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Supporting STEM Success Through Prematriculation Undergraduate Research

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Abstract

The STEM Scholars program at Bucknell University was originally supported with a five-year National Science Foundation STEP grant to begin recruitment for a summer program in 2014. The grant, with a one-year no-cost extension, supported six cohorts of students. The recruitment of participants was specifically designed to attract typically underrepresented populations into STEM (Pell eligible, first generation, students of color, female identifying). As a result of successful implementation as measured by retention, persistence, and graduation rates, the university has secured private donations from generous alumni to endow the program. The tenth cohort of scholars participated in the summer of 2024.

Keywords: *diversity, equity, and inclusion (DEI), retention, STEM*

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In 2012, a subset of the authors submitted a National Science Foundation Division of Undergraduate Education (NSF DUE) STEP proposal titled "STEP: Using Early Introduction to Undergraduate Research to Recruit, Retain, and Graduate More STEM Majors" (STEM Scholars; no.1317446) with its stated goal "to increase the number of undergraduate students, particularly under-represented students, who graduate in the sciences by taking advantage of the mentor education model that addresses the social and academic needs of these students. The program is designed to prepare students for long-term careers in science, either in academia or in industry, through an early introduction to research." The project was created to find ways to attract and retain students, in particular typically excluded students, in STEM fields.

A developmentally appropriate and expected experience of first-year undergraduate students is something called "major switching," which is when an incoming student intending to major in one field switches to a different major during their college career. Major switching, however, exacerbates the less than optimal number of STEM graduates, since more students tend to switch out of STEM fields than into them. Although major switching occurs in virtually every area of study, it is particularly pervasive and problematic in the sciences, especially for underrepresented groups (Ma and Xiao 2021). At Bucknell, at the time of the NSF proposal, over 80 percent of students who initially matriculated as a STEM major graduated with a STEM major, but only 70 percent of African American students and 69 percent of Latino students who declared a STEM major completed a STEM degree. For this reason, a component of the STEM Scholars program was to intentionally market to and recruit underrepresented students, defined broadly, who possess a variety of demographic measures that are typically excluded.

The now widely recognized solution of using undergraduate research to retain students in STEM majors (Hunter, Laursen and Seymour 2007; Russell, Hancock, and McCullough 2007; Seymour and Hewitt 2004), found similarly effective for underrepresented groups (Gregerman 1999; Shields, Hewitt, and North 2010), was the main component of this program. Not only has undergraduate research been found to help with retention, it has further been identified to help students develop a greater sense of what graduate study is like. Students who participate

in undergraduate research are more likely to obtain an advanced degree and are more likely to anticipate earning a doctoral degree (Russell et al. 2007). STEM Scholars was also intended to help, in small numbers, meet the need for increasing diversity in the pipeline for postbaccalaureate degrees.

STEM Scholars built on the success of prior efforts at two different institutions that used early introduction of undergraduate research to promote student success and increase the number of science majors (Shields et al. 2010; Shields, Gajdosik-Nivens, and Ness 2017). The first, Hamilton College, was a highly selective private college, and Armstrong Atlantic State University (now part of Georgia Southern) was a public university. In the following sections, the authors describe STEM Scholars and the results of the first eight years of the STEM Scholars program at Bucknell University, a highly selective private university.

Program Description

The STEM Scholars program is situated in a robust preexisting summer research program at Bucknell, involving faculty from all STEM disciplines. At the start of STEM Scholars, over 100 undergraduates participated in summer research funded by competitive internal grants, departmental funds, and external research funds, including NSF Research in Undergraduate Institutions and Research Experience for Undergraduates grants.

The admissions office at Bucknell advertises the STEM Scholars program to students in their final year of high school. Students are invited to apply to the program after they have been admitted and before they have decided where to attend. The intent is to signal to admitted students Bucknell's emphasis on varied opportunities to engage in undergraduate research. Although the application is open to anyone and available on the website, admissions personnel make a concerted effort to individually invite students who are underrepresented in STEM (except for biology), which the program designers identified as first-generation (1st Gen), students of color (SOC), Pell-eligible, and female-identifying undergraduate students.

The model for the program was based upon learning community models, which have been shown to promote coherence and a sense of community among group members, increase academic achievement and retention, and encourage continuity and the integration of diverse curricular and cocurricular experiences (Schroeder and Mable 1994). The infrastructure of the five-week summer STEM Scholars program includes the following:

1. *Student recruitment*. Students are recruited by the admissions office before they begin their first year at Bucknell through direct mailings, advertisements on the Internet, presentations at high school outreach programs, and publicity at incoming student open houses.
2. *Faculty-student matching*. Students and faculty mentors enter into a mutual selection process. There is a STEM Scholars website that hosts descriptions of past and future summer research projects of faculty mentors. On the application, students share their interests after viewing faculty project descriptions. Faculty review applications and individually rank students based on their expressions of interest. Then, in a meeting at which all mentor faculty are present, there is a placement process that best matches the interests of the students with the needs of the research teams. Since students are selected in April, prior to their decision to attend Bucknell, waiting lists for many labs are determined. The original grant provided funding for cohorts of 20 students, but over the course of the project it was found that 10 to 15 students was optimal and achievable. The research team sizes vary across the faculty mentors, from two people (the faculty mentor and STEM Scholar) to eight (which might include more than one STEM Scholar). The size is based on the needs and capacity determined by the faculty mentor.
3. *Peer mentoring*. Two paid peer mentors are selected (usually from the previous year's cohort) to meet one-on-one with each STEM Scholar every week for the five weeks. They discuss any concerns about their faculty mentors, research projects, other STEM Scholars, and any other issues related to their transition. In addition, the peer mentors help to plan and orchestrate the many group activities over the summer. The relationship that is formed between the STEM Scholars and the peer mentors often extends through the first year, and for many students until the peer mentors graduate.
4. *Team building*. During the five weeks of the summer, STEM Scholars are housed together and provided opportunities for both planned and impromptu cohort building. The peer mentors lead the scholars over the course of the five weeks through a variety of team building activities. There is one group excursion planned per week that makes use of natural and human-made resources within an hour of campus (e.g., rock climbing and ropes courses, kayak and canoe trips, a local amusement park, and faculty-led tours through local caves, animal parks, and state parks).
5. *Weekly academic activities*. Outside of the 35 hours of research time, there are numerous focused academic activities that occur over breakfast or lunch. These activities include "meet and greet" sessions with faculty members of all the STEM departments and presentations by various academic support centers on campus, such as the Center of Teaching and Learning, Writing Center, and Health Center.
6. *Research presentations*. At the end of the five weeks, as a culminating experience, students are expected to share a "snap talk," which is a five-minute oral presentation

with accompanying slides. It is expected to be a summary of their research problem and the progress they made during the summer. Community and family members are welcome to attend.

The cost for each STEM Scholar is approximately $5000, which includes housing, a stipend for student and faculty, lab and presentation costs, excursions, team-building events, and seven meals per week.

Methodology

Findings are based on the first five cohorts and their comparison groups: STEM Scholars (treatment group), comparison group (control group), and other STEM intending. The comparison group was identified based on similar demographic backgrounds of STEM-intending students who matriculated at the same time, but did not participate in the summer program. The third group was composed of the rest of the STEM-intending students who matriculated at the same time as the first two groups. Over the first five cohorts, the number of students included 77 STEM Scholars, 95 in the comparison group, and 1,690 in the other STEM group. Approximately 75 percent of the STEM Scholars were female, 51 percent SOC, and 49 percent met at least two of the four diversity indicators (1st Gen, SOC, Pell eligible, and female). The data from our institutional research included retention rates, graduation rates, GPA, and standard postgraduation first-destination surveys. Additionally, pre- and post-summer surveys were administered to STEM Scholars, to learn how the program shaped scholars' professional development and career trajectory.

Results

To evaluate progress toward the above-stated goals, a variety of data and outcomes were collected for the three groups. Three important findings were as follows:

1. Overall, STEM scholars were retained in a STEM major from the first fall to the second fall and graduated in four years at higher rates than the other two groups. However, the differences of retention and four-year graduation rates among the three STEM groups were not statistically significant (Tables 1 and 2).
2. STEM Scholars had a higher percentage of SOC, 1st Gen, Pell-eligible, and female-identifying students. Even with increased diversity, STEM Scholars achieved higher retention, persistence, and graduation rates in STEM compared to the comparison and other STEM groups (Tables 1 and 2).
3. A one-way analysis of variance revealed a significant effect on the first-year cumulative GPA on SOC STEM Scholars ($p < .05$). A post hoc test showed that SOC STEM Scholars significantly outperformed those in the comparison group in the first-year cumulative GPA, with a first-year cumulative GPA of 3.13 compared to 2.77 ($p < .05$; Table 3).

Earlier studies identified the benefits of engaging undergraduates early in their career for retention in STEM (Russell et al. 2007; Seymour et al. 2004), with some focused particularly on underrepresented students (Gregerman 1999; Shields et al. 2010). Similarly, investigation of the STEM Scholars program indicated that typically excluded students engaging with a cohort participating in research with a faculty mentor during the summer before matriculation to an undergraduate program benefited from persistence in a STEM field and outperformed students who did not participate.

In addition to supporting students in their dream of graduating with a STEM degree, the STEM Scholars program sought to increase the number of typically excluded students in the pipeline for STEM graduate degree programs. To study this, the authors relied on preexisting data from the Office of Institutional Research and Planning. Bucknell conducts annual surveys to gather information from graduating students about their first destination following graduation with a 97 percent response rate, providing a comprehensive and detailed understanding of where alumni transition to after completing their studies. Approximately 16 percent of Bucknell STEM majors attend graduate school (in any field) in the first year after graduation. The postgraduate survey data revealed a significant difference in the pursuit of graduate schools in STEM fields among three groups who applied to graduate schools. STEM Scholars had a significantly higher likelihood of pursuing graduate school in STEM fields compared to their counterparts (STEM Scholars 73 percent; comparison group 46 percent; other STEM 68 percent; $p < .05$). Of the STEM Scholars who attended graduate school within one year of graduating, 20 percent were in medical school and 53 percent were in an MA or PhD program in engineering, physical science, or natural science. The comparison group had approximately the same percentage of students attending medical school, but only 25 percent were pursuing a graduate degree in a non-medical STEM field. This may suggest that participating in this undergraduate research program cultivated students' curiosity and perseverance in studying STEM beyond the undergraduate level.

To further understand STEM Scholars' experiences, coauthors also conducted a postgraduate survey of the STEM Scholar graduates (35 percent response rate). A large majority, over 90 percent, strongly agreed or agreed that the STEM Scholars program was an important part of their Bucknell experience, helped them persist in STEM, and helped them be better students. Additionally, all survey participants strongly agreed that they would highly recommend the STEM Scholars program to interested incoming students. Although the quantitative results are impressive, the students' own voices illuminate the true value of the program. Open-ended responses indicated

TABLE 1. First-to-Second Year Retention in STEM Field

STEM type	2014 Cohort	2015 Cohort	2016 Cohort	2017 Cohort	2018 Cohort	Total
STEM Scholar	93%	94%	82%	87%	71%	86%
Comparison group	94%	81%	67%	85%	92%	82%
Other STEM	80%	80%	84%	77%	82%	81%

TABLE 2. Four-Year Graduation Rate in STEM Field

STEM type	2014 Cohort	2015 Cohort	2016 Cohort	2017 Cohort	2018 Cohort	Total
STEM Scholar	93%	71%	59%	93%	64%	75%
Comparison group	88%	62%	63%	65%	92%	72%
Other STEM	66%	72%	69%	63%	66%	67%

TABLE 3. First-Year Cumulative GPA

STEM type	*n*	Mean	Standard deviation	*F*	*p*
STEM Scholar	39	3.13	0.65	3.385	0.035
Comparison group	40	2.77	0.61		
Other STEM	302	2.89	0.64		

that the STEM Scholars program was important to many students' retention and persistence. The most frequently identified benefit was the establishment of the students' social networks. One student stated,

> STEM Scholars kickstarted my research career. Without it, I don't know that I would have continued to pursue it with the same enthusiasm. . . . Additionally, my STEM Scholars cohort formed the foundation of my social circle at Bucknell. Having a highly motivated group who were navigating the challenges of research together right at the beginning of our college careers gave us a fantastic start at Bucknell. This was incredibly important to me. I'm still friends with these people today.

One final by-product of developing the NSF grant to create the STEM Scholars program was to increase the undergraduate STEM research taking place on Bucknell's campus during the summer. In 2013, the number of STEM students engaged in summer research was 100 students; during the eight-year period between 2018 and 2021 (which mirrors the period of STEM Scholars) there was a 120 percent increase in students (n = 221) participating in STEM research on campus, only a small portion of which was funded by the STEM Scholars program. Additionally, the total number of undergraduates engaged in any field of research in the summers, as of 2021, had risen to 304 students, which is approximately 8 percent of the total student population at Bucknell.

Conclusion

Achievement will always be gated by people—good support groups, networks are absolutely key to success. (STEM Scholar, Class of 2018)

Bucknell's STEM Scholars program has proven to be a successful tool for recruiting and retaining underrepresented students in STEM disciplines. The prematriculation introduction to research, dedicated faculty and peer mentoring, and strong cohort development attributes of the program all play a role in encouraging persistence, a sense of belonging, and professional development of the students. A key lesson learned, despite the early skepticism of some faculty members, was that prematriculated students could contribute to research progress. This same effect was noted previously at two other institutions (Shields et al. 2010; Shields et al. 2017), and therefore we expect this to be a persistent effect at any institution implementing this program. Based on the excellent results of Bucknell's STEM Scholars program and generous donors, the program is now funded to continue indefinitely.

Although some might argue that the small numbers of students in programs like STEM Scholars at Bucknell may

not move the needle much, it has long been recognized that liberal arts colleges and other predominantly undergraduate institutions are ideal environments for addressing these goals (Cech 1999). Scalability may come in the way of increasing the number of liberal arts institutions adopting a project like this rather than attempting to scale it for larger universities. Historically, for example, in 1992, the US Congress attributed the narrowing of gaps related to gender and major selection to small liberal arts colleges, community colleges, and historically black colleges and universities (Parsad, Lewis, and Farris 2001). Additionally, the apprenticeship model of education promoted by many small liberal arts colleges is an optimal preparatory model for all students interested in pursuing a STEM career. These institutions have typically been able to overcome problems of faculty unresponsiveness, poor teaching quality (often associated with extensive use of teaching assistants and lack of interest of research-oriented faculty), and lack of student-faculty collaborative opportunities, which have been cited as some of the underlying reasons that students, especially women and underrepresented minorities, switch majors (Seymour and Hewitt 1997).

Bucknell's STEM Scholars Program effectively combines early exposure to research, a strong cohort model, prematriculation academic programming, and robust faculty and peer mentoring into an effective strategy for recruiting and retaining underrepresented students in STEM disciplines. We saw evidence for increased academic engagement among STEM Scholars in their early undergraduate years and more developed STEM career trajectories in their later undergraduate years when compared with nonparticipants. We encourage other institutions to consider similar programs to help increase retention and academic success in STEM.

Data Availability

The data underlying this study are not publicly available due to FERPA. They are available from the corresponding author upon reasonable request.

Institutional Review Board

Review board found research to be exempt.

COI

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