FEATURE ARTICLE

A Collective Impact Model Towards Increasing STEM Major Student Retention

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ABSTRACT

This article presents the research findings of a multidisciplinary team's collective research effort at one university over a five-year period as funded by the National Science Foundation's *Improving Undergraduate STEM Education* (IUSE) program. A collaborative learning and retention action research effort at a large Hispanic Serving Institution is analyzed using mixed methods to document the power of collective impact as the foundation for a learning support model for students historically underrepresented majoring in science, technology, engineering and mathematics (STEM) academic programs. The actions of the team of researchers are presented to describe the *Rising Stars Collective Impact* model and the impacts achieved. This is a model that aligns objectives, intervention efforts, and reports collective results. The long-term goals of the *Rising Stars Collective Impact* multiple programs managed by the funded program team included the following: (a) to improve the campus sense of community for students historically under-represented in STEM, (b) to establish innovative and robust STEM education research-based practices to support critical skill attainment for students, and (c) to support faculty understanding of the funds of knowledge of diverse students. The positive student retention and success impacts of this research effort are measured through quantitative statistical analysis of the changes in second-year STEM undergraduate student retention rates and representation rates of women, Hispanics, and African American STEM majors.

The continued call to provide greater support for college and university student learning to encourage their completion of an increased number of degrees in science, technology, engineering, and math (STEM) is now coming from coordinated policy efforts that claim it is time to scale the adoption of evidence-based instructional practices and key strategies that may support students in their STEM courses (Committee on STEM Education of the National Science & Technology Council, 2018). While many important research efforts focus on isolated approaches by single or small groups of researchers, it may be time to consider the potential value of system-wide research approaches that encourages multi-disciplinary collaboration and conduct action research as a collective. At our university in 2014, a group of faculty with research interests in engineering education, chemistry education, physics education, mathematics education, and computer science education came together to design a series of interventions. These faculty were guided by university goals to support strategic STEM goals (Texas State University, 2013) and of assisting students to persist and succeed in their STEM courses and academic preparation for STEM careers. The intervention ideas proposed by this team included strategies to redesign courses; to provide mentoring and academic advising; to support supplemental instruction innovations; to establish learning communities; and to create academic and key skill development workshops for learners historically underrepresented in STEM and learners encountering new technologies. Educating a diverse, technologically capable workforce from all sectors of the population is of utmost importance (Page, 2007) and identifying best practices to support undergraduate students in particularly challenging fields such as in STEM was approached by this team as a collective effort.

This paper presents the final report research findings of this research team's collective research effort at one university over a 5-year period as funded by the National Science Foundation's-Improving Undergraduate STEM Education (IUSE) initiative. Specifically, this NSF initiative supports research proposals that include potentially effective approaches towards improving student learning in STEM while also offering high potential for broader societal impacts. The goal of this STEM education and research initiative was to create a professional learning community of faculty at a large university that would find ways to positively impact student learning, while attending to motivation and persistence of historically underrepresented students in STEM academic fields of study. A collective impact framework (Kania & Kramer, 2011) served to guide the team to carry out various programmatic interventions for a large cohort of undergraduate students. The professional learning community's approach to organizing and managing this effort relied on a complementary vision of establishing and managing an infrastructure that would promote synergy among stakeholders to achieve a more comprehensive understanding of the most challenging diversity and inclusion issues while developing and disseminating evidence-based strategies that support increased student success in STEM.

Literature Review

The vision for the fundamental approach to this work is grounded in an understanding of the interrelated set of complex issues that contribute to the systemic challenge of diversifying the STEM workforce (Committee on Equal Opportunities in Science and Engineering, 2014) and the need to support students who may be underprepared to carry out college-level work in foundational mathematics and science courses (Jackson & Kurlaender, 2014). For example, many students benefit from early exposure to captivating STEM experiences to ignite their imaginations and propel them toward future STEM pursuits. Studies based on nationally representative longitudinal data suggest that to attract students into the sciences and engineering fields, educators should pay close attention to children's early exposure to science at the middle and elementary grades (National Academies of Sciences, Engineering, and Medicine, 2011; Tinto, 1993). Further, the quality of STEM instruction students receive often determines whether they have the foundational skills and academic backgrounds to be successful in STEM. The need for more and better-prepared science and mathematics teachers is prevalent nationwide, but is especially important for regions of the U.S. that have rapid growth rates and large concentrations of minority populations who can benefit from professional preparation in these careers.

Despite a multitude of past interventions, the cumulative impact of research investments on the overall participation of minorities and persons with disabilities in STEM has been minimal.

Inequality in STEM Career Representation

Once on the STEM pathway, students need continuing opportunities to learn about new applications for their learning and mentoring from role models with whom they can identify. This is especially important for women as the National Research Council (Heldenfels IV et al., 2013; Swail, Redd & Perna, 2003) and the Committee on Equal Opportunities in Science and Engineering (2013) have reported gaps in unequal participation of women and minorities in STEM occupations. Gender equality in STEM is a challenging issue in that women often report feelings of isolation and lack of credibility in the workplace and in their academic pursuits (Waitzer & Paul, 2011); the complex issues surrounding equity, access, and inclusion in STEM comprise the *what* that is the focus of the research project. The question of *how* presents another set of equally complex issues in creating the conditions in which members can learn from and support one another's work and can coalesce around issues that can be advanced collaboratively by combining the talents and efforts of the whole network (Turner, Merchant, Kania, & Martin, 2012).

Collective Impact

Despite a multitude of past interventions, the cumulative impact of research investments on the overall participation of minorities and persons with disabilities in STEM has been minimal (National Science Foundation & National Center for Science and Engineering Statistics, 2013). The answer to this intractable social issue may lie in recent developments along three fronts of social research including the areas of collective impact, social network management, and systems theory. Large scale social problems such as poverty, health, education and the environment compound these problems, and even if a solution were known, no one individual organization is able to compel all players involved to adopt it. Important variables that influence the outcome are not often known and/or cannot be readily predicted in advance. Under these conditions of complexity, predetermined solutions rarely succeed (Kania & Kramer, 2013), and in many ways, this phenomenon explains the limited, isolated impact of past efforts in reducing the national gap in STEM education career participation by women and students from historically underrepresented groups. We consider other transformational practices from the field of community development, community building, and civic engagement such as Guajardo, Guajardo, Janson, and Militello's (2015) approach to creating a "Community Learning Exchange" through the use of participatory practices and a collective leadership to complement the collective impact primary model.

Gaps in Target University STEM Student Participation and Retention

In 2012, STEM majors constituted about 7.7%

of the overall undergraduate student population at the target university (2,264 of 29,458). About 33% of those STEM undergraduates were Hispanics and African Americans, and 22.6% were females. Through analysis of retention rates by ethnicity and gender, several gaps were detected; Figure 1 identifies those that were addressed as part of this research effort.

Identified Gaps at Target University			*Goals*
	All Undergrad Students 2012 Data	**All STEM Students 2012 Data**	**4-year Goal (%) Target Goal**
Gap 1: Hispanic and African American students not proportionately represented in STEM majors	**36%** of undergraduate students are Hispanic or African American.	**27.7%** of STEM majors are Hispanic or African American.	Increase the percentage of Hispanic and African American students choosing STEM majors to reach a target of **34%** representation.
Gap 2: STEM majors not proportionately retained in their chosen field of study	**67%** of 2nd-year students are retained in their chosen field of study.	**62.7%** of 2nd-year STEM majors are retained in their chosen field of study.	Increase the 2nd-year retention rate of STEM majors to reach a target of **67%** retention.
Gap 3: Hispanic and African American students do not graduate at the same levels as majority students in STEM	**29.7% of** all bachelor degree graduates are Hispanic or African American.	**28% of** STEM bachelor degree graduates are Hispanic or African American.	Increase the % of Hispanic and African American graduates in STEM to **34%**.
Gap 4: Female students not proportionately represented in STEM majors	**57%** of undergraduate students are female.	**22.6%** of STEM majors are female.	Increase the percentage of female students graduating in STEM to reach a target of **25%** representation.

Figure 1. Identified gaps and goals based on 2012 student data. This figure illustrates the identified gaps in student representation, success, or retention at the target university.

The above gaps are intertwined. For example, increasing the retention rate of Hispanics and African Americans (Gap 3) would also impact Gaps 1 and 2. In this research effort, activities were designed to address student needs that would contribute to reducing some of the gaps.

Over the past decade *scaling what works* has captured the attention of the social sector. The consensus amongst social entrepreneurs is that those who wish to scale must learn to transition from an "enterprise to an ecosystem" (Waitzer & Paul, 2011; Meadows & Wright, 2008). It is with a deep understanding of and appreciation for the multitude of complex issues surrounding both the *what* and the *how* that the collective impact approach provides a networked community in which members can explore issues and test solutions. This approach has provided opportunities and avenues for members to showcase and disseminate evidence-based practices and has empowered members to be path-lighters for practitioners and policymakers who have a vested interest in achieving a more diverse and equitable STEM workforce.

Methodology

Research Design

While each of the various embedded research studies pertinent to our overall study utilized varying mixed methods, the overall impact study is presented as a case study in order to facilitate a deeper investigation of this real-world contemporary collective impact phenomenon (Yin, 2012).

Collective impact as the theoretical organizing framework. Collective impact initiatives most often prove to be long-term commitments by groups of important actors from different sectors guided by a common agenda for solving a specific social problem as studied by Kania and Kramer (2011); Malcom and Feder (2016). Achieving large-scale change through collective impact involves five key conditions for shared success. These include: (a) having a common agenda, (b) establishing shared measurement modes, (c) enacting mutually reinforcing activities, (d) assuring continuous communication, and e) counting on backbone support (Waitzer & Paul, 2011).

Defining a common agenda. The *Rising Stars Collective Impact* team developed a common agenda consisting of three major long-term goals and five supporting objectives identified as a result of a College of Science and Engineering student success data self-study (Ortiz & Sriraman, 2015). The shared long-term goals of the *Rising Stars Collective Impact* were the following: (a) to improve the campus sense of community for students historically under-represented in STEM, (b) to establish innovative and robust STEM education research-based practices to support critical skill attainment for students, and (c) to support faculty understanding of the funds of knowledge of diverse students. We then developed the five program objectives based on careful consideration of specific STEM fields with greatest equity gaps and measurable outcomes that might be realistically realized in the 5-year life-cycle of the project. From here forward, when STEM is noted, we refer to the five academic STEM units at Texas State University that highlight the greatest participation or success student equity gaps: mathematics, chemistry, physics, engineering, engineering technology and computer science. The following five objectives were developed and served as the common agenda for the project/research team:

1. Increase the percentage of Hispanic and African American students choosing STEM majors to achieve a 34% representation by 2018.
2. Increase the retention rate of all STEM majors to achieve a target of 67% retention rate in 2018.
3. Increase the percentage of Hispanic and African American graduates in STEM majors to achieve a target of 34% representation by 2018.
4. Increase the percentage of female students participating in undergraduate STEM degrees programs to achieve a target of 25% representation by 2018.

Establishing shared measurement modes. The common agenda gaps and goals identified above are what drove the various sub-project research efforts. Progress towards these goals was gauged using shared measurement modes such as data sources and common survey instruments. A university wide system of databases is available with a dashboard interface that provides consistent data about graduation rates, grades, retention from year to year, and demographic data regarding representation in any particular college, major, and time period.

Enacting mutually reinforcing activities strategies. The *Rising Stars Collective Impact* project identified four strategies to support the objectives and goals of the group. Each of the faculty co-investigators led a set of activities designed to achieve the project goals and objectives. One key activity from each of these strategies will be featured. The evaluation of the strategies and activities is described in the following sections:

Strategy 1: Redesign critical computer science (CS) classes and improve instruction. As shown by the retention statistics in critical courses analyzed during the College of Science and Engineering's self-study, the majority of declared undergraduate computer science majors who leave the field do so in their first two years. Contributing to this problem is that students are typically introduced to computer science in introductory courses that focus on programming and syntax without a broader understanding of how computer science is relevant to their lives. To address this need, the introductory course was revised by developing course modules containing contexts focused on familiarizing students with computational thinking, data-driven analysis, and multidisciplinary approaches early in their careers in contrast to the traditional expository instructional methodology currently prevalent in these courses. The new high context computer science modules were designed to enable students to see the big picture of how computer science affects our lives. For example, one of the first modules was designed to help students understand how information and communication technologies (ICTs) are rapidly connecting people and things together and to think about what could go wrong in the increasingly connected infrastructure. The researchers conducted a pilot study of the introductory course entitled Computer Science 1428 (CS1428), a freshman level required course, to determine the differences in the survey responses between student groups who experienced instruction embedded with and without these newly designed modules. Data were collected related to student attitudes, awareness, and understanding of the field of computer science post-instruction. The study results showed differences favoring the student groups who participated in the course embedded with the new modules (Rodríguez Amaya, Guirguis, & Marquez, 2019).

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Strategy 2: Provide career exploration and visual spatial skill development. This strategy was intended to provide opportunities for engineering and engineering technology students to more clearly understand STEM fields of study, related career options, and to develop important visual spatial skills. Students were provided specific opportunities to connect with field-specific learning communities through early and frequent interaction with faculty, peers, and representatives from industry while developing these skills. A special course to refine spatial visualization skills and create community among students was developed and delivered twice per semester over the span of three years. All freshman in STEM fields, as well as students registered for physics-mechanics and fundamental of architectural problem and design courses, were invited to take the Purdue Spatial Visualization Test – Rotations (PSVT-R) online, prior to taking an intervention workshop. The students who scored below 70% were invited to register for a spatial visual thinking skills (SVS) training workshop designed to help them refine these skills. The workshop program consisted of six 2-hour training sessions that included a talk by a speaker related to the practical applications of spatial visualization, faculty lectures, the use of a SVS computer-based training program, and practice with specialized materials.

Strategy 3: Foster meaningful student engagement experiences. This strategy was focused on increasing STEM student-reported feeling of community by building connections with peers and mentors and creating opportunities for students to interact with professionals in their chosen fields. A special engineering section of an existing freshman required university seminar was created. The new section *University Seminar (US) 1100-Engineering* and was offered once a year exclusively to incoming freshmen who indicated an intention to study engineering or engineering technology. The course covered the required seminar content while additionally using introductory engineering content elements. An engineering design project was integrated into the *US 1100-Engineering* introductory course and students were introduced to a university *maker space*—a creative student-run lab with equipment, simple tools, and materials.

Another meaningful way to engage students is to provide early career internship experiences. An industrial internship program was created to enable second year students to participate in a guided professional experience that combines academic and professional components. The program represented a fundamental change in a long-standing internship program that previously was only available to students the summer before senior year. This change was supported by the department's three advisory boards with input from internship supervisors in industry. The administrators, faculty, and industrial representatives worked together to reach consensus on the desired changes for the new internship program. In the previous internship program, students were required to complete at least 75 hours of coursework, including completion of all math and science courses, before engaging in the internship experience. In the new approach, the students now complete 45 hours of coursework and two math and/or science courses before their internship experience. This change enabled students to complete sufficient coursework to prepare them for the internship while allowing them to participate in the internship early enough in the experience academic program to gain a positive career engagement experience.

Strategy 4: Support student learning through evidence-based instruction. Two related models of peer-assisted learning, the Supplemental Instruction program and the Learning Assistant (LA) program, have been used in some STEM courses at our university. A goal of the *Rising Stars Collective Impact* project was to expand these programs to serve more students in the first and second year gateway STEM courses such as introductory calculus, chemistry, and physics. The following describes the activities within this strategy, and we present some data on their impact.

Expansion of the supplemental instruction (SI) program. The university had already implemented a Supplemental Instruction (SI) program in select chemistry and mathematics courses since 1995. SI is a nontraditional form of tutoring that focuses on collaboration, group study, and interaction led by a student peer, referred to as a Student Supplemental Instruction Leader (SI Leader). A study by Hodges and White (2001) investigated the effect of high-risk students' participation in an SI program at a very large university and concluded that a positive impact upon high-risk students' academic achievement could be achieved. Based on this and other related efforts in developmental education research, the *Rising Stars Collective Impact* project expanded the SI program to include additional courses in Chemistry, Calculus and Physics. In the SI program, the SI Leader attends class sessions and models good study skills and habits to those who are taking the course. The SI Leader also meets with students outside of class and helps them to work collaboratively in discussing readings, comparing notes and sharing ideas for improving study skills and class material. In our implementation, one SI Leader was assigned to each faculty member teaching two sections of the target course. The SI Leader attended one section of the course and made appearances, when possible, to the other section. Student participation data was collected for the supplementary instruction activities hosted and demonstrated that the participation rate was higher for students in which the SI Leader primarily attended.

Use of peer mentors. Another major support component of the *Rising Stars Collective Impact* program was the Peer Mentor program for women in STEM. This program was implemented to help support women and increase their retention in STEM. The peer mentors set office hours in order to enable students to meet with them to discuss their progress. The mentors met with the women students at least twice during the semester to monitor their progress. The enrollment in the chemistry and mathematics departments increased- potentially as a result of several factors including the *Rising Stars Collective Impact* program's recruitment and support initiatives, the overall increase in university enrollment, and potentially due to specific academic programs in nursing and engineering which require chemistry and mathematics courses. The enrollment in the Calculus I and Calculus II courses continues to trend upwards with an increase in the number of students served in the Spring 2017 compared to the Spring 2015. For example, the enrollment in MATH 2471 increased to 453 in 2017 from 325 in 2015. Similarly, MATH 2472 enrollment increased to 327 from 280 which had been the attendance during the previous 2 years. Analysis of the data showed that the variation in participation rates depended upon the faculty member teaching and whether the course had or did not have an SI Leader assigned to the course. The average grades of the calculus courses also increased during the study period's five semesters. MATH 2471 had an average grade difference over five semesters of 0.49. For MATH 2472, the average grade difference over this same period was 0.44.

Expansion of the Learning Assistant (LA) program. The LA program is another peer-tutor model program designed to benefit both the students that are assisted by the LAs as well as the LAs themselves. Through the *Rising Stars Collective Impact* program, we were able to expand the university's LA program to be included in all sections of introductory calculus-based physics: five sections of *mechanics*, four sections of *electricity and magnetism*, and one section of *waves and heat* per semester. In the LA program, the LA attends the assigned class to assist the instructor by mentoring students, facilitating collaboration among learning teams, and by assisting in facilitating student understanding, and in grading. In addition, they work in the Physics Help Center, a walk-in tutoring center that is open 35 hours a week. They also serve as laboratory instructors for the calculus-based *mechanics* course. Applicants for the LA position must have successfully completed the first course in the introductory sequence and be recommended by faculty or current LAs regarding their communication skills and facility with productive small group interactions. Students of all STEM majors are encouraged to apply, and special efforts are made to recruit women and students from underrepresented minorities.

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Data Analysis

We used a comprehensive evaluation process and included varied strategies for data collection and examination of each activity within the four major initiatives supporting the student, faculty, and institutional objectives of the program. The effectiveness and impact of the various new support systems were evaluated by answering the key questions shown in Figure 2. The program evaluation approach involved a mixed-methods approach for formative and summative assessment. Formative assessment tracked program implementation and facilitated timely feedback to the project team to assure continuous project improvement. This evaluation component assessed student participants' learning by measuring changes in their STEM learning based on pre/post assessments, course grades, and the degree to which students reported a continuing interest in STEM fields of study. Questionnaires and collected artifacts were used to determine if targeted STEM faculty demonstrated use of best practices relevant to program components. The impact of the project upon the university was a long-term goal that is assessed by the impact upon current faculty and in the future, by enacting policies that reward and encourage faculty to continue using learning-centered instructional practices. This is a distinct component of the impact on increased learning and success for Hispanic, African American, and female students in STEM courses. Given the project's core goals of supporting student persistence and completion rates, we have used a longitudinal database for tracking participating students and a survival analysis statistical method to analyze rates of student persistence/attrition among project participants. Survival analysis is a powerful statistical tool for tracking time-dependent variables; therefore, this analysis was used to determine hazard functions to evaluate the relationship of explanatory variables to survival time.

Participant Population

The student population who are considered as participants in our team's various strategic interventions varied in number from 2014-2018. We agreed to define STEM majors as students in five specific majors: chemistry, computer science, engineering, engineering technology, mathematics and physics. Students in these majors were targeted as participants in specific intervention programs, and data for these groups as a whole were examined year-to-year. The Strategy 2 efforts involved 251 students beginning Fall 2015 to Fall 2018. Analysis of students' surveys administered during the entire period for some of the interventions permitted us to conclude that Viz Stars training, spatial visual thinking skills (SVS) embedded training in special sections of the freshman introductory course (*US 1100*) and summer orientations, not only increased career awareness but also grew students' confidence and expectations of success. This is particularly noteworthy since for some student populations, confidence and expectations of success are not at the highest level when coming in to the student freshman orientations.

Results and Impact

The following overall results are supported by the data collected over the tenure of the project.

Identified Gaps at Target University			*Goals*
	All STEM Students 2012 Data	**5-year Goal (%) Target Goal**	**5 and 6 year Metrics (%) 2017/18 Data**
Gap 1: Hispanic and African American students not proportionately represented in STEM majors	**31.9%** of STEM majors are Hispanic or African American.	Increase the percentage of Hispanic and African American students choosing STEM majors to reach a target of **34%** representation.	**2017: 44.3%** of STEM majors are Hispanic or African American. **2018: 46%** of STEM majors are Hispanic or African American.
Gap 2: STEM majors not proportionately retained in their chosen field of study	**2012-2014:** **62.7%** of 2nd-year STEM majors are retained in their chosen field of study.	Increase the 2nd-year retention rate of STEM majors to reach a target of **67%** retention.	**2015-2017:** **66.3%** of 2nd-year STEM majors are retained in their chosen field of study.
Gap 3: Hispanic and African American students do not graduate at the same levels as majority students in STEM	**27.7% of** STEM bachelor degree graduates are Hispanic or African American.	Increase the % of Hispanic and African American graduates in STEM to **34%**.	**2017: 35%** of STEM majors are Hispanic or African American. **2018: 37.6%** of STEM majors are Hispanic or African American.
Gap 4: Female students not proportionately represented in STEM majors	**22.6%** of STEM majors are female.	Increase the percentage of female students graduating in STEM to reach a target of **25%** representation.	**2017: 26%** of STEM majors are female. **2018: 25.2%** of STEM majors are female.

Figure 2. Identified STEM majors' goals compared to 2018 student data. This figure illustrates the identified reductions in gaps based student representation, success, or retention data at the target university.

Discussion

Impact of Strategy 1: Redesigning Courses and Improving Instruction

The second-year retention rates for students in computer science courses exhibited a slight improvement as shown in Table 1 below.

Table 1
2nd-year retention rates of STEM students in CS

	Started Fall 2012	Started Fall 2015	% change 2012 vs 2015
Hispanic and African American	64.30%	67.70%	3.40%
All ethnicities	65.50%	69.50%	4.00%

The retention rates increased by 3.4% for Hispanic and African American students and by 4% for students of all ethnicities. Thus, it is not clear if the introductory course modules that illustrate how computer science is relevant to their lives had any specific impact.

Impact of Strategy 2: Motivating Career Exploration and Visual Spatial Skill Development

Pre- and post-surveys were administered using the Revised Purdue Spatial Visualization Test (Guay, 1976). The survey evaluated the students' changes in self-efficacy by examining confidence, motivation, anticipation of success, and anxiety. The pre-surveys were administered as part of the semester's design project and the post-surveys were administered on the last class day. All of the increases in the post survey ratings were statistically significant. The positive results from the survey included: an increase of 20 (out of 100 points) both in average student confidence in engineering design abilities and in average student anticipation of success in conducting engineering design; gains in average student motivation to conduct engineering design; and lower post-test average of student anxiety in conducting engineering design. Despite the effectiveness of the infusion of engineering elements into the *US 1100* course, the seminar format posed a number of constraints, including the number of students that could be served by the course (20 per section). During the year, we worked with the College of Science and Engineering to help establish a new Introduction to Engineering course that incorporates the core elements from the content and activities developed for the *US 1100* course as well as additional elements to further enhance the course. The Introduction to Engineering course was offered and funded by the College of Science and Engineering and highlights a successful institutional implementation of this initiative.

Impact of Strategy 3: Meaningful Student Engagement Experiences

Strategy 3 included various social activities designed to bring students together to network, learn about resources, and have fun. Pre and post surveys were administered to evaluate students' changes in self-efficacy by examining confidence, motivation, anxiety and anticipation of success. The pre-surveys were administered as part of the semester's design project and the post-surveys were administered on the last class day. All of the increases in the post survey ratings were statistically significant. The positive results from the survey included: an increase of 20 (out of 100 points) both in average student confidence in engineering design abilities and in average student anticipation of success in conducting engineering design; gains in average student motivation to conduct engineering design; and lower post-test average of student anxiety in conducting engineering design. Despite the effectiveness of the infusion of engineering elements into *US 1100* course, the seminar format posed a number of constraints, including the number of students who could be served by the course (20 per section).

The revised summer internship required students to dedicate approximately 400 hours of effort during the 10-week internship period. This intensity provided an in-depth experience for the participating students. During the first week, the supervisor made a preliminary evaluation, followed by a midterm evaluation at five weeks, and the final evaluations at 10 weeks. The industry supervisor rated the students on each of the following attributes: critical thinking and problem solving, ability to learn, taking initiative and ability to engage in self-directed professional development, interpersonal skills, team working skills, ability to work well in a diverse environment (culture, gender, age, etc.), oral and written communication, professional skills, good work habits, sound ethics and integrity, timeliness, time management, knowledge of contemporary issues, and understanding of the societal impacts of technical solutions. The evaluations were also used to offer recommendations for improvements to the program.

During the previous year, an analysis of the data from the industry supervisors' evaluations indicated that the new internship program was perceived to be working well and did not identify any major issues requiring corrective action. The evaluation form used a Likert scale in which a rating of 4 indicates "Sometimes exceeds expectations, "and a rating of 5 indicates, "Exceeds expectations." In order to encourage a deeper critical analysis of student performance by the supervisors, the evaluation forms underwent a major revision. The review of the comments made by supervisors continue to indicate a positive view of the new internships' program provide more specific information to improve interns' performance during their academic program.

... project components such as the SI and LA programs have positively impacted the retention of students in science and engineering courses.

Impact of Strategy 4: Enact Instructional Approaches

The Physics Learning Assistant Program has grown to include between 30 and 40 participating student LAs. Between 25% and 39% of LA participants have been women; between 24% and 32% have been Hispanic; and between 5% and 12% have been African American. Instructors met with LA members and indicated the challenges of coordinating the course schedule with the LAs personal schedule of classes and suggested that it would be helpful for the LAs and instructors to meet before the semester to coordinate the schedules and to also enable instructors new to the LA program to plan more effectively how to integrate the LAs into their class sessions. The present program provides for meetings during the semester between the LAs and all the faculty who teach the courses in that department to discuss problems and to identify ways that the department can more effectively use the LAs to address those problems. The LAs interviewed suggested that it might also be helpful to increase the frequency of meetings between LAs to more quickly respond to observed student learning challenges. In addition, a study led by one of the collaborative lead investigators examined the process of transformation that occurs through participation in the LA program. The focus of the study was on understanding what happens during the LA experience that leads to the positive outcomes observed in other studies. The data for the study were gathered from multiple sources including video recorded interviews, teaching reflections and program applications. The following themes and elements emerged from the data:

Students negotiate their learning experiences and recognize personal gains.

- LA students find helping other students to be rewarding.
- LA students can shape other students' ways of learning and interacting.
- The act of helping students and the experience of participating in the LA program strengthens the LA's own understanding of physics concepts.
- Serving as an LA strengthens the LA's relationships with peers and faculty.

Students become members of new communities and gain confidence.

- LAs become more competent and confident in physics.
- LAs feel like part of a supportive and collaborative community.
- Being an LA increases teaching competence and reshapes LAs' concepts of good teaching.
- Participation in the LA program changes ways of learning and of being a student.

Consistent with previous years, the incorporation of the Supplementary Instruction and LA programs continues to provide evidence of the impact of these initiatives in reducing the number of students who withdraw from courses or receive a grade of D or F. Of particular note are the results from the calculus-based introductory physics sequence in which the LA program was integrated beginning the Spring 2012 into one section of introductory calculus-based mechanics course ("mechanics"). The program was subsequently expanded to serve all sections of mechanics in Fall 2012, and over the following three semesters expanded to serve all sections of all three courses in the calculus-based introductory sequence.

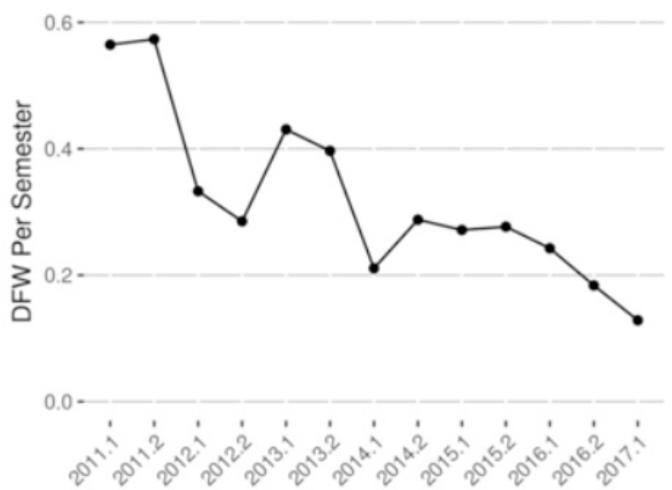

Figure 3. DFW rate (fraction of students who withdrew from course or receive grade of D or F) by semester shows increased student success after course reforms implemented in Spring 2012 (labeled 2012.1).

As can be seen in Figure 3 (above), there is a clear improvement trend demonstrating a decrease in the fraction of students who withdrew from one of these courses or received a grade of D or F, as compared over semesters after course reforms implemented in Spring 2012 (labeled 2012.1). It is clear that both the SI and LA components of the *Rising Stars Collective Impact* have had a major impact on the retention of students in chemistry, math and science introductory courses. It is also a positive finding that the SI program has been institutionalized by the university through financial support by the Office of the Provost. The study also points to the positive impact of the LA experience in the students' personal learning trajectory and for the potential to increase interest in science as well as sense of identity and membership in the science community.

Limitations

The manner in which this case study is structured, involving thousands of students over five years, leads to a great quantity of data that challenges easy analysis. Furthermore, since the groups of students who participate in various events change from year to year, there is limited data from the same students across the many interventions. This collective impact study focuses on the overall impacts of interventions over a long period of time (five years). This means that the naturally occurring demographic changes of the student body at the target university are also included, thereby masking or exaggerating the impacts of the interventions on their own. In future analyses, a smaller cohort can be specifically followed and documented closely to provide an even richer description of student motivation, an explanation of the effects of unique interventions, as well as, collective efforts.

Conclusion and Future Study

The data-driven results presented related to each of the above activities provide strong evidence of the positive trajectory of the collective impact project toward achieving its goals. To recap, the *Rising Stars Collective Impact* project components such as the SI and LA programs have positively impacted the retention of students in science and engineering courses. Specifically, the representation of Hispanics and African Americans has increased during the past five years. Since the inception of the *Rising Stars Collective Impact* project, the number of Hispanic students earning a bachelor's degree has more than doubled from 85 to 229. This is also true for African Americans students in which 16 completed their bachelor's degree in 2012 compared to 60 in 2018.

At present, 48% of STEM majors are Hispanic and African American. This represents an increase of 15% from the base numbers of the project of 33%. Although there may be a number of factors contributing to this increase, the student survey and interview data support the view that the *Rising Stars Collective Impact* project initiatives for first year students, such as the New Student Orientations, STEM New Student Orientation Day, and the new introductory course for Engineering and Engineering Technology have contributed to the increases in enrollment. The number of female students completing undergraduate STEM degrees has increased from 23 in 2012 to 60 in 2018. This represents a greater than 250% increase. In 2018, 25.2% of STEM majors are females, representing an increase of 2.5% from the base numbers for this project of 22.6%.

This project has operationalized a collective impact vision while employing a robust theory of change framework. To realize the large-scale, systemic change, the cultivation and nurturing of effective cross-sector partnerships has been critical to the success and well-being of the initiative.

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