S-STEM Engaged Engineering Scholars: Insights from Year 1

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S-STEM Becoming Engaged Engineering Scholars (BEES): Insights from Year 1

Abstract

The Becoming Engaged Engineering Scholars (BEES) is an NSF S-STEM project that responds to the challenges in recruiting and retaining academically talented, low-income students from diverse backgrounds into undergraduate engineering programs. The new, ABET-accredited engineering programs at Western Washington University (WWU) have faced unique challenges in recruitment and retention, particularly in the first two years for pre-engineering students. Building on the success of prior S-STEM awards in other disciplines at WWU, the proposed program provides a systematic sequence of academic, social, and career support services specifically designed to enhance the success of engineering students during these first two years of undergraduate study.

The primary program goal is to ensure the engineering programs offer an equitable pathway into engineering careers, particularly for low-income, academically talented students. In addition to providing financial support for participants, the BEES program adapts existing institutional support structures to offer a one-week bridge program prior to the start of their first year, implements a multi-level mentoring system that includes internal and external mentors, engages students in multiple curricular and co-curricular activities including an engaged engineering project experience, and offers a first-year seminar focused on engineering and society.

The project devotes significant resources to studying the impact of the proposed activities. Specifically, the research seeks to answer how and to what extent the program activities support retention through the end of the 2nd year of engineering study, as well as how and to what extent the program activities impact students' self-efficacy, identity, and sense of belonging. In this paper, the proposed program and its various support structures are described in detail, and some insights and results from the first year of the project are reviewed and discussed.

Introduction

This study is taking place in Western Washington University (WWU), a public master's-granting institution with approximately 15,000 full- time undergraduate students. The Engineering Department at WWU is a new department formed in 2014 out of the former Engineering Technology department as part of a state-funded effort to transition the engineering technology programs to accredited engineering programs. Three engineering programs are participating in this study: The Electrical Engineering (EE) program, the Manufacturing Engineering (MfgE) program, and the Plastics & Composites Engineering (PCE) program.

The transition to engineering has resulted in steady growth of the student body in the three engineering programs (from 31 students in the inaugural graduating Class of 2016 to 79 expected graduates in the Class of 2020), and a 167% growth in tenured/tenure-track engineering faculty (from 6 faculty in 2013 to 16 faculty in spring 2020 plus 4 new hires expected to join in the fall). Accreditation of these new programs had been the primary focus since the creation of the new department; with accreditation granted in Fall 2017 (retroactive to October 2015), the department has refocused its efforts to address issues of equity and inclusion that have arisen during the transition to engineering. These issues have arisen primarily due to a gradual shift in demographics of engineering versus engineering technology students, combined with higher requirements for entry into the new engineering programs brought about by the increased mathematical rigor. The departmental focus on equity and inclusion mirrors a unified effort at the university and college

levels, particularly relating to expanded access to majors that are in the highest demand (i.e., predominantly STEM majors). To tackle these equity and inclusion issues, there are two department-specific attrition points the program under study is designed to address:

- To formally enter the engineering programs and to be able to graduate in 4 years, all admitted engineering students must be "calculus ready" when they arrive. Alas, a large fraction (60.0%) of admitted students who initially express interest in engineering do not place into calculus after taking the university's math placement exam just prior to the start of freshman year, and many of them ultimately choose another major besides engineering. This situation impacts many engineering programs nationally [1–4], and it disproportionately impacts Pell-eligible engineering students at WWU.
- Students who successfully complete the second year of the engineering programs are retained through graduation at a relatively high rate (95.4%). However, retention from the point of expressing initial interest in engineering (i.e., the start of the first year) to the end of the second year is much lower (38.8%), consistent with a trend seen nationally in many engineering programs [5, 6]. The challenges of first and second-year retention disproportionately impact Pell-eligible engineering students at WWU.

Program overview

A cohort of twelve incoming first-year students (referred to as Scholars in this paper) is selected each year over five years to participate in the BEES program. The program responds to the challenges in recruiting and retaining academically talented, low-income students from diverse backgrounds into the three undergraduate engineering programs at WWU. The program is designed to provide a systematic sequence of academic, social, and career support services specifically tailored to enhance the success of engineering students during the first two years of their undergraduate study.

A total of forty-eight (48) unique S-STEM scholarships will be awarded to four cohorts of entering first-year undergraduate students and provide them with an average of $6,250 of financial support annually for both their first and second years. The objectives of this program are: (i) to prepare academically talented, low-income students for careers in engineering by supporting their completion of engineering degrees, (ii) to study the impact of a math-focused bridge program and first-year seminar on retention through the end of the 2nd year, (iii) to study the effects of program activities on Scholars' self-efficacy, identity, and sense of belonging, and (iv) to study the impact of cross-disciplinary "engaged-engineering" projects on retention through the end of the 2nd year.

Moreover, this program has the potential to benefit society in a variety of ways. It will contribute to the development of a diverse, globally competitive STEM workforce by preparing students for careers in engineering. The program also contributes to the full participation of women and underrepresented minorities in engineering by incorporating program features that are known to increase the retention of these groups in engineering [9]. By measuring and studying the effects of the program elements and disseminating results, the research conducted will inform the development of similar programs elsewhere, further broadening the impact. Finally, carefully sequenced programming and interventions will be available to all engineering students through the institutionalizing of the program, thereby impacting students who are not part of the scholarship

program. Because the programming and interventions are attached to existing university programs, they are sustainable and will impact students well beyond the project completion.

Program support structure

To achieve the above-mentioned objectives and goals, this BEES program focuses on the first two years of engineering study, with a cohort of 12 students per year, and contains the following systematic sequence of academic, social, and career support services specifically designed to enhance the success of engineering students. The services all adapt existing support structures and programs on-campus—programs with which the new engineering department currently does not have a presence:

Math preparation: After the 12 Scholars are selected each year, they will receive details about the engineering curricula, the importance of placing into calculus upon arrival, details about the math placement exam, and details for accessing a preparatory/learning module to be completed prior to the first attempt at the math placement exam. Through interactions with students and interviews with pre-major advising counselors, we know that incoming engineering students are frequently unaware of the importance of placing into calculus immediately, and incoming students often admit to having done little preparation for the math placement exam. Because the exam is administered in the summer, most students have not been actively studying math for the prior several months, and thus they may not be in the ideal mindset to recall and employ math concepts. Our expectation is that simply by increasing awareness of the importance of placing into calculus on the exam, and by providing more targeted advice as related to preparation materials, we will see small gains in Math Placement Assessment (MPA).

Math-focused Bridge Program: WWU has an existing campus-wide bridge program called Viking Launch where participating students arrive on campus one week early for an intensive week of study and preparation in their chosen discipline. Consistent with other research on bridge programs [7], the Viking Launch program has been shown to have a positive effect on the first-year retention at WWU according to data provided by the Vice Provost for Undergraduate Education (VPUE). The engineering department, however, has not historically participated in the Viking Launch program, and as such, there has not previously been a bridge option for pre-engineering students. By adopting this existing support structure, we offer an intensive math-focused bridge program designed for students interested in engineering. The VPUE assigned an instructor from the math department to be the primary instructor for the bridge program. The selected instructor is intimately familiar with the math placement exam and has experience teaching pre-calculus review classes. All the week-long courses in this bridge program consist of several common programmatic elements known to improve student success [8], combined with discipline-specific learning. These common elements include social gatherings and organized meals for members of the cohort, as well as workshops focused on student success, financial literacy, study skills, and tutoring services available on campus.

First-year interest groups (FIGs): WWU offers a series of first-year programs called “First- year Interest Groups (FIGs)” which consist of a cluster of three courses taken by a single cohort. Typically, two of these three courses are general education courses (math and science, for example), linked with a two-credit seminar. The learning community environment created by the FIG cluster is intended to help students connect more quickly to university life, and first-year

seminars are known to improve persistence and retention [9]. The FIG program is well-established at WWU, and is now in its 18th year; however, the engineering department has not historically offered a FIG program. Again, we adapted this existing support structure to offer an engineering-focused FIG required of all Scholars. Because all three engineering disciplines require completion of MATH 124 (Calculus I) and PHYS 161 (Physics I) in the first quarter, we have chosen these two courses as the general education components of the FIG. All Scholar students will enroll in the same section of MATH 124 and PHYS 161 to preserve the cohort structure, and they will additionally take a 2-credit seminar taught as part of the regular teaching load by a rotating group of faculty. The theme underlying the seminar course is "socially responsible engineering", and the course will include reading and discussion on such topics as ethics, societal "grand challenges" in engineering [10], and recent technological progress in addressing those challenges. Engineering topics with obvious societal benefits have been shown to improve recruitment and retention of traditionally underrepresented groups in engineering, such as women [11]. In addition, the seminar curriculum includes practice with spatial visualization, as spatial ability has been shown to be a predictor of student success in first-year engineering students [12]. The students are also trained to develop metacognitive skills and work to develop growth mindsets, both of which have been linked to success in STEM courses [13–15]. Importantly, this seminar is also serving as the launch point for peer and faculty mentoring.

Engaged engineering projects: As part of this project, Scholars are invited to participate in Engaged Engineering projects which focus on enabling our Scholars to tackle real-world/authentic design challenges [16] with the goals of improving sense of belonging [17, 18], and gaining engineering skills that are required for upper level capstone senior projects, and, more broadly, the workplace [19]. We hypothesize that an early project experience is a significant contributor recruitment and retention of Scholars based on the supporting literature [20] and our own experience with past successful undergraduate project advising. Indeed, early exposure to projects involving engineering problem solving with direct and clear benefits to society and the local community have been shown to be especially beneficial to women and underrepresented minority students [20, 21], and highly useful as retention tools. These projects are taken for a variable number of credits (1 to 3), and generally consist of teams of 3–4 students across all three engineering disciplines, and fit within the existing project advising framework at the engineering department in one of three ways: (1) As engineering directed-research projects, with a requirement that projects identify a societal connection. (2) As service-learning projects advised by engineering faculty in partnership with local not-for-profit organizations; projects will be required to address a problem or need that lies at the intersection of technology and society. (3) As community-based engineering projects through the Small Business Development Center (SBDC) and local for-profit businesses. Some of these projects can be ongoing projects that span multiple quarters or years, while others might be completed within a quarter. To facilitate the structure and placement of the Scholars in these projects, we survey all Scholars a month before course registration each quarter to determine Scholars' interest in registering for project credits. Based on the survey results and to maximize cross-disciplinary interaction and project continuity, teams of students from the three engineering programs are assigned to projects and partners/advisors the following quarter. For project assessment, we are adopting the successful approach used by the EPICS program [22] which employs a four-level formative assessment approach.

Multi-level mentoring program: Mentoring has been shown to improve retention and support success of low-income students [23]; as such, each Scholar is assigned three mentors for the duration of the two-year scholarship: a faculty mentor, a peer mentor, and an early-career professional mentor. Faculty mentors attend social events, serve as academic advisors, meet with advisees regularly, and serve as the primary conduit for Scholars into the projects. Scholars who have completed the program and are juniors or seniors are asked to serve as peer mentors; for the cohort under study, the Peer mentors were selected from a group of high-achieving juniors/seniors such as those in leadership positions. Peer mentors receive a modest annual stipend and are asked to meet twice per quarter with their assigned mentee(s), respond to an end of quarter survey, and to attend social events. Each Scholar will also be assigned an early-career professional mentor who is a recent alum working at a local engineering company. We are planning for this at the starting of the second year for the Scholars. We are adopting a "tip-sheet" of best practices for mentoring based on [24, 25]; and we distribute this tip-sheet to early-career mentors.

Extracurricular Events and Field Trips: Regular get-togethers are held twice per quarter and range from social events exclusively for the Scholars, to panel discussions, presentations, and workshops with professionals in the field open to all engineering students. Topics planned for workshops and panel discussions for this cohort and the following ones include resume writing workshops, mock interviews, time management, group dynamics, and how to address biases in the workplace. A welcoming event was held at the start of this year (and will be for the upcoming years), and a celebration event will take place at the end of each year.

Results from program first year

As this is the first year of the project, our major activities consisted of getting the various support structures in place, as described below:

Project recruitment effort: We designed the website and scholar application, issued a press release through the university media relations (which was picked up locally by radio and print media), advertised through social media, and we directly emailed 209 low-income students to apply to the program. We received 38 eligible applications (pre-filtered as being low-income and high-achieving), and after conducting interviews both in-person and through Skype, we selected 15 students to join the first cohort of scholars. Of those, 11 students ultimately accepted. Two chose not to participate because they did not choose to attend the institution, and two did not participate because they were not able to earn a sufficiently high score on the MPA. From a diversity standpoint, cohort 1 in this program is shown to be more diverse compared to the three engineering majors in department and to the institution student population, as shown in table one below.

Table 1: Students diversity measures

Diversity Measure	*BEES program*	*Engineering department*	*WWU*
Pell-Eligible	73%	27%	25%
First-Gen	45%	26%	32%
Female	36%	15%	57%
URM	55%	23%	26%

Implementation of Math Placement Assessment communication campaign: Through a brochure we designed and an associated email campaign, we developed an approach to better communicate the importance of the MPA to students, including details about preparing for the exam and instructions for accessing appropriate online learning/preparation modules. In addition, we carefully monitored the students' progress using the online ALEKS system which shows the number of attempts, scores of each attempt, and hours students spent working through the preparation modules. This helped us provide encouragement and guidance to the students to let them know if the time and effort they spent were in line with expectations toward earning the necessary placement score. The brochure and the careful monitoring of student progress over the summer led to 11 of 13 students earning the necessary score on the MPA, which is far higher than the department average. Table 2 below shows a breakdown of the MPA attempts and prior math experience. The data in table 2 indicates that there might be a correlation between prior experience with advanced math in high school and how the students will perform on the MPA. Data from the upcoming years of the program will be used to validate this hypothesis.

The results of implementing this "intrusive advising" approach in the preparation for MPA was shared with the department in an effort to institutionalize this implementation. We modified the brochure we used to create a non-program specific brochure that describes why students should spend time preparing for the math placement assessment, include the economic incentive of not having to pay for a 5th year of classes. As a result, the department is putting together a committee to create a plan to communicate better about math placement and will engage with the Admissions staff about this as well.

Table 2: First cohort MPA results

MPA Exempted	*4 scholars*	*College math or AP credits*
Pass after 1st attempt	2 scholars	Pre-Calculus and AP Calculus in high school
Pass after 2nd attempt	3 scholars	No AP Calculus in high school, highest ALEKS scores among the scholars
Pass after 3rd attempt	2 scholars	No AP Calculus in high school, lowest high-school GPA

Development and offering of bridge program: We developed and offered a one-week bridge program to the scholars focused on math preparation as well as spatial visualization. In addition to developing the course content, this effort required overcoming numerous institutional hurdles relating to dorms, course approvals, and other complications that arose due to the fact that this program took place during a somewhat challenging time, logistically (i.e., the week before fall quarter starts). This program included numerous social events (e.g., a picnic), and an all-day field trip to Boeing's advanced manufacturing facility for their jumbo jets. Scholars' feedback on their overall experience in this bridge program was overwhelmingly positive. One suggestion that we will be adapting in the next offering based on the scholars' feedback will be the breakdown of the morning sessions to include more breaks and possibly a combination between math and spatial visualization activities.

Development and administration of First-Year Interest Group (FIG): The course content for the FIG seminar was developed and delivered to the 11 scholars in Fall 2019, as shown in table 3 below. The students' outcomes that were assessed during this seminar class are: 1) demonstrate an

understanding of inquiry and creative processes from disciplinary and/or interdisciplinary perspective(s). 2) articulate individual learning goals in the context of a liberal arts education and identify means for achieving these goals. 3) enhance competency in academic skills, including framing questions/posing problems, critical literacy, evaluating information sources, writing, oral communication, and collaboration. The class was graded on a pass/fail basis with a passing grade of 70%. 40% of the grade designated to class attendance and active participation since this is a seminar class. There were also six short assignments on various discussion topics that counted for 30% of the grade. Three extra-curricular assignments were also required for 10% of the class grade. These assignments were to attend and document (through a short essay submission) three out-of-class events such as a student club meeting of choice, a campus lecture or talk, and one additional event on campus or the local community. The latter event can be any of the following: another student club meeting, another campus lecture or talk, a varsity sports event, an on-campus music event, local community-based event, or any other possible options (students were asked to check with the instructor beforehand if they have any questions about the suitability of the event). The remaining class grade (20%) was designated to the student presentations focused on the National Academy of Engineering's "Grand Challenges for Engineering."

Table 3: FIG course content during Fall 2019

Week of	*Topics*
23-Sep	Introduction
30-Sep	Learning strategies
7-Oct	Group dynamics
14-Oct	Engineering disciplines, application to the major
21-Oct	Engineering careers
28-Oct	Spatial Visualization
4-Nov	Spatial Visualization
11-Nov	Winter quarter class schedules, registration
18-Nov	Engineering grand challenges
25-Nov	Engineering grand challenges
2-Dec	Student presentations

Implementation of the peer mentoring program: All scholars were paired with a 3rd-year student mentor from their prospective major. Materials were developed to provide guidance on nurturing an effective mentoring relationship, and a kick-off event was held for mentors to meet the scholars and review program logistics. Peer mentoring guidelines and expectations were shared with the mentors and mentees during the kickoff meeting. An example of these guidelines and expectations for mentors are provided in table 4 below. In their second year of the scholarship, each Scholar will also be assigned an early-career professional mentor who is a recent alum working at a local engineering company. We expect that this early-career mentoring program will strengthen connections between the department and alumni, and will expand Scholars' awareness of career pathways, and will allow mentors to gain valuable leadership and mentoring experience.

Table 4: Peer-mentors' guidelines and expectations

Guidelines	*Expectations*
• Be an active listener; clarify if you do not understand something and be inquisitive. • Be professional but humanize yourself; you do not need to be friends with your mentee. • Be proactive and reach out to your mentee. • Learn about your mentee; ask them about their background, goals, motivations, and experiences. • Accept them for who they are and tell them about the thing you have in common as you learn more about them. • Keep in mind that this peer mentoring is not only beneficial for your mentee; you will gain invaluable benefits as well, such as personal growth, leadership and coaching skills, and networking opportunities.	• We expect you to be proactive about meeting times and schedules. • We expect you to meet with your mentee at least three times per quarter. • We expect you to be prepared for your conversations by reviewing the question/discussion topic (when applicable) or preparing talk-points ahead of the meeting. • We expect you to guide the conversation between you and your mentee around the discussion topic but to leave space for other ideas as they evolve. • We expect you to take notes of what you discussed and keep a record of dates/times you met and respond to short questionnaire at the end of the quarter

Development and administration of first of two surveys: The survey instrument we are using to assess sense of belonging, identify, and self-efficacy is the SUCCESS survey from Purdue, supplemented with several questions focused on self-efficacy. We have modified the survey by adding identifiers so that we can track students longitudinally.

All 11 scholars consented and complete the first administration of the survey, as did 38 students from a matched comparison group. After isolating individuals who were first-year engineering majors, we were left with 12 comparison group students. The two groups' mean scores on composite survey factors related to self-efficacy, identity, and sense of belonging were compared using independent samples T tests. Though some small differences in group means were evident, none of these rose to the level of statistical significance. This suggests that the comparison group was well-matched, as these students' baseline levels of self-efficacy, identity, and sense of belonging were indeed closely comparable to those of the Scholars.

Looking at individual survey items rather than composite factors, Scholars had a significantly higher rating (M = 5.82, SD = 0.751) than comparison students (M = 4.50, SD = 1.168) for the item "The faculty in engineering make me feel wanted and accepted." Given that the first survey administration took place early in the fall quarter of these students' first year, this is encouraging, as it suggests a positive impact on Scholars' sense of belonging in response to the fairly limited interactions they'd had with engineering faculty up to that point.

We have begun initial planning for the second, program-specific survey that will be administered in the spring. Findings from this survey will allow us to determine the extent to which the entire first-year sequence offered to Scholars led to differential gains in their self-efficacy, identity, and sense of belonging vs. students in the comparison group.

Initial plans for institutionalization of BEES support structures: We have preliminary plans in place for institutionalizing the bridge program, the first-year seminar, and the improved communication surrounding the MPA. We plan to expand the bridge program in the coming year and invite non- scholar students to participate. In parallel with our development of the FIG seminar, a recently hired Director of First-Year Programs within the department has developed a similar seminar with our input which will first be delivered in Fall 2020; we expect this department-wide seminar to replace the FIG seminar which is being offered in Fall 2019.

Conclusion and future directions

As this was the first year of the BEES program, we have fortunately cleared most of the institutional hurdles of getting the various support structures in place, so moving forward we will be spending less time bringing new programs online, and more time improving the program and the Scholars' experience. As our first cohort will be moving on to become second-year students, we will put the specific second year supports in place, including professional mentoring. We will continue coordinating all the activities from this first year (including recruiting a new cohort of scholars, managing the various support structures and programs, and data collection) to make the following years' planning and implementation more efficient. In addition, we are planning to work with our external evaluator to develop a program-specific survey instrument and conduct our first focus groups this Spring. After these data are analyzed by the researcher and evaluator, we will have a full set of program results to disseminate.

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