohort."*

Scholar Responses

We sought to understand the experiences of I-ACED scholars who participated in experiential learning opportunities. Namely, we questioned the types of experiences in which they engaged to and the skills they developed from those experiences. Most respondents (n=7) engaged in internships; 4 engaged in research experiences and 3 engaged in both. Not all scholars answered all items; therefore, the numbers vary slightly across assessments.

Opportunities for Real-World Impact. Participants discussed how their internship and research experiences created meaningful opportunities to make real-world impacts across STEM disciplines. For example, both research and internship participants mentioned working on projects advancing medical technologies. One research participant described, *"working to develop a sensing socket for prosthesis."* Another provided an overview of the focus of their internship with a medical company. They noted:

> *I researched potential solutions for [a] low-cost, high accuracy pulse oximeter that works for all skin tones. Designed circuit schematics, wrote firmware, built prototype on breadboard, designed and 3-D printed parts, and tested changes to pulse oximeter algorithm to correct for skin tone bias.*

One participant who worked on a manufacturing project mentioned the role of their work in improving quality of life:

> *I was a manufacturing intern and helped create fixtures for process efficiency and operator quality of life. I also worked on a new product introduction project collecting data on part numbers and sending it off for raw material quotes.*

Similarly, some participants engaged in research opportunities to improve environmental concerns and sustainability. In one example, a research participant explained how their research involved *"constricted visual representation of hurricane paths and their effects on coastal oil refineries."*

STEM Career Preparation. Participants explained how their internship and research experiences provided them with the skills to enter their professional fields. One internship participant explained how their internship provided them with bioengineering technical skills including, *"coding, circuit design, part procurement, research skills, prototyping, CAD design, 3D printing, breadboarding, circuit troubleshooting, (and) design verification."* Another internship participant explained how their internship gave them the chance to strengthen their professional skills through learning *"communication, needs finding, self-management, critical thinking, and professional relationship building."*

Research participants described how their experiences equipped them with skills necessary for academic careers. For example, one research participant described how their skills facilitating a scientific publication involved *"independent research, using instrumental analysis devices, writing a scientific article."* Another explained learning a *"GIS development Python/SQL thesis framework."*

Technical and Professional Skills Developed. When asked about the extent to which skills they developed specific knowledge, skills, and abilities during their experiential learning opportunities, all research participants indicated they "a lot" or "somewhat" for all skills categories (Figure 3). Results for scholars participating in internships varied more (Figure 4). While most indicated their experiences helped them develop most of the listed skills "a lot" or "somewhat", many indicated the experiences helped them "a little" or "not at all". The skills most scholars reported developing were communication skills and creative thinking and problem solving; both were 90% "a lot"/"somewhat", though the distributions within those categories differed (creative thinking and problem solving were stronger). Scholars reported the least development in project management (50% "a little"/"not at all") and leadership abilities (56% "a little"/"not at all").

Figure 3. Extent to which Research Experiences Supported Scholars' Skills Development (Fall 2025, n=5)

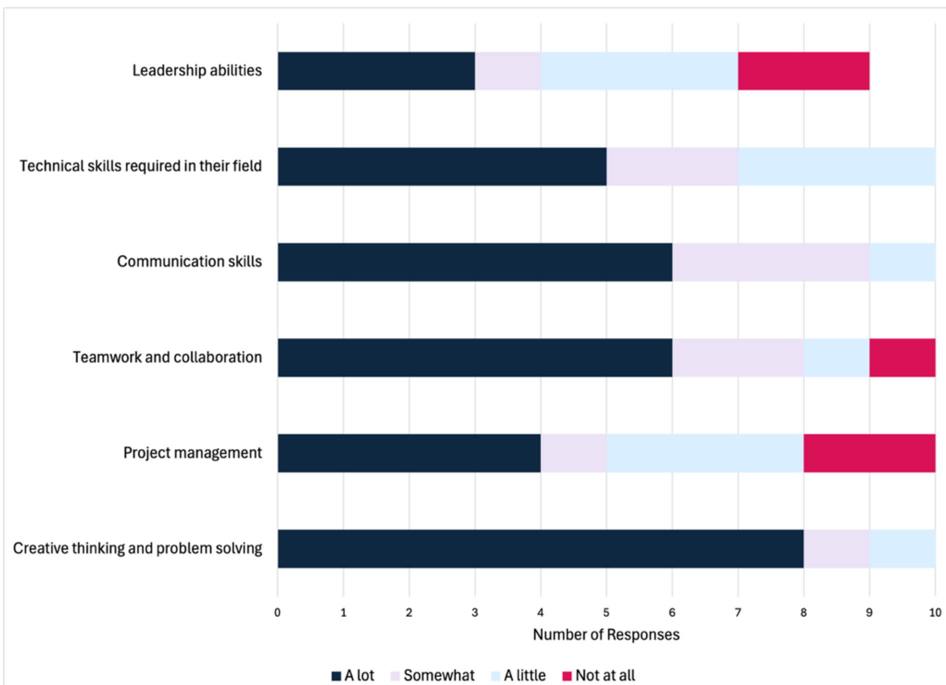

Figure 4. Extent to which Internships Supported Scholars' Skills Development (Fall 2025, n=10)

Limitations

The data we collected did not ask scholars their post-graduation plans; thus, we were not able to determine their intentions and how experiential leaning helped shape those intentions. Currently, the evaluation team captures this information in a different survey. That survey reflects most scholars plan for careers in industry rather than more advanced degrees; this was true for all scholars surveyed in Spring 2025 who indicated they would graduate in Fall 2025 or beyond. We will request that the evaluation team add a question to the experiential learning survey for future administrations so we will have the career interest data along with the experiential learning data. Additionally, only three scholars completed both research and internship experiences. The small number speaks to how scholars are 'primed' to think of their experiences in constraining ways, possibly presenting a challenge for them to adopt the FIRE model as intended. With the limited data, and not having their post-graduation plans, we were not able to determine whether scholars envisioned more flexible opportunities because of participating in a broader range of opportunities.

CONCLUSION

This work-in-progress study explored the experiences of scholars and members of the MTS managing the I-ACED project. Findings revealed how the FIRE model (i.e., flexible experiential learning and educational opportunities) provided scholars with professional development toward STEM careers in academia and industry. Results showed scholars gained valuable professional skills for their future careers, with research participants reporting higher gains than internship participants. Further, scholars reported opportunities for their work to have real-world impacts for both research and internship experiences. Additionally, findings showed that most I-ACED team members had clear understanding of their roles in support the scholars' career success, though the degree of role clarity varied by team.

In future work, our goal is to explore how the FIRE model influences STEM career decision making and motivation for I-ACED scholars as they transition into their careers. We also aim to explore the underlying mechanisms shaping how team members execute their roles, including how organizational norms help or hinder their ability to do so, and identify ways to strengthen communication among team members.

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