Leveraging a Multi-Partner Approach to Develop Successful STEM Outreach Programs

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Abstract— **Careers in the U.S. that require STEM knowledge have grown rapidly, reinforcing the need to develop a future workforce that is prepared to meet growing business needs and solve global challenges. Considering that there is a low number of students pursuing STEM degrees and the low percentages of minority students in the STEM pipeline, STEM education has been a focus of local and national education curriculum reform efforts. Extending beyond the classroom, university, industry, and other stakeholders have partnered to develop the future workforce by focusing on STEM K-12 outreach programming. We discuss a unique partnership that moves beyond the traditional context of university based outreach programming in which the National Society of Black Engineers (a non-profit organization) is working toward scaling up a nationwide summer outreach program through partnering with major research institutions and industry sponsors. We introduce the partners, provide an overview of the research and assessment plan, and discuss preliminary lessons from the partnership.**

Keywords— assessment; outreach; university-industry partnerships; National Society of Black Engineers

I. INTRODUCTION

Stakeholders in the K-12 sector, higher education, and industry have been challenged to develop innovative approaches to support critical junctures of persistence along the science, technology, engineering, and math (STEM) pathway. A primary focus has been targeting K-12 spaces as areas to infuse engineering to promote early engagement for students to become motivated to pursue engineering for their educational and career trajectories. However, engaging the interest of K–12 students in engineering, specifically, is particularly difficult because engineering content and courses have only recently begun to be widely taught in elementary and middle schools.

As a response to this challenge, stakeholders have forged partnerships to explore additional spaces and settings for developing K-12 students' interest in engineering. A wide range of partnerships have been examined in the research literature to address such needs, including student work experiences, research collaborations, industrial field trips, and targeted programs [1-7]. In this paper, we describe some of the unique elements of a targeted program that focuses on STEM outreach. Targeted programs are partnerships that allow students and industry stakeholders to accomplish specific goals related to financial sponsorship, underrepresented student support, and knowledge growth [8]. Such programs provide students with opportunities to learn both technical and non-technical skills, and can establish relationships with potential employers that may influence students' ultimate entrance into the engineering workforce.

For elementary-aged students, targeted programs often take form as out-of-school programs that promote informal STEM learning. These programs have long served as opportunities to engage K-12 institutions and university partners in an agenda to advance student exposure to engineering concepts [9-14]. However, such partnerships extend beyond university and K-12 stakeholders. Non-profit organizations, museums, and others have also engaged in outreach programming to enhance elementary students' exposure to engineering [e.g., 15-18].

In this paper, we discuss a unique partnership that moves beyond the traditional context of outreach programming. We introduce a partnership in which a non-profit organization is working toward scaling up a nationwide summer outreach program through partnering with major research institutions and industry sponsors. Supported by the National Science Foundation via the ITEST program, *Strengthening the STEM Pipeline for Elementary School African Americans, Hispanics, and Girls by Scaling Up Summer Engineering Experiences*, the National Society of Black Engineers (NSBE) in partnership with Virginia Tech and Purdue University aim to advance an industry sponsored outreach program from 16 programs in 2016 to 31 programs by 2019.

II. STEM OUTREACH PROGRAMS

Productive STEM programs are outlined to include three criteria by the National Research Council: 1) engages young people intellectually, socially, and emotionally, 2) responds to young people's interests, experiences, and cultural practices, 3)

connects STEM learning in out-of-school, school, home, and other settings [19]. Although research literature on the impact of engineering summer camps for elementary school students is limited, there are studies demonstrating statistically significant changes in STEM learning outcomes that illustrate the National Research Council's statement that out-of-school programs are "a critical piece of the STEM learning ecosystem and are particularly well-suited to building interest in STEM and identity as a STEM learner" [19].

For example, The Engineering Place, an umbrella for all engineering K–12 outreach at North Carolina State University, has run weeklong day camps for grades 3–5 in locations across the state for 20 years. These camps' evaluations have shown that, with only 40 contact hours per summer, students achieve statistically significant attitudinal gains in math, science, engineering/tech, and 21st century skills from pre-test scores to post-test scores [20]. In 2010, researchers from the University of Nebraska–Lincoln conducted a study of the impact on STEM learning of one-week summer camps (40 contact hours) for middle school students with a robotics/GIS curriculum. Students in the intervention group showed significant increases in their STEM learning scores on a 37-question multiple choice pre-test and post-test, while the control group scores remained unchanged [21]. These studies parallel the assessment results of this paper's focal outreach program, which have shown increases in learning and in positive attitudes towards STEM over the course of a three-week program with 105 contact hours.

Despite the demonstrated effectiveness of the focal program, scaling up the program does come with challenges. Research shows that the challenge of scaling-up educational interventions is formidable. When transplanted to different locations, successful interventions face changed contexts, new leadership, and the difficult task of finding new funders. Developers have to build constituent support, find new collaborators and partners, and provide professional development to teachers and mentors [22]. Another major obstacle to scaling-up these kinds of experiences are the difficulty and expense of collecting enough data to enable the kind of informed decision-making that leads to validation and sustainability [22]. The amount of funding that is needed to conduct social science research on program effectiveness across multiple contexts far exceeds the strategic interests of local industry sponsors. In our study, we aim to proactively understand and address these scale-up challenges via a research program to understand the most influential contextual factors of the program. Empirical evidence from this study can serve as a guide for establishing similar programs in the future.

III. CONTEXT

The multi-partner approach to scaling up the focal program involves the National Society of Black Engineers, Virginia Tech, and Purdue University. Collaborative efforts center on the Summer Engineering Experience for Kids (SEEK) outreach program. The non-profit and industry stakeholders direct SEEK activities, and the university stakeholders lead the research, assessment, and dissemination efforts. Each partner is described in more detail below.

The partnership in this project is guided by two objectives that provide continuous opportunities to contribute to the research to practice and practice to research cycle:

- Objective 1: Evaluate the proposed program's success at influencing STEM-related academic and career identity, conceptual knowledge, and interpersonal and intrapersonal skills

- Objective 2: Generate evidence and a greater understanding of organizational context factors that operate to enhance, moderate, or constrain SEEK's impact from site to site

A. About SEEK

SEEK is a summer program for African American and other children from minority populations in grades 3–5. Since the pilot in 2007, 18,000 students have participated in SEEK's three-week program across 18 cities. SEEK engages participants daily in hands-on, team-based engineering design projects led by collegiate mentor/teachers. SEEK is offered at no cost to the families, making it uniquely accessible to low-income students. NSBE member dues and generous contributions from industry sponsors in the host cities underwrite expenses.

Assessment data from previous SEEK programs demonstrate that students make statistically significant gains in STEM vocabulary as well as math and science learning. This is a result of exposing students to mentoring, STEM competitions, STEM curricula, and multiple engineering disciplines. Every year, one third of SEEK students are returning participants, a tribute to the SEEK program's ability to engage the interest and enthusiasm of its students and their parents/guardians.

B. Partners

1) National Society of Black Engineers (NSBE): NSBE is a professional society that was established in 1975 and is currently composed of over 16,000 pre-college, collegiate, and professional members. As one of the largest student-governed organizations in the United States, NSBE aims to increase the number of culturally responsible Black engineers who excel academically, succeed professionally, and positively impact the community. With a vision to graduate 10,000 Black engineers annually by 2025, NSBE hosts the SEEK program to attract the next generation of STEM talent by exposing students to engineering in an interactive, team-based project environment while connecting students to underrepresented mentors. For this ITEST project, NSBE will continue to lead programming efforts and direct the day-to-day operations of the three-week experience. Additionally, NSBE will continue to develop the infrastructure needed to support the program by 1) building strong working ties with urban school districts, 2) leveraging its broad membership network to recruit participants, mentors, and site leaders, and 3) fostering robust relationships with industry partners.

2) Virginia Tech: The Virginia Tech research team is leading the research efforts (including data collection) for the

project. The team has designed student assessments (pre and post) that measure conceptual knowledge as well as student interest in and attitudes toward STEM. In addition, the team is leading research efforts to investigate how to scale up the experience in a sustainable manner (described subsequently). In collaboration with Purdue, the Virginia Tech team will disseminate research findings to the scholarly community as well as develop site reports for each SEEK location.

3) Purdue University: The Purdue University research team members serve as pre-college engineering education advisors. In this role, they have provided input on the research plans and have been evaluating the curriculum to help connect this project to prior work within the national pre-college engineering education landscape, have been developing materials for mentor training, and will lead dissemination efforts related to translating the research into resources.

Using research-informed assessments and rigorous data analysis will provide NSBE stakeholders with robust results related to the impact of the SEEK program. Overall, we anticipate that this work will have tremendous impact on over 50,000 children across the three-year project timeline and illuminate how children from underrepresented populations can increase STEM learning and interests through participation in a summer learning experience at a critical age when children begin to develop lasting interest in STEM and STEM self-efficacy [23].

Findings generated from research objective two can serve the STEM community as a guidebook to establish how university-industry partners in alignment with desired outcomes can approach outreach programming.

IV. THEORETICAL FRAMEWORK

An adaptation of Terenzini and Reason's framework [24,25] organize this study to help the project team explore student outcomes as well as the organizational factors that facilitate or hinder those outcomes.

As shown in Figure 1, Terenzini and Reason's organizing framework [24,25] connects students' experiences in SEEK to a set of learning outcomes and allows us to investigate how the impact of SEEK might be replicated in different contexts—the relationships between the SEEK experiences and student outcomes have been demonstrated in previous years of the SEEK program, are supported by educational theory (e.g., social cognitive theory), and will be tested in the current project under objective one.

Applying Terenzini and Reason's organizing framework [24,25] in this way, the project addresses the second research objective by examining the following aspects of the SEEK organizational contexts:

1. *Local structures, policies, and practices* – e.g., the influence of the host school, supporting local industry partnerships, access to resources

2. *SEEK programs, structures and policies* – e.g., NSBE-provided curricula, site development procedures, participant selection policies

3. *Mentor/Teachers' Culture* – e.g., beliefs about engineering education, training programs

V. ASSESSMENT METHODS

To capture the individual student experience as well as the organizational context, we developed an assessment plan to measure changes in student learning and perceptions, as well as collect data on program elements, including both local and national organizational characteristics. The student assessment consists of instruments with demonstrated reliability and validity to capture students' conceptual understanding as well as interests in the field (shown in Table 1)—addressing objective one. (Instruments established via previously supported NSF projects were incorporated when possible.) Table 2 highlights the components of the assessment that focus on understanding contextual elements of the SEEK program and the differences in contexts as viewed across volunteers and paid SEEK administrators and mentors. Data sources are displayed as a function of the three aspects of the SEEK organizational contexts described earlier (see theoretical framework section). Combining these data sources will allow us to gain perspectives from site leaders/mentors, parents, NSBE staff members, and industry partners to allow us to paint a comprehensive picture of SEEK implementation across sites.
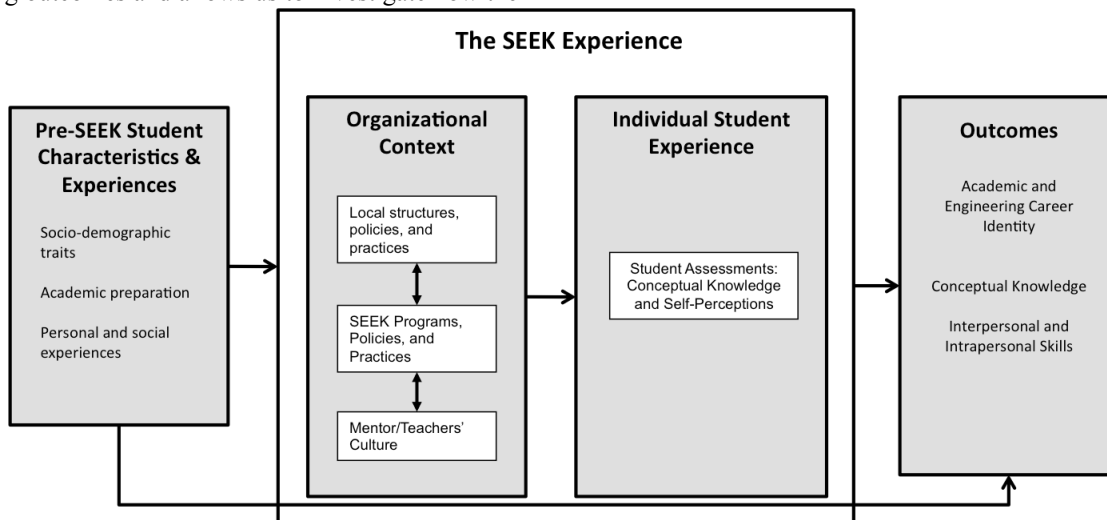

Fig. 1. Organizing "student impacts" framework for research component

TABLE I.   STUDENT LEVEL ASSESSMENTS-TO SATISFY OBJECTIVE 1

Assessments	Pre-Test Day 1 or 2 of camp	Post-Test 3rd Thursday of Camp
Youth Life Skills Inventory	X	X
Engineering Identity Development Scale	X	X
Conceptual Knowledge 10 Math, 10 Science, 10 Engineering	X	X
MUSIC Model of Motivation		X
Perceptions of Engineering		X
Attitudes Towards Math and Science	X	X
Personal Interest Inventory	X	

TABLE II.   ORGANIZATIONAL LEVEL ASSESSMENTS-TO SATISFY OBJECTIVE 2

Data Source	Data Collected	Aspects of the SEEK Organizational Context		
		Local structures, policies, and practices	SEEK programs, structures and policies	Mentor/ Teachers' Culture
Parents	Survey (pre)			X
	Survey (post)		X	X
Mentors	Survey (post)			X
	Interviews	X	X	
Site Leaders	Survey (post)			X
	Interviews	X	X	X
NSBE Staff	Program documents		X	
	Interviews	X	X	X
Observations	Field notes	X		
	Program documents	X		

VI. PRELIMINARY LESSONS FROM PARTNERSHIP

To date, considerable efforts have focused on understanding the current state of the program and crafting a mutually beneficial partnership that supports both program implementation success as well as rigorous research. To this point, several preliminary lessons regarding such collaborations can be shared:

- Although the project is guided by two clear objectives, a multiplicity of goals of individual partners has required compromises. For example, the research design has undergone a few adjustments to fit within organizational contexts, such as resource constraints, SEEK programming goals, and curriculum. Curriculum-tailored assessments shifted to a single broader conceptual assessment for all sites and grades levels to accommodate a variety of curricula across various sites. Additionally, data entry responsibilities were shifted to the responsibility of the Virginia Tech team to maintain data entry quality control.

- In collaborating with multiple university partners, we have gained insights and new ideas that would not have occurred with a single university partner. A notable contribution of the Purdue University research team, for example, has been recommendations of valid and reliable assessment instruments at the 3rd-5th grade level. Researchers have shared best practices and lessons learned in addition to piloting instruments with students to determine administrative techniques.

- Partners have identified future opportunities to intermingle their research activities with practice,—providing opportunities to streamline research efforts that support direct outcomes for practice. For example, researchers with prior established curricula could find new ways to support the SEEK program. This "spin-off" partnership could provide SEEK staff with research-based curriculum recommendations, while simultaneously advancing faculty members' research agenda by implementing instruments and modules with a different context.

- Graduate students are afforded professional development opportunities as they lead various elements of the project. Students from both universities have participated in training site leaders directly or by developing training material for mentors. Assessment data from those efforts can complete the research-to-practice loop to yield scholarship that will help advance these new researchers' careers.

These preliminary lessons serve as early indictors to demonstrate that a successful multi-partner collaboration can lead to a larger impact than any one institution can have alone. Ultimately, leveraging expertise from each partner has benefited the approach to selecting and identifying assessment approaches and understanding the organizational context for a successful STEM outreach program.

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