Leading Educational and Academic Directions to Enhance Retention in STEM

Dr. Ronald B. Bucinell, Union College

Dr. Bucinell is an Associate Professor of Mechanical Engineering at Union College. He is a fellow of the American Society of Mechanical Engineers, a former fellow of the Kern Family Foundation, a four time NASA Summer Fellow, and a past awardee of the IBM Faculty Award. He served as Chairman of the Department of Mechanical Engineering from September 2005 until June 2008, and as Chair of the Union College Faculty from September 2012 to September 2015. Since joining Union College in September of 1993, he has taught courses and laboratories in engineering mechanics, design, and entrepreneurship. His other responsibilities include undergraduate academic advising, senior design project supervision, undergraduate research supervision, and graduate research supervision. Dr. Bucinell has advised the SAE Baja, SAE Formula, and projects related to the ASME Human Powered Vehicle project. Dr. Bucinell has directed the International Virtual Design Studio project that ran in collaboration with the Middle East Technical University in Ankara, Turkey; Altim University in Ankara, Turkey; and ESIGELEC in Rouen, France. He also founded a chapter of Engineers Without Boarders at Union College and has traveled to Boru Village in Ethiopia to develop clean water supplies for the village. Dr. Bucinell supports the development efforts of many local companies in the areas of advanced materials. Central to these efforts are his Composites Manufacturing and Experimental Mechanics Laboratories at Union College. Prior to joining Union College, he spent 10 years in industry and continues to support the development of technology in local businesses.

Dr. Rebecca Cortez, Union College

Dr. Rebecca Cortez is a materials scientist in the Mechanical Engineering Department at Union College. Current research activities include the morphological and electrical characterization of nanoscale materials and thin films. Interests also include additive manufacturing of metals. Previous research activities involved the fabrication and characterization of radio frequency microelectromechanical systems (MEMS) devices; low-cycle and fretting fatigue testing of metal alloys; and thermal plasma arc processing for heavy metal immobilization.

Dr. Holli M Frey, Union College

Holli Frey is a professor and department chair of Geology at Union College. Her fields of expertise are volcanology and igneous petrology, with an emphasis on understanding magma storage conditions and evolution. She conducts field-based research in Dominica and Oregon and uses a variety of analytical tools, including bulk and mineral chemistry and zircon geochronology. Holli has been an active member of the Keck Geology Consortium, which promotes undergraduate research in geology and aims to recruit underrepresented students into STEM fields.

Prof. Joanne D. Kehlbeck, Union College

Joanne Kehlbeck received her BS in Chemistry from Duquesne University in 1992. She continued her interest in physical organic chemistry in her doctoral studies with Stuart W. Staley at Carnegie Mellon University receiving her PhD in 1999. Her multidisciplinary doctoral work combined organic synthesis, ab initio molecular orbital calculations and NMR studies as tools to understand fundamental issues in charge transfer. In 1999 she moved to Yale University in New Haven, CT to complete postdoctoral studies under Alanna Schepartz, the Milton Harris '29 Ph.D. Professor of Chemistry and Professor of Molecular Cellular and Developmental Biology at Yale. While there, Kehlbeck studied the chemical biology of protein–protein and protein–nucleic acid interactions and the design of very small, yet well-folded proteins that inhibit or promote protein-protein interactions with exceptional levels of specificity. In 2002 she took the position at Union College in Schenectady, NY. She teaches organic chemistry, culinary chemistry and medicinal chemistry courses. Her research interests span a broad range of topics in chemical biology and organic chemistry, including design and synthesis of enzyme inhibitors, natural product fractionation and structure determination, synthesis of organic ligands for materials science applications and the study of

evidence based practices in undergraduate education and research that supports inclusivity access, retention and student success in STEM fields.

Prof. Michael E Hagerman
Dr. David A. Cotter, Union College

David A. Cotter is a sociologist with interests in gender inequality and rural issues. As part of the NSF-funded (S-STEM) grant (#1742407). "SUCCESS-LEADERS: Leading Educational and Academic Directions to Enhance Retention in STEM" he has been studying the intersections between gender, race, class, and place in STEM access and success using both national panel data and data on cohorts of Union College students.

Leading Educational and Academic Directions to Enhance Retention in STEM

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This project aims to develop, refine and implement practices that will advance understanding of the factors affecting retention and career pathways of low-income, at-risk populations. The production of academically talented, energetic STEM students with diverse backgrounds trained as leaders capable of propagating transformative mentoring skills will positively impact this nation's workforce. We aim to produce innovative technological leaders who thrive in a diverse multidisciplinary community. Our institution has a longstanding history of success with NSF STEM education initiatives and has used program assessment to build upon these successes in establishing lasting institutional enterprises based on funded models. The small and supportive nature of a liberal arts college provides significant strength in encouraging at risk students to persist in STEM disciplines through strong mentoring in both curricular and research arenas. As a small liberal arts college offering engineering we are particularly suited to facilitate the development of future leaders of a diverse STEM workforce. This project was funded by NSF DUE-S-STEM Track 2: Design & Development.

Introduction

The need for expanding the STEM workforce in the United States has been well articulated by the National Academies [1-5]. These reports also identify the importance of a more diverse STEM workforce and the challenges associated with attracting underrepresented groups to STEM fields. The SUCCESS-LEADERS (Leading Educational and Academic Directions to Enhance Retention in STEM) project aims to develop, refine and implement practices that will advance understanding of the factors affecting retention and career pathways of low-income, at-risk, and underrepresented populations in rural communities.

The focus of this project on underrepresented groups in rural areas was motivated by the High School Longitudinal Study 2009 (HSLSO9) [6] that was sponsored by the Department of Education. This study sampled 23,000+ students across 944 high schools. This study followed students from 9th grade through approximately three years past high school. This study found that rural or town males and females were less likely, compared to their suburban and urban counterparts, to pursue STEM majors (Figure 1), enroll in highly selective four year schools (Figure 2), perform research projects with faculty members in college (Figure 3), and were more likely to leave STEM majors (Figure 4).

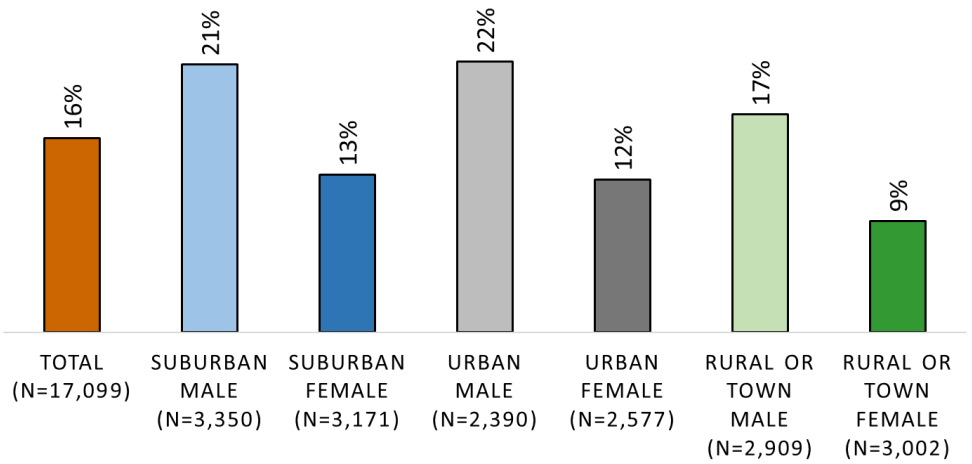

Figure 1: Results from the High School Longitudinal Study 2009 (HSLS09) [6] showing the distribution of STEM majors in college by gender and place

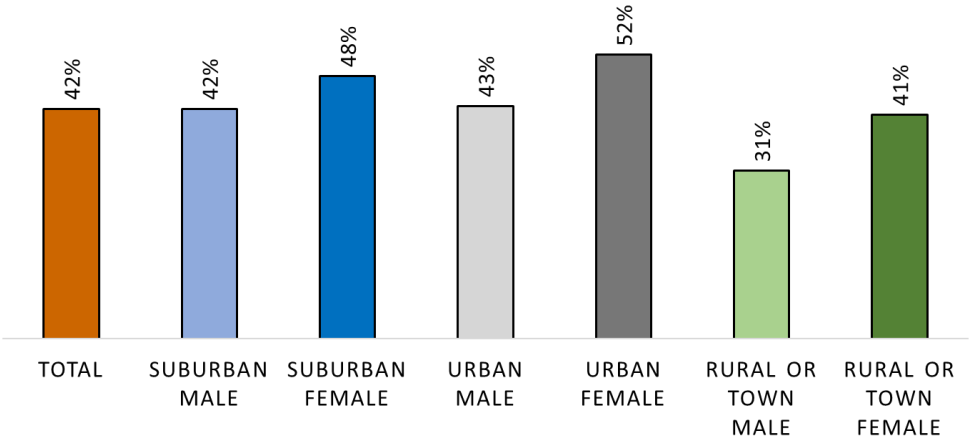

Figure 2: Results from the High School Longitudinal Study 2009 (HSLS09) [6] showing STEM enrollments at highly selective four year schools by gender and place.

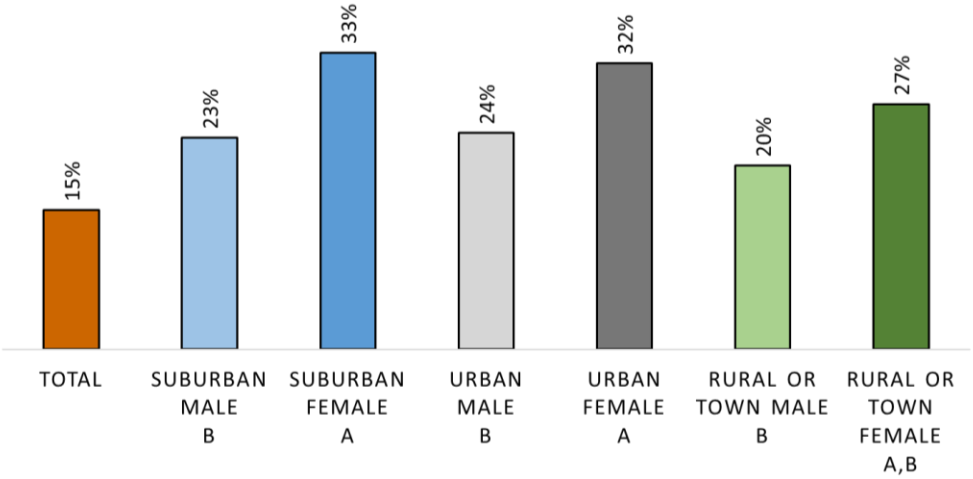

Figure 3: Results from the High School Longitudinal Study 2009 (HSLS09) [6] showing STEM majors that reported working on a research project with faculty members as undergraduates.

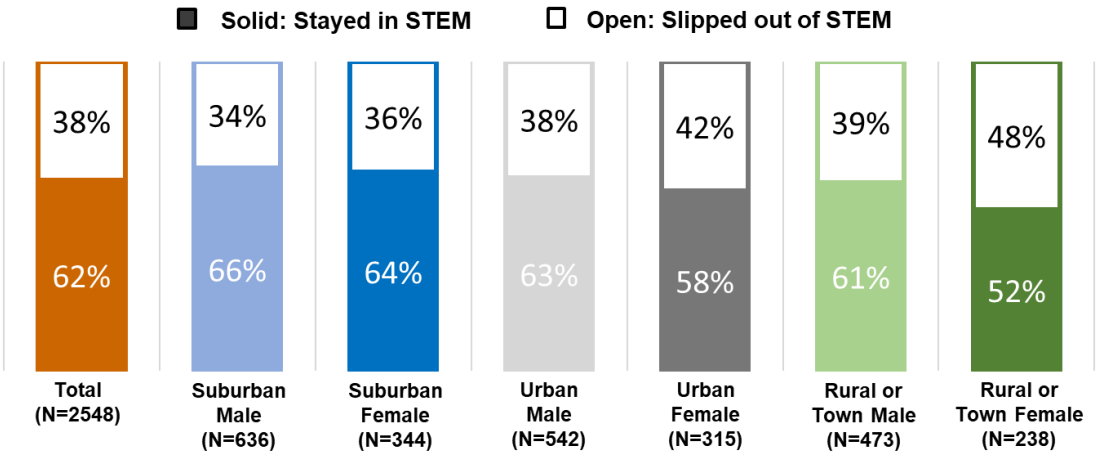

Figure 4: Results from the High School Longitudinal Study 2009 (HSLS09) [6] showing STEM majors that reported working on a research project with faculty members as undergraduates.

This project further broadens our inclusive recruiting strategy by building relationships with small, rural under-resourced public high schools in order to attract and retain talented students to STEM fields. Students originating from rural areas face unique challenges persisting in STEM fields. We aim to address these challenges by providing dedicated mentors and enabling the development of a tight knit, supportive cohort of scholars across disciplines. We focus on professional development activities that build the skills necessary to participate in mentoring activities, both as a mentee and a mentor to others. Connecting scholars with potential mentors, 1) in their peer group; 2) in their discipline as academic advisors; 3) in courses as professors; 4) in research as project advisors; and 5) in the workforce as professional contacts, enables personal growth and professional advancement of both the mentor and mentee. To encourage the students to be proactive in making professional contacts, we stress attendance at seminars within their STEM disciplines. Students are offered an opportunity to participate in the IMPACT program that aims to connect students to STEM professionals in industry. Placing students in the role of mentor, as STEM ambassadors to their community high schools, fosters student leadership and builds capacity for the initiative going forward. The program includes placing STEM students together into general education courses like the "first-year preceptorial" and the "sophomore research seminar" themed with sufficient breadth in order to ask students both to embrace how their discipline can contribute to the emerging concerns within the theme, but also to encourage discourse among the students in different STEM disciplines.

In addition to internal assessment conducted as part of the analysis for our current grant, data from a longitudinal retrospective analysis will be presented on the academic and professional pathways of prior NSF-DUE funded students. This will include prior cohorts totaling approximately 90 students who have matriculated over the last decade to compare their academic pathways during their undergraduate years and beyond against similar STEM-oriented students of the same class years in order to critically examine our efforts and identify the most impactful practices in achieving the project goals.

The development of this project was informed by four previously supported NSF projects dating back over a decade.

1. DUE-0324165; 9/1/03-8/31/08; “Helping Promising Students Enhance their Future.” The CSEM program components were designed to: 1) provide support for students in introductory STEM courses through supplemental learning in engineering and computer science courses; 2) enhance opportunities for career exploration; 3) provide internships and research opportunities earlier in their academic career; 4) provide peer and alumni mentoring; and 5) enhance communication and study skills through additional assessment and more individualized programs.

2. DUE-0631082; 1/1/07-12/31/12; “Supporting Scholars in Science and Engineering.” The goals of this project were to: 1) improve recruitment and retention of academically-talented students in STEM fields; 2) increase the number of women in engineering, physics, and computer science, and underrepresented groups in all disciplines; 3) provide students with opportunities to enhance their education through research, study abroad, internships, and leadership training; and 4) enable these students to make connections between their major and other disciplines through pursuit of a minor, interdepartmental, or dual major.

3. DUE-0850242; 9/1/09-8/31/14; “Supporting Scholars in Science and Engineering.” The goals of this project were to: 1) improve recruitment and retention of academically-talented students in STEM fields at Union; 2) increase the number of women in engineering, physics, and computer science, and underrepresented groups in all disciplines; 3) provide students with opportunities to enhance their education through exposure to summer research opportunities, internships, study abroad, and leadership training; and 4) enable Scholars to make connections between their major and other disciplines through pursuit of a dual major, minor or interdisciplinary major.

4. DUE-1356398; 3/1/14-2/28/19; “SUCCESS: Stimulating Undergraduates: Creating Contributors in Engineering and Science for Society.” The overall goals of the proposed project are to: 1) increase the number of applications and admissions from academically-talented students from under-resourced, rural high schools 2) improve retention and success of these students in STEM fields by specifically addressing the challenges faced by students from small, rural high schools with limited academic opportunities; 3) increase the number of women in engineering, physics, mathematics and computer science, and underrepresented groups in all disciplines; 4) provide students with early introduction to research opportunities, connections to industry and internships, study abroad, and leadership training; and 5) improve undergraduate educational experiences and promote professional advancement by facilitating fruitful mentoring relationships.

Many the successful program elements implemented under the prior S-STEM projects were structured to targeted student engagement from identified rural schools. These elements – designed to encourage scholars to achieve their best academic performance and enable them to enter the workforce or continue studies in their fields – support the key program components of: multi-dimensional mentoring with discipline-specific advising; enhanced academic programming

with active learning communities; critical student support services focused on addressing points of attrition; and opportunities to develop leadership and mentoring skills.

Project Objectives

The objectives of this project are to: 1) increase the number of applications and admissions from academically-talented students from under-resourced, rural high schools 2) improve retention and success of these students in STEM fields by specifically addressing the challenges faced by students with limited academic opportunities; 3) increase the number of women in engineering, physics, mathematics and computer science, and underrepresented groups in all disciplines; 4) provide students with opportunities to enhance their education through early introduction to research opportunities, connections to industry and internships, study abroad, and leadership training; 5) improve undergraduate educational experiences and promote professional advancement by facilitating fruitful mentoring relationships in order to address typical areas of attrition in STEM; and 6) use evidence from a retrospective longitudinal study to assess the long range impact of the elements refined through NSF funded initiatives that were designed to retain at-risk populations in STEM.

Project Description and Participation

The key elements of this project are designed to encourage the scholars to achieve their best academic performance and enable them to enter the workforce or continue studies in their fields – support the key program components of: multi-dimensional mentoring with discipline-specific advising; enhanced academic programming with active learning communities; critical student support services focused on addressing points of attrition; and opportunities to develop leadership and mentoring skills. Specific objectives include:

1. Weekly cohort luncheon meetings led by the Cohort Mentors that generate a productive learning community where Scholars with diverse STEM interests gather to share experiences. Intercohort meetings encourage peer-to-peer mentoring relationships.

2. Faculty research lab crawls allow Scholars early in their academic career to explore interdisciplinary research endeavors that engage Union faculty and students in active learning communities.

3. Workshops introducing support services and developing professional skills will highlight the skills necessary to participate in beneficial mentoring relationships, both as a mentor and a mentee.

4. Visits and tours hosted by local STEM professionals will enhance Scholars' exposure to a wide range of career options and build connections between the liberal education and workforce learning. Professionals in areas such as semiconductor research and applied statistics at a local nuclear propulsion laboratory will share their experiences. Scholars will also engage in outreach by visiting their high schools to connect to their community and propagate Union's SUCCESS initiative.

5. Scholar cohort placement in the same class section of introductory STEM courses is aimed to encourage study groups and enable intracohort mentoring and Common residential housing encourages bonding in a social learning community taking advantage of Union's Minerva House System.

6. Scholar Research Seminar on STEM topics designed to introduce scholars to research skills in STEM and demonstrate the value of multidisciplinary approaches to address important research questions.

7. Continuous and sustained research experiences including a summer research opportunity for scholars after their first year, participation in the Scholars Research Project during their second year, and continued engagement in research practica thereafter culminating in a senior thesis research

The first cohort of students entered this project in the Fall of 2018. The cohort consisted of 9 females and 1 male. The initial cohort is still persisting in STEM in majors in Engineering, computer science, and the physical sciences. The second cohort of students was admitted in the Fall 2019. In this cohort there are 6 females and 4 males. These students are still first year students, so it is too early to identify them by major.

Conclusions

The weekly meetings with the students have had the desired effect of building a tight bond between the members of the cohort. The lab crawls have made it much easier for the students to identify opportunities within faculty laboratories for research experiences. Several of the students are now working in faculty labs. The common Scholar Research Seminar helped to build a strong academic bond between the students, even though they are in different majors. This project also was identified by Insight into Diversity magazine as one of the 2019 Inspiring Programs in STEM.

Acknowledgement

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