Examining first-year engineering programs' impacts on sense of belonging across gender

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Introduction

This complete evidence-based practice paper examines the extent to which targeted curricular and co-curricular activities impact first-year students' sense of belonging in engineering, and whether these impacts differ by gender identity. The study used a quasi-experimental, mixed methods design wherein quantitative and qualitative data were collected from first-year student participants in a grant-funded scholarship program (Scholars – the "treatment" group), with quantitative data also collected from a matched group of first-year students who were not program participants (Comparison group). This study was a subset of a larger research project attached to the scholarship program. The project builds on prior research suggesting that affective factors including sense of belonging, identity, and self-efficacy play important yet not fully understood roles in science, technology, engineering, and mathematics (STEM) students' academic persistence and successful progression toward careers, and that these factors can prove particularly influential for individuals from groups that have been historically marginalized in STEM [1]-[6]. Prior studies conducted as part of this research project have demonstrated impacts of Scholars' math-related experiences on their developing identities [7] and found that structures associated with the scholarship program helped support Scholars' developing sense of belonging despite the shift to a virtual context that was necessitated by the COVID-19 pandemic [8]. The present study expands upon this work by specifically looking at the extent to which Scholars' sense of belonging differed from Comparison students, as well as gender-based differences in sense of belonging within both student groups.

Theoretical Framework

The theoretical framework applied in this research study and throughout the course of the larger associated research project has been referred to using the acronym SEIB to refer to the affective factors of self-efficacy, identity, and sense of belonging. In short, these factors are considered to play key roles in undergraduate STEM students' learning and development [9], and the research project has sought to understand how targeted curricular and co-curricular structures (in this case, associated with the scholarship program) mediate participating students' development across these affective dimensions. The SEIB framework draws upon social cognitive career theory (SCCT) and engineering self-efficacy research [3, 10-11], science identity and engineering identity research [1-2, 5], and research on sense of belonging among STEM undergraduates and college students more generally [1, 4, 12-13].

Overview and Rationale of First-year Engineering Program Activities

Western Washington University (WWU) is a public institution with approximately 16,000 full-time undergraduate students, 160 academic programs, and a vibrant campus community. The Engineering & Design Department (ENGD) offers three undergraduate-only engineering programs: Electrical and Computer Engineering (EECE), Manufacturing Engineering (MFGE), and Polymer Materials Engineering (PME). The Becoming Engaged Engineering Scholars (BEES) S-STEM scholarship program, funded by the National Science Foundation, provides academic and financial support to 4 cohorts of low-income undergraduate students interested in

majoring in engineering. The BEES program supports scholars for the first two years of their study at WWU.

In addition to two years of financial support, the scholarship program that provides the focal point of this study offers curricular and co-curricular supports for pre-major engineering students during their first and second years of undergraduate study. These include a summer bridge program, cohort course structure, multilevel mentoring, and social events [14]. The summer bridge program is a week-long course that all scholarship students take prior to the start of the academic year. It includes math review, hands-on projects, cohort building activities, and social events. All Scholars were enrolled in the same courses (math, physics, and engineering) during their first quarter to help support development of their cohort and were also provided with peer mentors and faculty advisors. The selection of these key activities (bridge program, first-year seminar style courses, mentoring) is supported by research suggesting the effectiveness of similar activities and structures for increasing participation and retention of students from backgrounds that are underrepresented in engineering, i.e., women, racial/ethnic minorities, students from lower-income households [15-17]. Due to logistical and budgetary constraints, the incorporation of these additional activities was limited to students participating in the scholarship program, providing the opportunity for a quasi-experimental study of impacts for Scholars vs. comparable pre-major engineering students experiencing "business as usual" conditions.

Methods

Data Sources & Student Sample

The sample in this study consisted of first-year student participants in the scholarship program (Scholars), plus a matched comparison group of first-year students who were not program participants (Comparison). Early in the fall quarter of their first academic year both Scholars and other pre-major engineering students throughout the department were invited to complete a pre survey, with entry into a gift card drawing offered as an incentive. The research study received Institutional Review Board approval and all participants completed an informed consent form at the time of their first survey administration. To create a matched group of Comparison students, individuals were identified within the pool of non-Scholar pre survey respondents who were similar to Scholars in terms of academic trajectories (i.e., planned major) as well as demographics (self-identified gender, race/ethnicity, and first-generation student status). Both Scholars and the identified Comparison students were invited to complete the survey a second time early in the fall quarter of their second academic year, thus bounding their first-year college experience with pre and post survey administrations. This process of survey data collection was repeated for each new cohort of incoming students over the course of the study. The instrument used was an adapted version of a survey developed by the Studying Underlying Characteristics of Computing and Engineering Student Success (SUCCESS) project [18-19], which includes items drawn from previously validated measures of self-efficacy, identity, and sense of belonging related to engineering [1, 11].

Unfortunately, at least in part due to impacts of the COVID-19 pandemic, response rates were lower on the post survey for both groups (and especially so for Comparison students). Because of the resulting small sample sizes within individual cohorts, three cohorts' worth of survey data (from students whose first academic years were '19-'20, '20-'21, & '21-'22 respectively) were combined before performing analyses. The total number of responses received on surveys are

shown in Table 1 below, organized by student type and self-identified gender. It should be noted that a respondent who identified their gender as non-binary was excluded from analyses because this would have resulted in a group N of 1 for this gender category.

Table I
Aggregate Count of Survey Responses by Student Type and Gender

Student Type & Gender	Count of Pre-Survey Responses	Count of Post-Survey Responses
Scholars	28	21
Female	12	10
Male	16	11
Comparison	31	11
Female	10	5
Male	21	6
Total	58	32

In addition to yearly survey completions, Scholars were invited to participate in focus group interviews during the spring quarter of each academic year. These were co-facilitated by the scholarship program's designated educational researcher and external evaluator. Discussion prompts focused on understanding the various ways in which curricular and co-curricular supports facilitated by the scholarship program impacted Scholars – both soliciting formative feedback for program improvement (evaluation) and seeking to understand how their experiences led to changes in affective factors including self-efficacy, identity, and sense of belonging (research). Because Comparison students did not have access to the same sets of activities and support structures offered to Scholars, they were not included in the focus groups.

Data Analyses

Surveys

Mean scores on the pre and post surveys were calculated for both individual items and composite factors assessing students' sense of belonging and disaggregated according to student type (scholarship participant vs. comparison) and binary gender identity. In addition, a series of independent samples t tests were conducted to assess whether any of the differences in means between Scholars and Comparison students on either the pre or the post survey were statistically significant. These t tests were conducted for all students, for women students only, and for men only.

Focus Groups

Focus group data were transcribed verbatim and coded using QSR NVivo software for the presence of both a priori and emergent codes [20]. The a priori codes included scholarship program structures and activities along with affective factors found in the SEIB framework. Matrix coding queries were then generated within NVivo to identify associations between facets of the scholarship program and particular aspects of the SEIB framework. For the purposes of this study, portions of Scholar focus group discussions that related to sense of belonging were identified and examined for connection to program activities and alignment with survey data.

Results

Looking at Scholars and Comparison students overall, differences between group mean scores on measures of belonging were minimal on both the pre and post survey except for feeling accepted in engineering, where Scholars scored significantly higher on the pre-survey. See Table II.

Table II
Composite Factors and Individual Belonging Item Scores – Scholars vs. Comparison (All)

Composite Factors & Individual Items	Scholar Mean Pre	Comparison Mean Pre	Mean Diff. Pre	Scholar Mean Post	Comparison Mean Post	Mean Diff. Post
Engineering Belonging Overall	5.49	5.05	0.44	5.46	5.12	0.34
"I feel comfortable in engineering"*	5.15	5.13	0.02	4.86	5.09	-0.23
"I am a part of engineering"	5.07	4.75	0.32	5.36	4.64	0.72
"I am committed to engineering"	5.71	5.16	0.56	5.79	5.55	0.24
"I am supported in engineering"	5.61	5.03	0.58	5.62	5.45	0.16
"I am accepted in engineering"	5.93	5.19	0.74**	5.71	5.00	0.71
Engineering Major Belonging	5.37	5.31	0.06	5.14	5.30	-0.16
"I feel comfortable in engineering"*	5.15	5.13	0.02	4.86	5.09	-0.23
"I feel I belong in engineering"	5.22	5.29	-0.07	5.21	5.09	0.12
"I enjoy being in engineering"	5.74	5.52	0.22	5.36	5.73	-0.37
Engineering Classroom Belonging	4.76	4.56	0.19	4.89	5.14	-0.24
"I feel comfortable in my engineering classes"	5.44	5.32	0.12	5.21	5.73	-0.51
"I feel that my engineering classes are large" (reversed scale)	4.07	3.81	0.27	4.57	4.55	0.03

N=28 Scholars, 31 Comparison on Pre; N=21 Scholars, 11 Comparison on Post
* Note: Item is repeated in table because it is included in calculation of both overall and engineering major belonging composite factors.
** Mean difference is statistically significant ($p < 0.05$) using an independent samples t test.

Looking at men only, differences in Scholar and Comparison group mean scores on measures of belonging were minimal on both the pre and post survey. The largest differences in group means were found on the post survey, however, none of these rose to the level of statistical significance. It is important especially on the post survey to note that the sample size is both low and unbalanced, with the number of Scholars being about double the number of Comparison students. See Table III.

Table III
Composite Factors and Individual Belonging Item Scores – Scholars vs. Comparison (Male)

Composite Factors & Individual Items	Scholar Mean Pre	Comparison Mean Pre	Mean Diff. Pre	Scholar Mean Post	Comparison Mean Post	Mean Diff. Post

Engineering Belonging Overall	5.35	5.60	-0.25	5.06	5.15	-0.09
"I feel comfortable in engineering"	5.27	5.13	0.14	4.64	6.00	-1.36
"I am a part of engineering"	4.81	5.14	-0.33	4.91	4.33	0.58
"I am committed to engineering"	5.56	5.33	0.23	5.45	5.17	0.29
"I am supported in engineering"	5.38	5.38	-0.01	5.30	5.33	-0.03
"I am accepted in engineering"	5.75	5.38	0.37	5.00	5.20	-0.20
Engineering Major Belonging	5.33	5.57	-0.23	5.03	6.06	-1.03
"I feel comfortable in engineering"	5.27	5.60	-0.33	4.64	6.00	-1.36
"I feel I belong in engineering"	5.13	5.50	-0.37	5.00	6.33	-1.33
"I enjoy being in engineering"	5.60	5.60	0.00	5.45	5.83	-0.38
Engineering Classroom Belonging	4.70	4.60	0.10	4.77	5.25	-0.48
"I feel comfortable in my engineering classes"	5.40	5.30	0.10	4.73	6.50	-1.77
I feel that my engineering classes are large" (reversed scale)	4.00	3.90	0.10	4.82	4.00	0.82

N=16 Scholars, 21 Comparison on Pre; N=11 Scholars, 6 Comparison on Post

The most noteworthy finding from survey data analyses was women Scholars scoring higher than women Comparison students on several measures of belonging related to engineering. On the pre-survey, women Scholars scored higher than women Comparison students and men students (both Scholars and Comparison) on composite factors measuring sense of belonging in engineering major, engineering classroom, and engineering in general as well as individual items assessing feelings of enjoying being in engineering, being a part of engineering, being committed to engineering, being supported in engineering, and being accepted in engineering. Several of the mean differences between women Scholars and Comparison students on pre survey items were statistically significant (see Table IV), while there were no significant differences on post survey items. Again, it is important to note that the sample size is low for both survey administrations, and especially on the post survey to note that the sample size is both low and unbalanced, with the number of Scholars being about double the number of Comparison students.

Table IV
Composite Factors and Individual Belonging Item Scores – Scholars vs. Comparison (Female)

Composite Factors & Individual Items	Scholar Mean Pre	Comparison Mean Pre	Mean Diff. Pre	Scholar Mean Post	Comparison Mean Post	Mean Diff. Post
Engineering Belonging Overall	5.68	4.56	1.12**	5.66	5.08	0.58
"I feel comfortable in engineering"	5.00	4.30	0.70	4.90	4.00	0.90

"I am a part of engineering"	5.42	4.10	1.32**	5.40	5.00	0.40
"I am committed to engineering"	5.92	4.90	1.02	6.40	6.00	0.40
"I am supported in engineering"	5.92	4.50	1.42**	5.80	5.60	0.20
"I am accepted in engineering"	6.17	5.00	1.17**	5.80	4.80	1.00
Engineering Major Belonging	5.42	4.93	0.48	5.17	4.40	0.77
"I feel comfortable in engineering"	5.00	4.30	0.70	4.90	4.00	0.90
"I feel I belong in engineering"	5.33	5.00	0.33	4.90	3.60	1.30
"I enjoy being in engineering"	5.92	5.50	0.42	5.60	5.60	0.00
Engineering Classroom Belonging	4.83	4.60	0.23	4.75	5.00	-0.25
"I feel comfortable in my engineering classes"	5.50	5.50	0.00	5.40	4.80	0.60
"I feel that my engineering classes are large" (reversed scale)	4.17	3.70	0.47	4.10	5.20	-1.10

(N=12 Scholars, 10 Comparison on Pre; N=10 Scholars, 5 Comparison on Post)

Quotes extracted from focus group transcripts suggest that activities experienced by Scholars early in their first-year sequence and prior to completing the pre survey (i.e., the summer bridge program and the cohort course structure in their first academic quarter) contributed to the differences in sense of belonging observed in the survey data. Below are several representative quotes demonstrating connections between these activities and Scholars' sense of belonging.

Summer Bridge Program:

> *I think it really helped me like get my foot in the door, like socially because I was like well it's all online and I've met no one, but by the first day of like actual classes, I was like I already know these people, and we have little jokes and stuff on. And it was not like a forced group, but like I was paired up with people who were more like me than just random people like we had, at least, you know, a couple things in common, which I really needed.* – Woman Scholar

> *Just nervous for the whole change moving off to college, that kind of stuff and think, between the [bridge program] thing and that seminar class we had with the group of us . . . It was a nice kind of way to ease into it, have somewhat of a friend group going in* – Man Scholar

> *I think that that sense of belonging, I mean, I know for me in my high school and things, I didn't really know anyone else that had an interest in engineering. And so being able to be around the other [Scholars] in that first week was really nice to know, just to be with other people that had the same interest and engagement with everything that I did. So that part was really nice and it was just like, okay, this is where you got to be.* – Woman Scholar

> *I think we all got along doing our projects pretty well and we all shared knowledge we had picked up along the way to coming to [University] and helping with CAD and all that kind of stuff. I think that really helped us feel connected. I worked together with some people just helping them out with their own projects. And so I feel that strengthened the feeling of the community in our cohort.* – Man Scholar

Cohort Course Structure:

> *I really like the seminar class . . . us as a group, I feel they get a little like closer and it was a comfortable environment for me. I'm shy and so it was a comfortable environment for me to learn to share my ideas with others and talk.* – Woman Scholar

> *Many of the people in these two classes were also in other classes with me, which really helped. Okay yeah so getting that community with folks both within that class and then in other classes that were kind of common amongst that group.* – Man Scholar

> *Oh yeah [the cohort course structure] helped because like I didn't have to make brand new introductions with people it was like oh there's [Scholar name]. . . and then we can communicate ideas and then we can be like you remember when we learned about the drawings and it was nice to like have them in the corner and they know what I'm talking about, my background with it.* – Woman Scholar

> *It's really nice to sort of ease into engineering. Not going straight into difficult physics or calculus, whatever it may be. While we did that at the same time, having that class was like a break where you got to think outside of the box and see what there is to engineering other than just the math behind it. And while that's a big part, it's not the only part. And going through those topics, made me feel like, this is a field that I belong in. I may not be the best at math or the best at physics or whatever it may be, but there are some of these topics that I think I would excel at. And that kind of made me feel less of an outsider.* – Man Scholar

Conclusion

The survey data analyzed for this study indicate that, toward the beginning of their first-year experience, Scholars (particularly women) score notably higher than comparable pre-engineering students on selected measures of sense of belonging related to engineering. Focus group data suggest one explanation for these findings, namely that participation in the summer bridge program experience and the cohort course structure (the first of which is complete before students take their pre-survey in the fall and the latter of which has been ongoing for multiple weeks by the time of pre-survey administration) are impactful on engineering students' sense of belonging, especially for women. The survey results appear to indicate that this initial "belonging boost" wanes over time, as both Scholars and Comparison women's' mean scores on belonging in the engineering major decreased over the first year while men students' mean scores on this measure increased during the same period. This might be attributed to the impact of women students' experiences as non-majority students in the department. Another interesting finding is that women Scholars' mean scores on "I am part of engineering" were higher than men counterparts (both Scholars and Comparison) on both the pre and the post survey. Again, our findings are limited by the small number of responses available when conducting gender subgroup analyses and when looking at post survey data.

This study helps us to gain insights into the women's experience in the scholarship program, specifically related to belonging, which can help to inform future work related to supporting underrepresented students in engineering. It reinforces the value of incorporating targeted curricular and co-curricular interventions early within first-year engineering students' trajectories, while also suggesting that additional activities may be valuable later on for mitigating negative climate experiences and maintaining positive impacts on effects on students' sense of belonging. Further research is needed, leveraging larger samples to both strengthen the conclusions that can be drawn from quantitative data and allow for more in-depth qualitative explorations of student experiences.

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