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Exploring the complex relationship between engineering students' math experiences and identity formation.

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Previously a high school science teacher, I am now an educational research and program evaluation specialist located in the The Center for Educational Partnerships at Old Dominion University. Though I have been involved in a wide variety of projects and initiatives, common threads throughout my work have included STEM teacher professional development and broadening participation in STEM among individuals ranging from elementary school all the way through to higher education.

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Andrew G Klein (Professor)

Exploring the complex relationship between engineering students' math experiences and identity formation.

Abstract

This paper shares the experiences of a group of S-STEM scholarship students as they progressed through their first year of undergraduate mathematics education including a math placement exam, a math focused bridge program, and calculus course(s). In addition, connections between student experiences and their math identity development were investigated with the goal of better understanding math identity formation.

The authors used a mixed-methods approach to explore the math-related experiences of 12 students over the first year of participation in an NSF-funded S-STEM program. Data includes answers to select survey questions and transcripts of student focus groups. First, each student case was examined to see if/how their responses to math-related survey items changed between pre and post survey administrations. Of particular interest were responses to a math-identity related item, "I see myself as a math person." Along with this, transcripts from focus group interviews were reviewed for quotes from these same students related to their math experiences, skill development, sense of math identity, and efficacy. Most students' responses to the math identity survey item either remained the same or changed only slightly however, students' focus group reflections on their math experiences were wide-ranging. The results of this study provide initial evidence that the summer bridge program is a positive experience for students, but the math placement exam is a barrier to the development of positive math identity, especially for underrepresented students.

Background

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 Plastics & Composites Engineering (PCE). 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 the scholars for the first 2 years of their study at WWU. Cohorts are small (12 max) and students are supported through a series of co-curricular and curricular elements including a math intensive summer bridge program, cohort course structure, multilevel mentoring, project opportunities, and social events (Alqudah, Litzler, Brobst, Davishahl, & Klein, 2020).

This paper examines the math-related experiences of the BEES scholars as they progressed through the program. One goal of the BEES program is to provide support structures that positively impacts student math skills and identity development. Students' experience with math is directly connected to their likelihood of success in engineering, as math identity has been shown to be an important predictor of engineering career choices (Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011; Godwin, Potvin, Hazari, & Lock, 2016). More broadly, there is an extensive

body of research tying secondary and postsecondary students' identity development to their interest, persistence, and success in STEM academic and career pathways, especially for individuals from groups traditionally underrepresented in STEM like females and students of color (Calabrese Barton, Kang, Tan, O'Neill, & Brecklin, 2013; Carlone & Johnson, 2007; Chemers et al., 2011; Gushue, Scanlan, Pantzer, & Clarke, 2006; Kim, Sinatra, & Seyranian, 2018).

In terms of student support structures, participation in both general and math-focused summer bridge programs is associated with increased rates of retention among STEM undergraduates (Gleason et al., 2010; Tomasko, Ridgway, Waller, & Olesik, 2016). What is not well understood are the ways in which bridge programs and other math-related support structures promote student retention and success vis-à-vis their math identity. This study addresses this gap using a mixed-methods approach, assessing how BEES students' math-related experiences have impacted their math skill development, sense of math identity, and efficacy.

Math Components of BEES

The math components of the BEES project consist of a series of elements targeted at supporting and guiding students through their math experience at WWU. All students enrolled in the BEES program must take calculus during their first academic quarter. Therefore, all entering students must place directly into calculus or pass the Math Placement Assessment (MPA) prior to the start of fall quarter. All scholars who are required to take the MPA are given detailed information about the test when they are accepted into the BEES program. The scholars are then connected with an engineering department faculty member who provides them with support and guidance as they prepare to take the MPA. The faculty member checks in with the students as they progress through the MPA process and offers additional support to students who do poorly on the practice exams and/or do not pass the exam on their first attempt. By a pre-determined deadline, students who do not pass the MPA are no longer eligible for the scholarship and are dropped from the program. Prior to the start of the fall quarter, all scholars are enrolled in a math focused bridge program designed to prepare students for their first calculus course and begin to cultivate a sense of community. The scholars then enroll in the same section of calculus and receive continued support from the instructor, department faculty (mentoring), and their peers (study groups).

Data Analysis

The data analyzed as part of this study consist of surveys and focus groups. The survey was administered in fall quarter of each academic year. Survey questions assess sense of belonging, identity, and self-efficacy. For this study, focus was placed on student responses to the question related specifically to math identity: "I see myself as a math person." Each student case was examined to see if/how their responses to the math-related survey item changed between pre and post survey administrations. In addition, all scholars participated in at least one hour-long focus group during spring quarter 2020 or 2021 (4 students from the first cohort participated both years) where they were asked questions related to their experience in the program. The meta evaluation question for the focus group was "To what extent do the interventions improve students' communication, math, calculus-readiness, and research skills." More specifically,

students were asked questions that assessed the impact of the interventions and supports on the development of their math skills and identity. Focus was placed on their experience with the MPA, the bridge course, and the first calculus course. All data gathered and utilized in this study follows approved IRB guidelines and protocols.

Due to the small sample size, quantitative analysis was limited to descriptive statistics – calculating the pre-post change on each Scholar's response to "I see myself as a math person" as a measure of math identity. Focus group recordings were transcribed verbatim, and transcripts coded to identity student references to math-related feelings or perceptions or to specific math-related program components (i.e., MPA, bridge program, calculus courses). Student case summaries were created by coupling together these math identity scores and student descriptions of their math-related thoughts and experiences.

Results & Discussion

Table 1 summarizes the demographic information and math progression and identity data of the scholars featured in this paper. Math identity change scores reflect scholars' pre survey score subtracted from their post-survey score. The identity item used a 7- point scale, where 7 indicates strong agreement with the statement "I see myself as a math person." Note that each scholar is given a number and will be referred to by that number in the remainder of the paper. For those students who completed the MPA, the number of attempts to pass is indicated. All scholars included in this paper were from the first two BEES cohorts, and each individual completed both a pre and post survey and participated in a focus group interview.

Table 1: Scholar demographic, math progression, and identity data

Scholar #	Gender Identity	Under-represented	Math Placement	Math Identity Change	Major
1	F	Yes	Direct	-2	EECE
2	M	Yes	MPA – 3x	-1	PCE
3	M	No	Direct	-1	PCE
4	M	No	MPA – 2x	-1	EECE
5	M	No	Direct	-1	EECE
6	F	No	Direct	-1	EECE
7	M	No	Direct	0	PCE
8	F	No	MPA – 1x	0	PCE
9	M	Yes	MPA – 3x	0	MFGE
10	F	No	MPA – 1x	0	MFGE
11	M	No	MPA – 2x	+1	MFGE
12	F	Yes	Direct	+3	PCE

In conducting the analysis of the survey questions and focus group transcripts, the researchers focused two research questions: 1. Do the BEES interventions help to improve student math skills? and 2. Do the interventions positively impact student math identity? The results of the

data analysis suggests that the answer to these questions depends on the specific student, prior knowledge, and unique set of experiences. Half of the students included in the present analyses showed a decrease in their math identity score, while the other half's scores either increased or remained the same. Shared below are student quotes selected to highlight experiences that stood out as being particularly impactful and of potential influence on students' math identity. While the study did not provide conclusive evidence that the BEES program supports accomplish what was intended, examining specific student experiences allows the project team to understand the more nuanced implications of the interventions. Gaining understanding of individual experiences allows for the purposeful structural adaptation of the program to better serve and support the diversity of student needs, experiences, and prior knowledge.

Experiences with the MPA

Only half of the students included in the present analyses had to complete the MPA (See Table 1). Focus group comments specific to the MPA were limited in number, but those students who chose to share their experience viewed the experience negatively. Student 4 said "I think the studying by yourself aspect was difficult, along with the system of jumping from subjects, trig to geometry, etc., which hurt comprehension." Student 2 was much more detailed in regards to his experience: **"**That was probably the hardest thing in my life to do. It was absolutely abysmal. But like I'm glad that I got it done . . . it was just me really grinding out in a room for up to four hours . . . Like, my brain would hurt and then I go back to work with my brain on fire . . . to put it plainly, it was very stressful and I hated every moment, every moment of that, sitting down was stressful but I was motivated because I really wanted to get the scholarship."

Experiences with the Bridge Program

As described above, the summer bridge program was math-focused and was intended to build cohort connections and help prepare students for their first calculus course. Several students felt that the bridge program achieved this goal: Student 9 stated "It did definitely help because a majority of us were going into Calc one, and that was pretty much just review for Calc one" while Student 12 described the program as "a bit of a good review from like having a full summer and also the quarantining from school for a while." In contrast, Student 1 saw the program as a good community-building exercise but not necessarily a positive math learning experience: "I liked the review, but it was more like tedious work that just wasn't, I just wasn't enjoying it, but I did like the [bridge program] as like getting to know other people and stuff, but not really much of like what I was there to learn." Multiple students focused their comments on the bridge program's value as a transitional experience, like Student 4 who felt it was "a really good foothold and like an introduction to like college classes and how you would expect things to go" and Student 3 who described it as a "wakeup call to get ready for school."

Experience in Calculus Coursework

Half of the students included in the present analyses provided focus group comments related to their experience in calculus, with a mixture of sentiments. On the positive side, Student 5 said "the coursework is manageable at the moment, for the time being I guess" while Student 8 commented "There's been like a few bumps in the road along the way, but at the moment I'm

feeling pretty confident." Student 1 shared a similar view, saying "I'm pretty, I'm okay on my math level. I'm pretty confident." At the same time, Student 1 expressed a bit of uncertainty looking forward: "When I need to apply it then I'll remember all the things and I'll remember the processes and stuff but I'm not gonna remember everything." This theme of current confidence but forward-looking trepidation was also evident in Student 10's response: "I'm also done with math, my math classes and those requirements and I'm kind of worried about how, about the applied, later on, but I'm pretty confident in just the technical area."

Student Experience and Math Identity Connections

Based on our currently available data, it seems plausible that students' experiences with math-related aspects of BEES contributed to changes in their math identity. That said, the nature of these connections appears variable both within and across students. Student 1 had the greatest decrease in sense of math identity from pre to post survey, which seems to align with her negative view of the math-related aspects of the bridge program and her mixed feelings toward calculus coursework. Similarly, students 2 and 4 both showed decreases in their sense of math identity over the first year of the program and both described negative experiences with the MPA during their focus group. In spite of this, Student 4's comments on the bridge program were quite positive, as were those of Student 3 (whose math identity score also decreased). On the opposite end of the spectrum, Student 12 showed the biggest increase in math identity score and, while her comments about the bridge program were positive, there was little else in her focus group responses to suggest reasons behind this increase.

Conclusion & Future Work

The relationship between student math related experiences and the development of their math identity is complex. By asking individual students to share their experiences, we can learn more about how particular interventions support or inhibit their success and development. In this study, the math placement exam was largely viewed as a negative, stress-inducing experience for students. The bridge program seemed to have a positive impact on most students and was valued just as much for its cohort development and transitional support as it was for the math-related content. Students experience in their calculus courses was mixed. On the one hand, calculus seemed to help them gain confidence in their technical competence however some students were uncertain about retention of knowledge and struggled to connect the technical content to application. With regards to the first research question (Do the BEES interventions help to improve student math skills?), the results are inconclusive. Although not included in the data presented above, we did investigate student progression and GPA in calculus but did not find any correlation between success in particular math courses and any particular BEES support. This would be worth digging into more in the future. Regarding the second research question (do the interventions positively impact student math identity?), results were mixed and how student identity was impacted by interventions really depended on the particular student.

We have reflected on the program support structures as they currently exist and recognize that they could be improved to better meet the project goals of supporting student math skill and identity development. The MPA experience can be extremely stressful for students, especially students who have not had positive experiences with math in the past. Eliminating the

requirement that students pass the MPA to enter the BEES program both reduces barriers for entry to the program (and eventually, engineering) and increases opportunities for students who have not have positive math experiences. Another option worth exploring is creating faculty supported cohort support groups for all students who take the MPA. The bridge program could be improved by creating modularized curriculum that meets students where they are in their math journey by providing them with a flexible learning structure capable of supporting their unique needs. These elements would likely lead to improved experiences in calculus since students would be more prepared and have a stronger math identity coming into their first calculus course. In addition, more tailored and flexible support along with increased access into engineering could potentially help to broaden participation and diversify the workforce.

By examining the experiences of individual students, we can begin to understand the complex relationship that exists between student prior knowledge, current experience, and development of skills and identity. It is not enough to simply create a support structure and assume it will work for all students. We must be flexible, adaptable, and be willing to make modifications to the program structure to support an array of student needs.

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