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Raising Interest in STEM Education: A Research-based Learning Framework for Improving Minority Participation

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Abstract

Despite efforts in the past three decades, participation of underrepresented minority groups is still an issue in STEM disciplines. Minority ethnic groups account for approximately 30% of the United States population, but only 9.1% of those working in STEM occupations. In this context, a program between the Community College of Philadelphia and Drexel University to provide research experience to underrepresented minority students (UMS) was implemented based on the hypothesis that learning about science and engineering is more effective if it is paired with the challenge of independent research in a specifically collaborative "micro-environment", as for example in active research laboratories. Six undergraduate UMS (three male, three female) were selected from a pool of twenty applicants in the inaugural year. Each student independently selected a faculty advisor and corresponding research group best aligned to their interests within the first two of the ten week program. From the outset, library integration underpinned the program. To this aim, students were personally introduced to key library professionals and digital library search tools and databases were immediately employed to review at least three journal articles relevant to their research foci, which assisted to form the basis for independent research proposals. By week four, students presented research plans before a panel of faculty and student judges. In order to complete the program, each student produced three final deliverables - an oral presentation, a technical poster and a paper describing their work. In addition, students were exposed to STEM research in an application-driven industrial setting through a visit to a private corporation known for its innovation. A final survey and individualized assessments were conducted to evaluate the effectiveness of the program and progress of the individual students, respectively. Students demonstrated familiarity with basic research methods and universally reported increased interest in STEM education and careers, with four continuing to work in their labs beyond the program's formal duration. Beyond the summer research program, the partnership facilitated: (i) tutoring in community college STEM courses by Drexel graduate students, (ii) a STEM career discussion panel, and (iii) a discussion among faculty and staff from both institutions on addressing challenges UMS face in STEM education.

Keywords—Research-based Learning, STEM education, Minority Participation

Introduction

Minorities in STEM

Despite efforts in the past three decades, underrepresented minority groups remain proportionally absent from STEM disciplines. Underrepresented minorities, defined herein as women and members of minority ethnic groups account for approximately 70% of today's college students, while comprising only 45% of students who receive undergraduate STEM degrees[1, 2]. In addition and as of 2011, minority *ethnic* groups account for approximately 30% of the United States population, but only 9.1% of those working in STEM occupations[2, 3]. As unrepresented minority groups become majority fractions of the United States population[1-3], greater involvement in STEM becomes necessary to maintain the nation's technical prowess and living standard. Directly comparing the demographics of the adult population against those of the STEM workforce as reported in the 2010 census exposes the extent of gender and ethnicity underrepresentation in STEM professions. For instance, white males currently account for 51% of the country's STEM workforce, while comprising only 32% of the adult population, as shown in Figure 1a.[4] White females account for 32% of American adults, but only 18% of the STEM workforce. The proportion of males and females in Hispanic and Black groups in the STEM workforce lags that of the adult population by a factor of two. As ethnic minorities (particularly Hispanics) comprise increasing fractions of school-age children (Figure 1b),[5] students from these minority groups must successfully pursue careers in STEM fields to ensure the strength of the American 21st century science and engineering workforce.

Minority students, who often are the first in their families to speak English as a second language, attend college, and tend to come from lower-income households, frequently face "intimidating situations" upon arriving in collegiate settings which they have little to no prior experience through family members or friends.[6] In the extreme case, such psychological impediments prevent enrollment and lead to higher dropout rates. Put succinctly, these students are handicapped by a lack of information required to succeed in a college environment. However, early interventions focused on socially and academically integrating students within higher education environments have been repeatedly demonstrated to overcome these factors. The "Tinto Model of Student Retention"[7] provides a useful framework for discussion of academic and social integration, adopted by existing successful programs such as National Science Foundation (NSF) funded Louis Stokes Alliances for Minority Participation (LSAMP), which aims to "build productive capacity and output within institutions having significant enrollment of minority populations" [8] in STEM fields. Specifically, Tinto's theory recommends tailored intervention to meet the needs of specific cohorts (e.g. transfer students, academically "at risk" students, "non-traditional" students). Interventions take the form of undergraduate research experiences, faculty and peer mentoring, and summer bridge programs,[6, 7] to be described in the next sections.

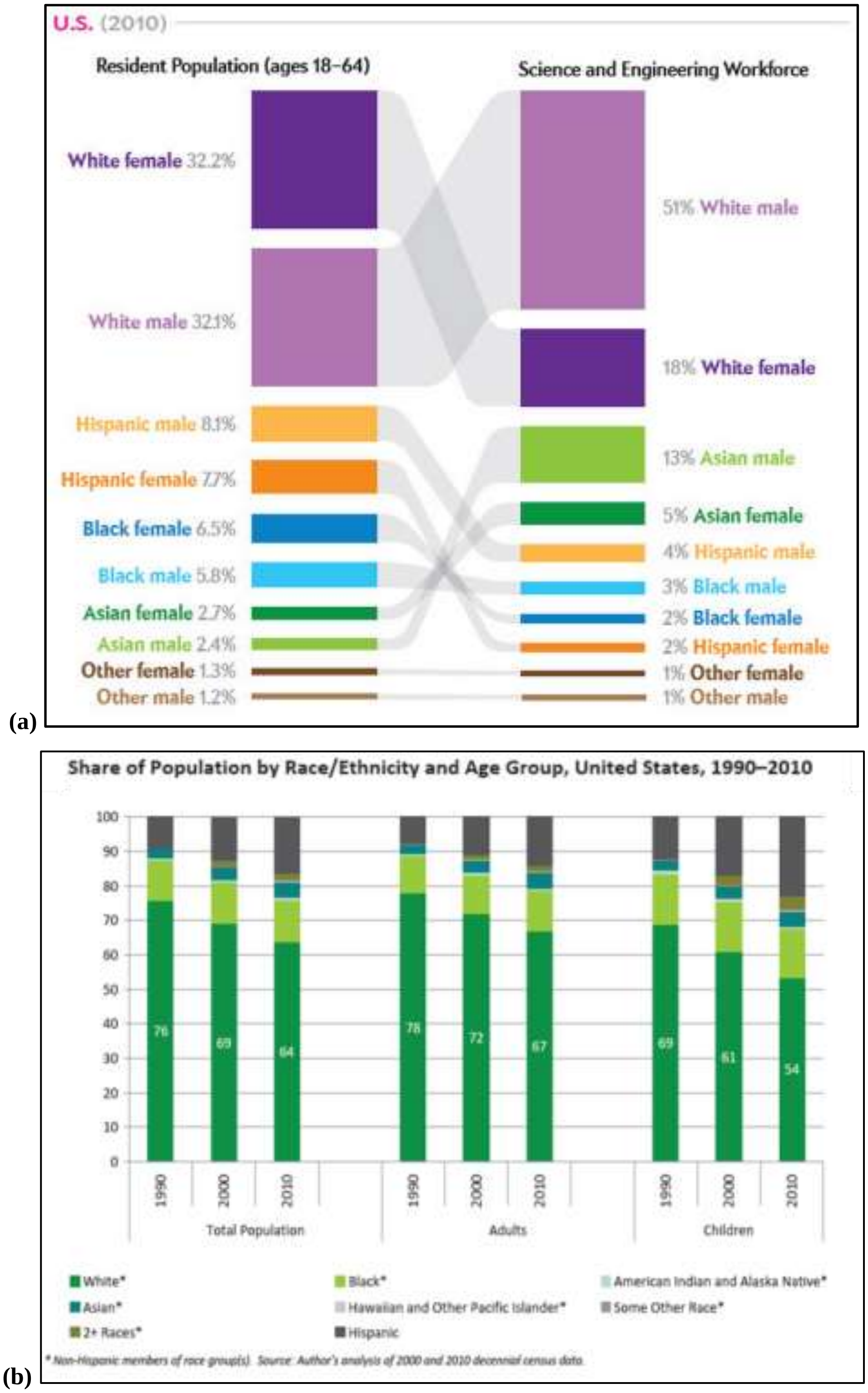

Figure 1: (a) A side-by-side comparison showing the extent of the mismatch in the demographics of the United States adult population versus those of the STEM workforce.[4] **(b)** A pronounced increase in the fraction of minority school age-children over a twenty year period highlights the urgency of raising minority participation and performance in STEM.[5]

The Role of Community Colleges in STEM Education

In recent years, community colleges (CCs), which are predominantly ethnic minority and first generation serving institutions[9] have grown faster in enrollment than any other sector of higher education. While often overlooked, CCs serve approximately 8 million (43%) of the United States' 17.6 million undergraduate students[9, 10], representing the most common gateway to United States higher education. Compared to four-year institutions, by virtue of proximity and affordability CCs are accessible to a much broader cross-section of the population in terms of ethnicity, socioeconomic status. This reality makes them ideal targets for undergraduate research interventions, demonstrably among the most effective ways to engage and retain STEM majors[1, 11, 12]. Partnerships between community colleges and research universities function as a mechanism for offering research experiences to CC students whom would typically not have such opportunities[1, 10, 13]. In simple terms, a community college student who has never heard of "materials science" would aspire to such a career by meeting a materials scientist at his/her working environment and by learning first-hand what such profession actually does. Awareness of available educational options and subsequent careers is key factor in the algorithm for choosing an occupation. However, the paths to completion of a four-year degree from community college origins are still fraught with barriers to be overcome. Faculty and staff at two-year and four-year institutions should form collaborations to create and promote transfer, "bridging the gap" between two year and four year education.

As a whole, 40% of students that declare STEM majors do not complete one, switching to non-technical fields[1, 14]. A 2012 report entitled "Engage to Excel: Producing One Million Additional STEM Graduates" highlights three major factors influencing persistence toward a STEM degree: (i) Intellectual Engagement (ii) Motivation (ii) and therefore identification with a STEM field. [1] Undergraduate research experience supports these factors, positively impacting retention among all students with a particularly pronounced effect on underrepresented minority students (UMS)[1, 12]. Mentoring and access to positive STEM role models are identified as particularly strong positive elements of undergraduate research experiences [1], giving students confidence to pursue advanced STEM education and careers of their choosing.

Furthermore, as Engineering Education shifts toward active-learning based pedagogies centered around "open-ended" problem solving experiences, librarians are given more opportunities to interact with students at all stages of their undergraduate careers. This interaction can be fostered through ***faculty-librarian partnerships*** or collaborations, provided that the relation is framed as a team effort dedicated to student learning. Distinct from a relation of simple "service providing", librarians as teaching partners should have confidence in their expertise, engaging in an actual dialogue on the fronts outlined in Wijayasundara's fish-bone diagram (Figure 2).[15, 16]

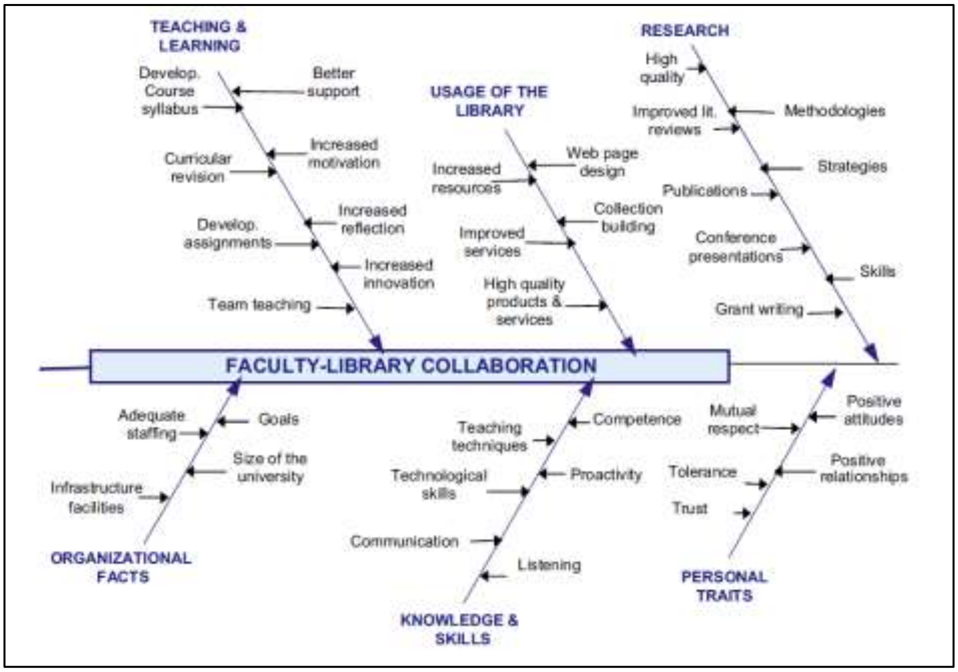

Figure 2: Fish bone diagram on the elements of successful faculty-librarian collaboration as presented in[15].

Objectives & Approach

The RISE program was structured to create an engaging, hands-on, and supportive learning environment targeting Underrepresented Minority Students (UMS), with following four objectives.

1. Improve the *understanding* of what is required to be successful in a STEM Major among *targeted students*.
2. Increase the learning support available to targeted groups at *critical course junctures*.
3. Improve *STEM faculty understanding* of the educational methodology that integrates concepts across STEM courses.
4. Strengthen *relationships* with four-year institutions, particularly project partner Drexel University, to encourage *transfer and on-going* STEM education.

Six UMS (three male and three female) were drawn from a pool of over twenty applicants in the spring of 2014. These six students were welcomed to Drexel in a kickoff event in which three students (one undergraduate and two graduate) gave their perspectives on research experience, followed by a session of over forty posters from fourteen labs representing all departments in Drexel's College of Engineering and School of Biomedical Engineering. A flowchart depicting the program timeline is presented in Figure 3.

In the first week of the program, students sought out prospective labs, making an informed selection from at least three candidate labs. Based on their selection, each student was paired with a PhD mentor to model the role of a research scientist/engineer and guide daily technical work. Students were financially compensated for their work, considered a full-time occupation over the ten week period.

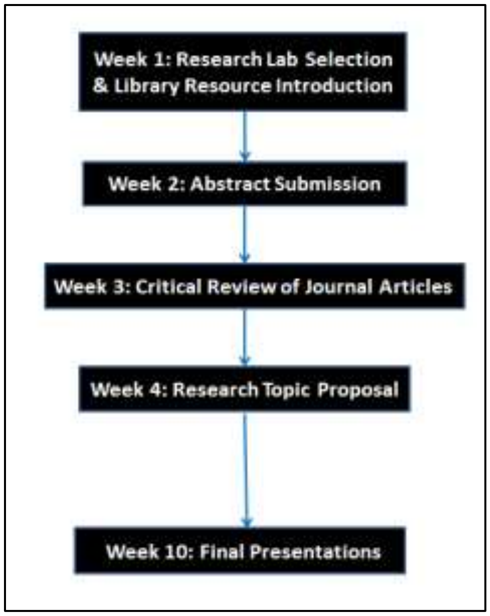

Figure 3: A schematic depicting the program timeline.

In addition, one graduate and one undergraduate were hired as "teaching assistants" to support the entire program, serving as mentors to all students and coordinating logistics. For general instruction in research methods and progress review, two one-hour classroom meetings were held per week, led by the Drexel faculty coordinator. These sessions served as an open forum for discussion of topics such as conducting a literature review, structuring an independent research project, technical writing, and presentation skills.

As shown in Figure 3, the program culminated in "conference style" presentations by each student, immediately followed by a poster session. Augmenting questions from the general audience, the work was critically and quantitatively assessed by a panel of independent faculty, the librarian, and graduate student judges.

Program efficacy was assessed through two surveys of the students, at the midpoint and following program completion, as well as a mentor survey. In addition, the teaching team assessed individual student performance through evaluation of written and oral deliverables. Mentors, faculty, and teaching assistants met on a weekly basis throughout the program to discuss the progress of each student and exchange "best [mentoring] practices".

To complement the activity on the university campus and broaden the impact of the program, a STEM career panel discussion was held on the community college campus (complementing a number of other activities exclusive to the community college partner). Institutional recommendations aimed at increased minority participation[6, 10] highlight the importance of increased sensitivity among faculty and staff to the needs and challenges of minority students. To this aim, a faculty and staff workshop composed of participants from both institutions facilitated discussion on the aforementioned challenges of minorities in higher education.

Results & Discussion

Participants universally expressed increased interest in advanced STEM education and subsequent careers, and reported a sense of "belonging" to their chosen labs. A striking qualitative improvement was observed in the technical writing and presentation skills of all students from research proposal to final presentation phase. A sampling of the diversity in students' chosen research topics is shown in Figure 4. Furthermore, this improvement was also captured quantitatively through the judges' evaluation sheets, in which students were rated on five elements of their oral presentation.

As a student reported on an exit survey, "*The program has given me the opportunity to learn and grow as an engineer, and I plan to use the tools that I have been given to continue to build on the foundations that have been laid.*" Another remarked, "*it was a tough but rich program, and the support of my mentors helped me stay focused and I ended up learning a whole lot*."

At the time of writing this article, two students were awarded research experiences at Brookhaven National Laboratory, with one also receiving an NSF Research Experiences for Undergraduates (NSF-REU) Fellowship at her baccalaureate-granting institution. These particular students also expressed newfound aspirations to pursue advanced degrees.

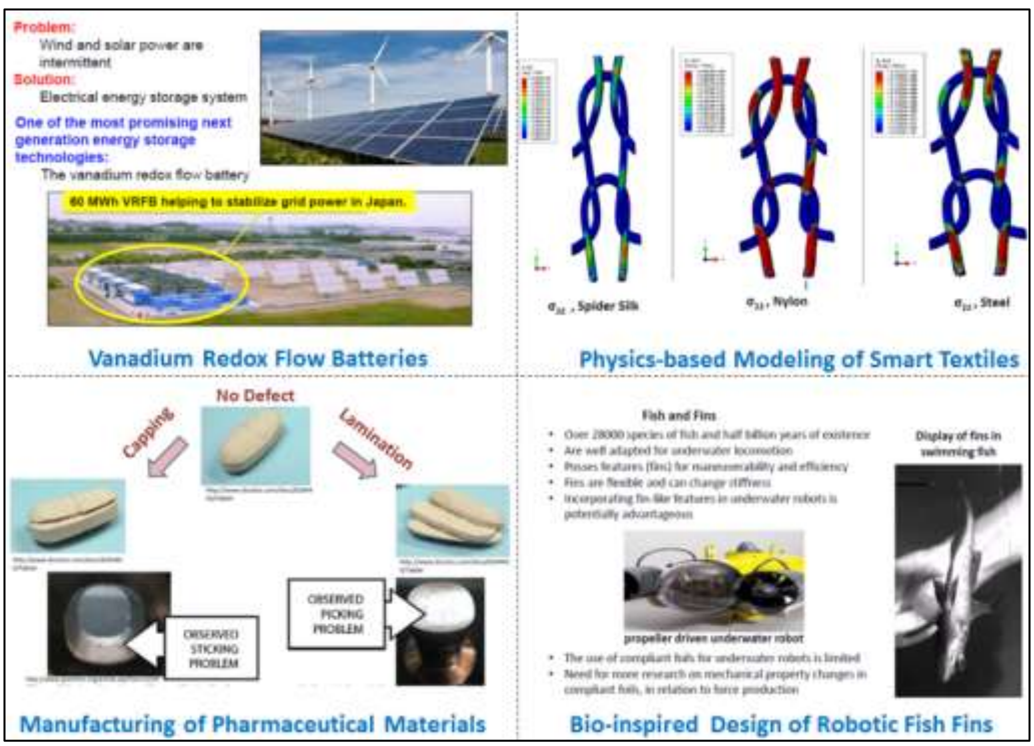

Figure 4: A sampling of students' work, illustrating the diversity of research topics in the program. Clockwise from top-left: advanced energy storage technologies, constitutive modeling of "smart textiles", bio-inspired underwater robotics, and manufacturing of pharmaceutical tablets.

For the inaugural year, four themes in STEM (Simulation-based Science & Engineering, Advanced Manufacturing, Information Systems, and Energy & Environment) were selected for emphasis based on National Academy of Engineering (NAE) *Grand Challenges* for the 21st Century[17]. Each theme was covered through a series of invited seminars by research faculty actively working in each area. Teaching assistants also contributed scholarly reading materials to develop a background for discussion of each theme, through topics including numerical analysis tools/methods, additive manufacturing techniques, and information management systems. All were able to link their research topics to one or more of the NAE Grand Challenges. In many cases, students reported that these sessions were their first guided exposure to such topics, thus we plan to continue this element in future years of the program.

Complementing academic research with industrial experience, the group visited the global headquarters of a widely known research-driven private company for a tour, followed by a roundtable discussion of STEM career paths with experienced R & D professionals. This exposure provided participants with greater insight on possible career paths. The STEM career discussion panel, composed of panelists with diverse backgrounds broadened students' perspectives on the utility and value of a STEM education, framing it as a mindset for identifying, decomposing and solving human problems.

As digital information becomes increasingly ubiquitous, innovative librarians continually adapt to fulfill non-traditional roles for the profession, such as directly engaging with students during presentation practice sessions and critically reviewing their written work, complementing the faculty and teaching assistants. This concept is referred to as "Embedded Librarianship", where the librarian inserts him or herself into the daily functions of a user group[18]. As a testimony of this new role, students participating in this program came to see the engineering liaison librarian as a trusted mentor they could turn to for guidance at any point during the program. Library guides, online tutorials, library instruction sessions, presentation practice, and citation management training also provided valuable insights to students in organizing their research results and reporting them during presentations, supporting the aim of life-long learning.[19]

In addition to the summer research component, the program facilitated a discussion among faculty and staff from both institutions on addressing challenges UMS face in STEM education, emphasizing the pivotal role of faculty and staff in promoting an environment of inclusivity allowing minorities to succeed.

To reach a broader cohort of students than those accepted for the summer program, a STEM career discussion panel was held on the community college campus featuring an array of STEM professionals (including females) at different stages of their careers, presenting a set of examples for students to draw inspiration from. This activity furthered understanding of the elements required for success in a STEM major and career.

Conclusions

Through a research-based learning pedagogical strategy, students were introduced to foundational research methods (e.g. conducting literature reviews, writing scientific publications) which they directly applied in the program and will carry forward in subsequent STEM education. Notably, none of these students had taken fundamental courses in their chosen research topics. This research-based learning approach equipped students with lifelong learning skills needed to succeed in searching, obtaining and applying relevant information to conduct independent research projects and disseminate that knowledge through effective written and verbal communication. A key factor impacting performance was integration into an academic environment, identifying with a research group and the host university. Faculty-student interaction in non-classroom settings and near-peer interaction were deemed major elements of such integration. While the body of literature on mentoring is rich, further investigation is needed in understanding how to incorporate mentoring at scale for targeted students. he program models how teams of faculty, professional staff, and graduate students can transcend departmental and institutional boundaries to form strong collaborative partnerships to encourage on-going STEM education. Results from year one of this project support the research-based learning hypothesis made in this effort as an enabler for engagement in STEM in first two years of a student's studies. The team involved will continue to track the progress of the inaugural group during the next few years. Based on the success of year one, the program may be expanded to include eight or more students per session in subsequent years.

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