A Cohort Scholarship Program that Reduces Inequities in STEM Retention

Ryan D. Sweeder, Merve N. Kursav, Sean A. Valles
Michigan State University

Abstract

Lyman Briggs College is a small residential college within Michigan State University, devoted to preparing students for STEM careers via preparation in the biophysical sciences that is paired with the humanistic and social scientific study of science and sciences humanistic and social dimensions. This paper reports and interprets the quantitative outcomes of an ongoing NSF-sponsored S-STEM project, begun in 2009, seeking to improve STEM retention in the college via a combination of scholarships and cohort-based curricular and co-curricular activities. The program supported scholars in their second through the fourth year. In examining the over 90 participants against a comparison population (eligible students who did not participate in the program), there was no statistical change in graduation rates from Michigan State University, though there was a statistical increase in retention in STEM majors. Moreover, the program has shown success in closing some inequitable STEM retention gaps between demographic groups with more or less social privilege (especially students with high financial need and students with low pre-college math preparation), while not closing others (for underrepresented racial and ethnic minorities).

Introduction

Lyman Briggs College (LBC) is a small residential college within Michigan State University (MSU), devoted to preparing students for STEM careers via preparation in the biophysical sciences that is paired with the study of the historical, philosophical and sociological dimensions of science. As such, the college is heavily invested in the dual concerns expressed by numerous STEM education institutions of (1) supporting students in order to retain STEM majors through college and into the STEM professions and (2) ensuring that students from socially marginalized and underrepresented demographics are fully included and welcomed into STEM broadly. The Scholarship Program for Retaining, Inspiring, and eNabling Graduates (SPRING) Project began in 2009 as an effort to primarily achieve concern 1 and then transitioned in 2016 to more intentionally achieve address concerns 1 and 2 together.

National Context:

STEM professionals are needed more than ever. According to economic forecasts, the country may face a workforce deficit in STEM majors unless college graduation rates are improved (Olson & Riordan, 2012). Yet even as the number of students in STEM fields is trending upward, high rates of attrition from STEM have kept the STEM workforce from growing faster (Hurtado, Eagan, & Chang, 2010). In fact, according to The President's Council of Advisors on Science and Technology (PCAST) report (2012), fewer than 40% of students intending on majoring in STEM fields at enrolment received their degrees in STEM. More worrying is that the students who leave STEM majors are typically high-performing students who could have been capable of entering the STEM workforce (Seymour and Hewitt 1997; Lowell, Salzman, Bernstein, & Henderson, 2009). These data are problematic for multiple reasons: (1) ensuring a STEM workforce, including by reducing avoidable departure rates, is a matter of public interest (Watkins, Mazur, 2013), and (2) beyond STEM workforce needs, an equitable undergraduate institution should strive to make educational success achievable for all admitted students taking STEM courses.

Seymour and Hewitt (1997) identified that most of the students leaving from a STEM field do so in the first or second year of enrollment (King, 2005). Women, underrepresented minorities, first-generation students, students with low income (Anderson & Kim 2006; Hill, Corbett, & Rose 2010; Griffith 2010; Huang, Taddese, & Walter 2000; Kokkelenberg & Sinha 2010; Shaw & Barbuti 2010) and students with weaker academic preparation (Astin & Astin 1992; Kokkelenberg & Sinha 2010; Mendez, Buskirk, Lohr, and Haag, 2008; Shaw & Barbuti 2010; Whalen & Shelley 2010) leave STEM fields at elevated rates. Research has also shown that completing STEM degree requirements take longer than other degrees, making financial support even more important for STEM student retention compared to the retention of students in other fields of study (Fenske, Porter, & DuBrock 2000; Whalen & Shelley 2010). Other factors also depress STEM retention such as the quality of teaching in higher education institutions, lack of interaction and communication between faculty and students (e.g., Watkins & Mazur, 2013; Seymour & Hewitt, 1997), and lower sense of belonging (Marra, Rodgers, Shen, & Bogue, 2012).

As Chen (2013) points out, there are large disparities in which groups tend to depart from STEM degree programs. Among bachelor's degree STEM entrants, more females switched to non-STEM fields than males (32% and 26% respectively), even though males overall drop out of college more often than females (24% and 14% respectively). First-generation students and students with lower-income backgrounds leave STEM fields by dropping out of college at higher rates: 25% of Pell Grant recipients drop out of college, compared to 18% of non-Pell Grant recipients (Chen, 2013). However, providing solely financial support is not a solution. As an example, although high school graduates in Georgia were provided free tuition and book allowance through the HOPE (Helping Outstanding Pupils Educationally) scholarship program, most of the HOPE scholars lost their support at the end of the first year because of lack of academic support (Dee & Linda, 1999; Vickers, 1994).

These trends have impacted how the National Science Foundation (NSF) has shaped its Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM). The program's goals respond to the problems described above. "Recognizing that financial aid alone cannot increase retention and graduation in STEM, the program provides awards to Institutions of Higher Education (IHEs) to fund scholarships and to advance the adaptation, implementation, and study of effective evidence-based curricular and co-curricular activities that support recruitment, retention, transfer (if appropriate), student success, academic/career pathways, and graduation in STEM." (NSF, 2017). This NSF shift in objective has led to a growing body of literature examining the success of these programs (e.g., D'Souza, Shuman, Wentzien, Roeske, 2018; Kalevitch, Maurer, Badger, Holdan, & Sirinterlikci, 2015).

Local Context

According to the MSU Student Success Annual Report (2018), MSU has a relatively high six-year graduation rate among its peer institutions, 81%, but substantial racial and ethnic disparities exist within that rate. These

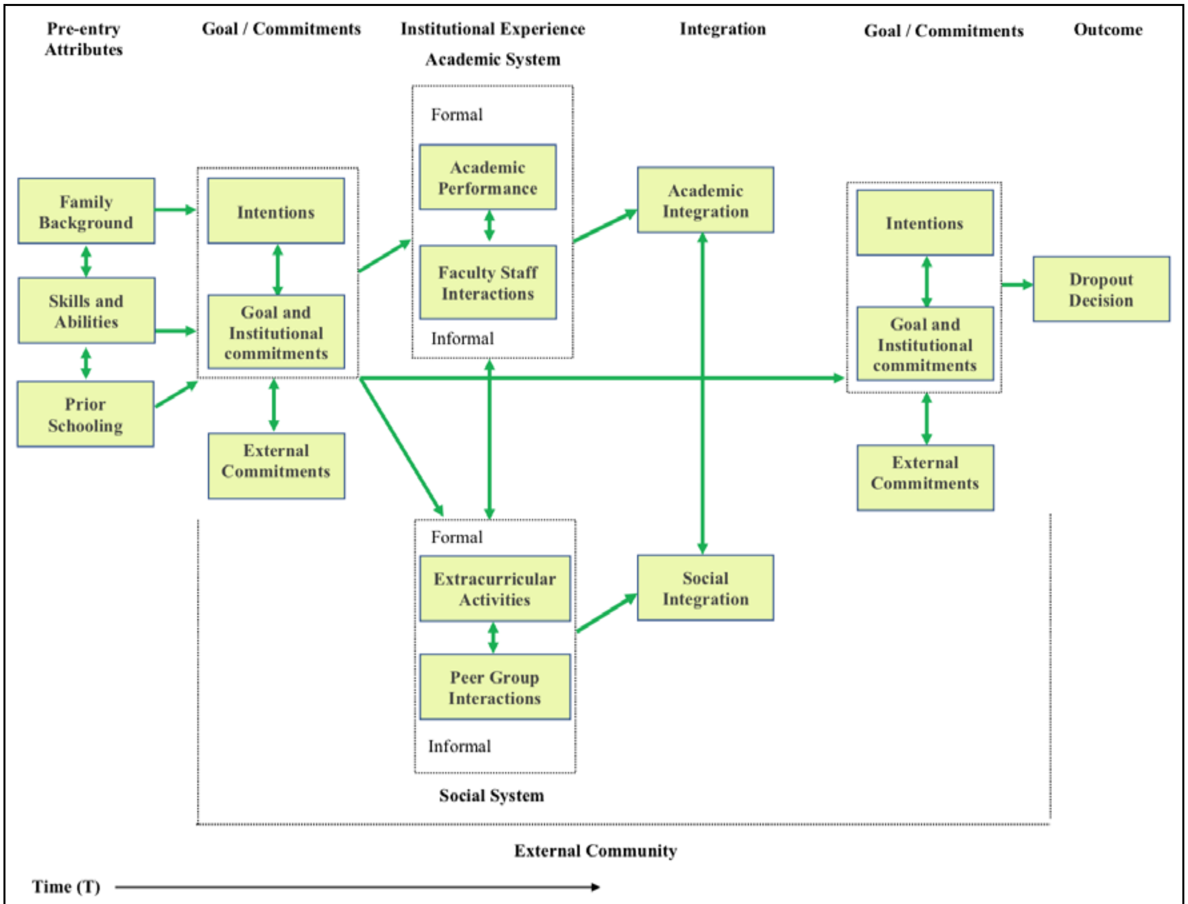


Figure 1. Conceptual Framework Schema adapted from Tinto (1993)

gaps include lower six-year rates of graduation among students receiving Pell grants (71%), as well as among Black/African American students (66%) and Hispanic students (65%), in contrast to White students (82%) and Asian American students (84%). These graduation rates are above the national averages for four-year public institutions, though key between-group gaps still differ from national averages: Black-White (16% MSU gap vs. 21.9% gap nationally) and Hispanic-non-Hispanic White (17% MSU gap vs. 12.3% gap nationally: Shapiro et al., 2017).

MSU STEM undergraduates are spread between multiple colleges (including Natural Science, Agriculture, and Natural Resources, and Social Science). Among those STEM colleges, Lyman Briggs College is a single-building residential STEM college that houses dormitories, classrooms and faculty/administration/advising offices, providing a sort of hybrid liberal arts-research university experience for students (who take a portion of their courses in the building other courses elsewhere on campus). In its curriculum, Lyman Briggs College is committed to preparing students for STEM careers via preparation in the biophysical sciences, as well as complementary education in the history, philosophy, and sociology of science (Sweeder, Jeffrey, & McCright, 2012).

Lyman Briggs College has an especially high STEM graduation rate (including students who matriculate into MSU then transfer to another STEM major within MSU) with 86% of students graduating within six-year and 73% with STEM majors (MSU Internal report, 2019). However, recognizing that there is still significant room for improvement, college faculty developed the Scholarship Program for Retaining, Inspiring, and eNabling Graduates (SPRING) Program. The aim of this NSF-funded program was to support a subset of STEM students who had a demonstrable financial need with scholarships and an academic support program designed, in part, to facilitate career exploration. The research questions and goals of this program are discussed below.

Conceptual Framework

We interpret the project's persistence findings via the theoretical framework offered by Tinto's Theory of Student Persistence (2017) and Departure Theory (1993). Essentially, student non-persistence can be understood as reactions to student's perceptions of the match (or mismatch) between their personal attributes and the expectations of the institution. For example, students who judge themselves as having low or middling math skills will then reflect on whether their academic program appears to support students with such skill levels; if not, the student might conclude that they cannot meet the expectations of the program and decide to drop out. This creates enduring equity problems because, as noted above, socioeconomic circumstances have very large effects on both students' preparation (e.g., race and class gaps in quality of college preparation in secondary schools) and their self-assessments. E.g., first-generation college students tend to have a harder time determining what the academic expectations are and how to achieve them in an unfamiliar and opaque new type of institution (Cataldi, Bennett, & Chen, 2018).

SPRING: A Cohort Model for Enhancing Support of STEM Career Pathways

The development of the SPRING program was built upon the underlying ideas of Tinto's (1993) departure theory (Figure 1). Within this context, there are several factors influencing students' decisions that a college level intervention can address (e.g. the institutional experience) whereas there are some that are already established prior to reaching college (e.g. pre-entry attributes). Building on the idea that small learning communities can provide highly personalized structure and support to students shape students' relationship with the institution (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2019), the SPRING program provides more than scholarships to students over three years. The SPRING program simultaneously employs a set of cohort-based experiences designed to help the students form the sorts of strong connections to the institution that would provide a sense of belonging and prevent departure. Further, the interpersonal connections with other scholars and faculty were designed to help build a support network to promote resilience to overcome the various challenges that arise during students' time in the college. The SPRING program sought out participants with strong academic potential and demonstrable financial need who would otherwise be at high risk of departure. Accordingly, the program included a variety of activities designed to help students connect to university resources or otherwise navigate the challenges that students face as they progress through their undergraduate degree program, challenges that could be especially daunting to first-generation students (e.g. identifying and pursuing graduate school options). In addition, the program engaged students in a variety of career exploration opportunities, often by connecting them with practicing scientists, in order to help them not only develop their knowledge about

Math Placement	Year 1		Year 2		Year 3		Year 4	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Low (INQUIRE)	INQUIRE, General Ed Classes	Chemistry 1, General Ed Classes	Chemistry 2	Major Courses	Major Courses		Major Courses	
High	Chemistry 1, General Ed Classes	Chemistry 2, General Ed Classes	Major Courses		Major Courses		Major Courses	

SPRING Program					
Academic Required Courses					
Intro Seminar		Science and the Public		Capstone Class	
Scholarship Support					
$3000		$6000		$9000	
Program Objectives					
Individual academic advising every semester Professional development Optional individual learning experiences (supported by $1000) Interactions with practicing scientists Career option exploration Faculty mentoring					

Figure 2. Overlay of SPRING program and typical student courses

potential career options but to help them develop their individual identities as scientists (Carlone and Johnson 2007; Sweeder and Strong, 2012, 2013).

The structure of the cohort-based SPRING program is depicted in Figure 2. The program supports the students through several different mechanisms. Students apply in the spring semester of their first year and then participate in their 2nd-4th years at the university. Financially, scholars are supported by a scholarship that increases from $3000 in their first year in the program to $9000 in their third year. Academically, students are required to complete one course each year of the program with their cohort peers. The first course is a 1-hour a week seminar course designed to begin building the cohort and explore university resources and career options (Sweeder and Strong, 2012). The second and third courses are special sections of college-required courses, tailored to specifically address the development of scholars' self-identities as scientists and explore career options (Figure 2). In the "Science and the Public: What Kind of Scientist Do I Want to Be?" course students studied the humanistic and social scientific complexities of science, with an eye toward exploring the range of different ways that each student could fit into the scientific enterprise. For example, students read examples of 'activist science' (e.g. the public health scholars advocating for gun control) and ethical literature on the debate over whether and scientists ought to relate to activism. The final project for the course required interviewing a scientist who works in an area that interests the student as a potential career, as well as doing additional research into the ethical/ social complexities of the field (e.g. current debates in the field about methods and priorities). In the senior capstone course, the cohort was directly involved in the development and construction of the course focus and content, thus each offering has been unique. Cohorts have focused on one or more core themes including science communication, science education, gender and racial disparities in science, and ethics in science. The class invariably focuses on students connecting these concepts to their own individual experiences and future career paths. The students also meet at least once per semester with an academic advisor who helps students choose and pursue their long-term career plans. Using an intrusive approach to advising (Jeschke, Johnson, & Williams, 2001), the advisor proactively probes students about academic and career plans and provides incidental information on the relationship between course selection and career options. These meetings help gauge student progress toward degree and ensure that they are using all available resources. Each year, students are expected to engage in one or more field trips to observe science being practiced in a variety of settings. These trips both strengthen the cohort through common experiences but allow students to meet with practicing scientists in a wide range of different careers.

Research Questions

In this paper, we investigate two research questions:

1. What is the overall impact of the SPRING program on STEM retention and graduation rates?
2. What are the differential impacts of the SPRING program on graduation and retention outcomes for students with diverse profiles (e.g., math placement score, gender, first generation status, Pell eligibility)?

Methods

The research questions outlined above necessitate quantitative methods to identify the degree of success of the program. In order to understand the impacts of this SPRING program, it was necessary to compare the outcomes of the scholars to other students in the college who did not participate. In this manner, the others in the student body can provide a comparative baseline for considering the outcomes of the SPRING program. This research was approved as exempt (X10-543e) by the MSU Human Research Protection Program (IRB).

Data on students' outcomes was obtained through the MSU Office of the Registrar. Data was obtained for all students who matriculated between Fall 2007 and Spring 2018 and were enrolled in LBC. For all such students, we requested demographic information including Pell eligibility, self-reported gender and ethnicity, first generation status, and semester-by-semester data about majors and GPA. Using the Department of Homeland Security STEM Designated Degree Program List (US Department of Homeland Security, 2016), we identified if each student's primary major indicated that they were in a STEM or non-STEM field. We also eliminated students whose first-semester enrollment was not in fall term, as these students likely had non-traditional paths. We also backfilled semesters for students who took a temporary leave of absence using the major code associated with the semester that they returned. For students who earned an advanced degree at MSU (e.g., a Doctorate in Veterinary Medicine) without completing their undergraduate degree, we determined their STEM or non-STEM status based on their advanced degrees. In determining a time to degree, each semester (fall, spring, summer) was counted as one-third of a year consistent with the National Student Clearinghouse Research Center methodology (Shapiro, 2016).

The quantitative data were analyzed using IBM SPSS Statistics Version 25 (IBM SPSS, 2017). For all analyses, the comparative population included students in the residential college who were eligible to have applied for the program, meaning that they remained in the residential college into year two and maintained a suitable college GPA. Additional restrictive criteria, such as first generation or Pell eligibility, were employed for analysis of subpopulations.

Results and Discussion

In order to address Research Question 1 (RQ1), understanding the impact of the program on relative graduation and STEM retention rates, we compared the spring scholars to other eligible to apply students. The six-year graduation rates of students who participated in the program is numerically, but not statistically, higher (95% vs. 92%, ($X^2(1, N= 2681) = 1.21$, $p>.05$ via z-test of proportions)). For the more recent cohorts that matriculated less than six years ago, their six-year graduation rates cannot be calculated yet. However, similar patterns existed within the four-year and five-year graduation rates. When comparing STEM retention, we observed that students participating in the SPRING program were more likely to remain in a STEM major: 94% of SPRING students remained in STEM at MSU at the end of their 4th year whereas 82% of non-SPRING students were still in the STEM field (($X2(1,N= 3581)= 8.21$, $p<.05$ via z-test of proportions).

Research Question 2 (RQ2) was designed to help determine how the SPRING program influenced the gaps that exist between different groups of students. More specifically, we investigated if SPRING helped to narrow achievement gaps or if it exacerbated those gaps by increasing average success but widening disparities between groups. The STEM retention data holds for both the students who entered MSU with low math placement scores as well as those with higher math placement, which starts to address RQ2. More importantly, the STEM retention gap between students with high financial need and lower financial need or between students with low incoming math placement scores and those with higher math placement scores are decreased among students participating in the program. Together these results suggest that not only does the program provide benefits for all students, but that there are more of the gains among students typically from more disadvantaged groups. These results and their impacts will be discussed in more depth in the sections below.

Graduation Rates

As indicated above, the six-year graduation rates are slightly higher for SPRING participants in the first four cohorts (2009-2013) than for the comparison population (95% vs. 92%), but the difference is not statistically significant (RQ1). The reason both groups' graduation rates are so high is in part because our analysis involves only students who were still STEM majors at the beginning of their second year; it excludes any students who departed MSU or at least a STEM major during/after their first year, a time point when many students leave STEM (Seymour and Hewitt 1997).

We interpret the statistical equivalency of the SPRING vs. comparison group graduation rates as a desirable outcome because all of the SPRING participants demonstrate significant financial need, which is a risk factor correlated with lower probabilities of successfully completing a degree (Scott-Clayton, 2015). This may be a benefit of the program in helping to decrease the graduation gap between students with financial need and those without. Yet, the graduation data alone does not provide evidence of any potential mechanism by which the intervention is operating. For example, the departure-preventing effect may be the result of the scholarship component (the students received $18,000 distributed over the three years of the program) or could be the result of having a supportive cohort that provides resources or encourages persistence. Comments provided by the students indicate that they value both the financial and academic/social support provided by the program. Thus, further research is necessary to understand what aspect(s) of the program are most critical for the observed results.

STEM Retention

As RQ1 suggests, graduation rates are not the only measure of success for the program, as the goal is to support students in pursuing STEM degrees in particular. For this reason, we focus on the STEM retention effects of the program. These outcomes are also where the largest impacts of the intervention can be seen. 94% of the scholars remained in STEM at the end of their fourth year compared to 82% in the comparison group (see Figure 3, ($X^2(5, N= 3033) = 22.08$, $p<.05$ via z-test of proportions)).

As discussed above, both the SPRING scholars and the comparison group were enrolled in STEM majors at the beginning of year 2 (after the very common departure point from STEM majors: the first year). This, in part, leads to the high retention rates within both groups. It also makes the statistical gains for the program participants even more surprising given that there is little room to demonstrably improve the STEM retention rates in this sample population.

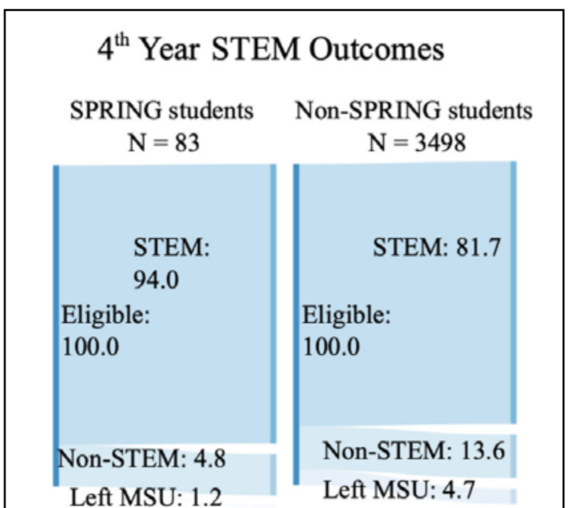


Figure 3. Student field based on major at end of 4th year SPRING scholars (left) and eligible to apply, but non-SPRING scholars (right).

Financial need

Financial need is a core component of the SPRING program, so to address RQ2, it was natural to try to understand how the program specifically impacted those students who exhibited the greatest financial need as defined by their eligibility for a federal Pell grant. Considering only those students in the matriculating classes from 2008-2013 who would have been eligible to receive the scholarship, we observe that among those students who were not Pell-eligible, the rate of earning a STEM degree within 6 years was 92% for the scholars with a statistically equivalent 81% of the non-scholars similarly earning a STEM degree ($X2(2, N= 1650)= 2.4$, $p< .05$ via z-test of proportions). Whereas for the Pell-eligible students, the gap between the scholars and non-scholars was 23% (95 vs. 72%) with the difference becoming statistically significant ($X^2(2, N= 523) = 10.7$, $p<.05$ via z-test of proportions). These results suggest that the greatest benefits in STEM retention are being accrued by those exhibiting the greatest financial need.

Impacts on students with low math placement scores

Understanding the differential impacts of the SPRING program on students with different profiles (RQ2) requires parsing the data more carefully. Low math placement students are known to leave STEM at a disproportionately high rates (NCTM, 2016), which holds true in our population (Sweeder et al, 2019). This is in part because of the importance of math skills in science courses and because math placement scores are associated with social resources such as access to well-resourced high school math programs (NCTM, 2016). For this reason, it is particularly interesting to understand how the SPRING program may impact these students versus their peers with stronger mathematics backgrounds. In 2009 the college developed a first-year intervention program (INQUIRE—Instilling Quantitative and Integrative Reasoning) aimed at increasing the success of incoming students with low math placement scores (Simmons and Sweeder, 2016; Sweeder et al, 2019). INQUIRE is a first-year program that focuses on helping students transition into college with a modified schedule of introductory STEM courses. From 2009-2015, all first-year students in Lyman Briggs College were eligible to apply for SPRING and a few INQUIRE students went through the SPRING program. However, starting in 2016. The

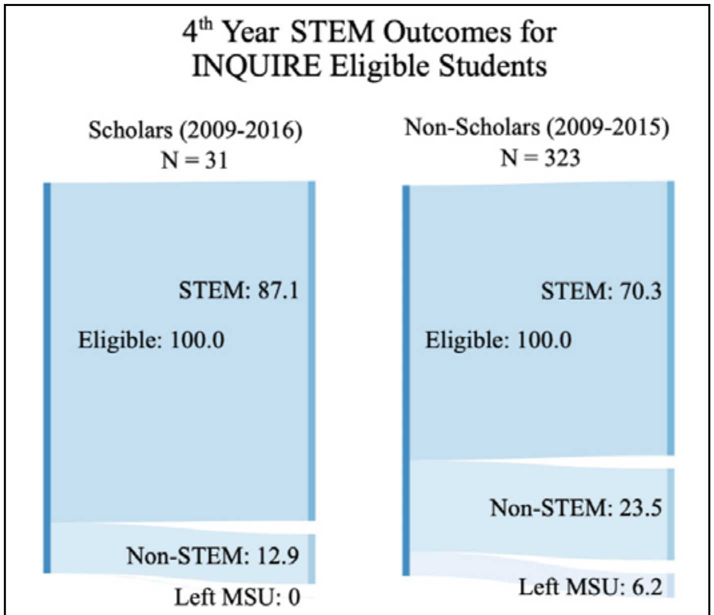


Figure 4. Students' major at the beginning for students with low-math placement scores separated by SPRING participation (left) and eligibility but nonparticipation (right)

	N	6-year graduation rate	Percent of students earning STEM degree in 6 years
First generation, non-SPRING	438	89%	70%
Not first generation, non-SPRING	2107	93%	80%
First generation, SPRING	25	88%	84%
Not first generation, SPRING	40	100%	100%

Table 1. Six-year graduation deficit of first-generation to non-first-generation students

	N	Graduation	STEM grad	N for 4-year STEM retention	4-year STEM retention
Non-SPRING NHW	2434	92.7*	79.0%*	2773	82.8%
Non-SPRING URM	283	82.3%	60.8%	330	69.7%
SPRING NHW	51	98.0%*	98.0%*	61	100%
SPRING URM	14	85.7%	78.6%	17	77.3%

†Underrepresented Racial and Ethnic Minority (URM) includes all students who self-identified their racial or ethnic identity as something other than solely Non-Hispanic White (NHW). Not included in this analysis are students who self-identified as Asian, as international, or who did not report these data.

Table 2. Underrepresented Racial and Ethnic Minority (URM) Students† and Non-Hispanic White (NHW) Student Graduation and STEM Retention, in Percent

SPRING project shifted its pool of eligible students to only including the students who participated in the INQUIRE program.

To explore the impact of SPRING on students with lower math placement scores, we separately compared the outcomes for the INQUIRE students who participated in the SPRING program to those who did not. Figure 4 shows that the STEM retention rates at the beginning of a student's 4th year are higher for the SPRING Scholars than other eligible students (87 vs. 70%) with low math placement scores (($X^2(1, N=353)= 3.983$, $p<.05$ via *z*-test of proportions). This 17% increase in STEM retention rates was higher than the 14% difference exhibited by the students with higher initial math placement scores. This suggests that the STEM retention impacts of the program are at least as beneficial for students with lower initial math placements as their counterparts.

First Generation Students

We also examined how the program influences the outcomes of first-generation students (RQ2). Considering only those students who matriculated in 2008-2013, we note that first-generation and non-first-generation students benefited differently from SPRING. First-generation SPRING students seemingly *did not* experience any gains in their graduation rates relative to non-SPRING first generations students (88% for SPRING and 89% for non-SPRING, Table 1). However, first-generation SPRING students *did* experience gains in terms of continuing in STEM rather than departing STEM to graduate with a non-STEM degree (84% for SPRING and 70% for non-SPRING).

Underrepresented Racial and Ethnic Minority Students

To better understand SPRING's impact on outcomes for racial and ethnic groups (inequitably) underrepresented in the STEM workforce (RQ2), we again turned to the population of students who matriculated in 2008-2013. The population of interest is "underrepresented minorities" and we use non-Hispanic White students as the comparison population because a large body of literature identifies (socially rooted) racial privilege, or lack thereof, as one of the variables driving the problem of inequitably high STEM departure rates (Arbona & Novy, 1990; Fry & Gonzales, 2008; Hernandez, 2000, 2002; Queveda-Garcia, 1987; Sorenson & Telles, 1991). This analysis does not include students who identify as Asian because that racially delineated population does not manifest the elevated STEM departure rate and workforce underrepresentation trends seen in other racial and ethnic minority populations tracked in the Department of Education demographic data.

As seen in Table 2, the SPRING intervention appears to increase graduation, STEM graduation, and four-year STEM retention rates (6-year retention data is not yet available for some students) for both underrepresented racial and ethnic minority (URM) students and non-Hispanic White (NHW) students, but NHW SPRING students seem to have received more benefit from the intervention than URM students did. The URM-NHW gap remains in both the comparison population and in the SPRING cohort. This follows the pattern that social benefits tend to accrue preferentially to those already benefiting from racial privilege; having existing social resources makes it easier to make use of newly provided resources (Phelan and Link 2015). We see here that STEM departure-related resources follow this trend in that NHW students participating in SPRING have a 100% 4-year STEM retention rate (compared to 82.8% for non-SPRING NHW students), while URM students get a more modest bump from 69.7% to 77.3%. More encouragingly for the equity-related impacts, among the SPRING cohorts that already graduated (the cohorts prior to the switch to only recruiting students with low math placement scores), STEM graduation rates for SPRING students were brought up to parity with the STEM graduation rates of NHW students who did not participate in SPRING (79%). In other words, SPRING participation for URM students appears to have a net departure-reducing 'pull' on STEM graduation rates (17.8% boost) that equals the net STEM departure 'push' that (statistically) afflicts URM students in the college.

Self-Selection and Gender Related Results

Understanding what impact, the SPRING program has on students (RQ2) also requires considering who engages with the program. Being accepted to the SPRING program required students to apply, which created an initial self-selection stage, followed by review and approval by a selection committee. In this process, one clear self-selection bias emerged which was that female students applied for the SPRING program (and hence were accepted) at a far disproportionate rate to their overall representation in the college population. Averaged over the 10 years of the SPRING program, 71% of the participants were female, compared to an eligible population that was 59% female. Surprisingly, the two most recent cohorts (restricted to students with low math placement) have shown an even stronger self-selection effect, with 88% of these students being female. One possible explanation is that a cohort-based program better aligns with female gender norms within the student population (collaboration and mutual support), which in turn conflicts with opposing gender norms that contribute to worsening trends in higher education enrollment/graduation for male students. Alternatively, the application process may be interpreted as a help seeking activity, something that women may be more likely to engage in (Morgan, Ness, & Robinson, 2003). Although a majority of students of the students in SPRING are enrolled in biomedical majors where women receive a majority of the degrees, it remains the case that the STEM workforce as a whole is disproportionately male, so the fact that this program's STEM retention impacts accrued primarily to women in STEM serves the goal of ameliorating underrepresentation of women in STEM professions.

Who left the SPRING program before completion?

Another way to understand the differential impacts of the program (RQ2) is to investigate the characteristics of those leaving the program. Among the few students who did not persist, there is a divergence in the reasons for non-persistence, leading to a particular kind of gap: high financial need students left the program with poor grades as a/the primary reason, while students with low or moderate need levels departed voluntarily or involuntarily due to a shift in career or major that made them ineligible for a STEM career scholarship. Putting this within Tinto's framework, high financial need students departed due to apparent mismatches between performance in their chosen programs, while low- and moderate-need students departed due to mismatches between their aspirations and their academic programs.

Disappointingly, five out of the nine students who left the program (regardless of what they did after leaving the program) were members of underrepresented minorities. Despite the small number of departures, this high proportion is disconcerting. However, several of the students who left the program continued to work toward a STEM major, including one who took an extended leave from the institution first. Among the two most recent cohorts (which focus exclusively on students with low math placement scores and typically exhibit more characteristics of students at risk of departing STEM), four out of the 32 students have had to take semester or more leaves of absence to address personal issues. This was not an issue ever encountered in the previous four cohorts (65 students).

The experiences of students who left or took leave from the program can be interpreted using Tinto's departure framework, illustrated in Figure 1. Specifically, we should recognize that there are "pre-entry attributes" of a student that any college level program cannot alter (although the college's first-year program that eventually got linked to SPRING is designed to help students quickly modify some relevant attributes after arriving in college). There are also other ongoing influences spread throughout Figure 1 that are similarly not directly modifiable by SPRING: "external commitments" (e.g. family obligations), and the wider "social system" (e.g. exposure to discrimination on- and off-campus).

Limitations

These graduation and retention results should be interpreted while keeping in mind that there are potential selection biases. First, all of the students have selected to enroll in a STEM residential college. There may be certain characteristics of such students that are not representative of their peers who did not seek such a college experience. Further, since student participation in SPRING was not via a randomized process, there is room for selection effects to appear. Our comparison population attempts to mitigate this bias in assessing the program by matching students based on STEM major and minimum GPA for all comparisons, thus comparing SPRING participants only with those who would have been eligible for the program.

In terms of the selection of the students, in the early years, the dominant selection criteria were expressed career interest –those expressing interest in pursuing medical professions were excluded. This meant that GPA was essentially a threshold criterion and anyone over the threshold was given equal consideration rather than selecting for students with the highest GPA. Yet with these selection filters through both self-selection (whether to apply) and selection by the scholarship committee (which focused on career plans), one could imagine that students who apply and express an interest in being a practicing scientist may be different from those who do not. With the shift to the smaller population of INQUIRE students in the later years of the program, essentially all of the applicants with demonstrable financial need and suitable GPA were accepted regardless of their expressed interest in medical professions. For these students, a self-selection bias to apply remained, however, the bias potentially brought by the scholarship committee was removed. There is no inherent reason to anticipate that differences would arise if the above selection criteria were removed but extending these results to other populations should be done cautiously.

It is also important to consider that there is no objective "right" STEM retention rate; some students will discover they are less attracted to STEM than to newfound passions about other subjects they are exposed to while in college. Thus, it should not be assumed that the ideal is a 100% STEM retention rate. However, there is ample evidence that a large segment of students are being pushed out of STEM by psychological (e.g. low self-efficacy among underrepresented racial minorities) (Williams, Phillips, & Hall, 2014) and social forces (e.g. racial discrimination limiting research opportunities) (Xie, Fang, & Shauman, 2015), rather than being pulled away by other more compelling goals (e.g. discovering a love for business administration). Yet the indication seems to be that comprehensive programs focused on STEM careers and career exploration can have a positive impact on student outcomes.

Conclusion and Implications

The results above highlight both the successes and weaknesses of the SPRING program. In total, 97 students have been involved in the SPRING program and 91% of the scholars completed the program (graduated within six years of matriculation or remain in the program now if less time has elapsed). Regarding RQ1, we see that the SPRING program has had no impact on the graduation rates for the participants relative to the other residential college students who would have been eligible (95% vs. 92% graduation rate). These high graduation rates really remind us that the biggest barriers that students face toward graduation in our population tend to happen in the first year; as students will have already changed their major out of a STEM field or have a GPA below 2.75 after their first semester. However, looking at retention in STEM is where we see the biggest impact of SPRING. Amongst all of our scholars, the percentage of SPRING scholars completing STEM degrees is 12 points higher than the comparison population.

Yet it is not only the average numbers that are important but as RQ2 indicates, we also must consider which students specifically benefit from SPRING. Because years 8 to 11 of the program restricted eligibility to students with both (1) financial need and (2) low math placement scores, we are able to very explicitly analyze how the SPRING program differentially impacts students of varied math background. Low math placement (Lewis, 2019) and high financial need (Castleman, Long, & Mabel, 2017) are both burdens in themselves making timely completion of a STEM major difficult. Both are also proxy variables for identifying students from underrepresented demographics since parental finances and high-quality pre-college math are strongly correlated with socioeconomic inequities of race, ethnicity, class, and so on. Thus the 20% improvement in the 4th year STEM retention rate of the INQUIRE students (low math placement) to match those with higher math placement (not involved in SPRING) is an accomplishment. Given the size of the program, this represents six additional students successfully majoring in a STEM field. The SPRING scholars with higher math placement still saw a benefit from the program, but their STEM retention rate only increased by 14%.

It is a matter of active debate whether it is a greater accomplishment for an intervention to close an inequitable gap (without raising mean performance) or whether it is sufficient for a program to act as a high tide that raises all ships –improving outcomes across all groups but not eliminating the inequitable gaps (Reid 2016). Our results indicate that the SPRING program accomplished both goals: persistence in STEM degrees was higher than the average of students in the comparison population and subgroup disparities narrowed. According to the primary outcome measure of the program and the NSF program funding it—students succeeded in the program with high frequency even if they had high financial need, have been underrepresented racial or ethnic minorities, and/or have been first-generation college students. Though, among the few students who left the SPRING program/cohorts, a disproportionate number were racial or ethnic minorities.

The fact that some but not all departure-related causal factors are susceptible to modification via the SPRING program helps us to make sense of two trends in the data: 1) generally, socially privileged group and non-socially privileged subpopulations both benefited from SPRING, but the SPRING group retained a gap between those subpopulations. All SPRING students received the same package of tangible and intangible benefits designed to prevent students from feeling they needed to depart STEM due to an inability to meet the institution's expectations. Yet, the less socially privileged students retained external pressures that continued to afflict them but not their more socially privileged peers (e.g. mistreatment by a misogynistic or racially hostile lab group member). 2) SPRING's effects were relatively strong in STEM retention measures and relatively weak in graduation measures. A scholarship and the co-curricular program cannot modify factors like pre-college preparation or external pressures (e.g. students dropping out of college due to family crises). That is largely outside the control of such a program. But for students who are able to finish a degree, the SPRING program helped maintain students' enthusiasm for STEM. It is an inevitable limitation of the program that external forces that contribute to student departure, such as family emergencies or unpredictable limitations in pre-college preparation, cannot be eliminated. These external factors may pose a limitation to a cohort program that builds resilience and generic academic skills, but SPRING was able to effectively encourage and sustain students' passion for STEM.

So how does the SPRING program help support the students' passion for STEM? The probable explanation is that participation boosts self-efficacy (Tinto, 2017) in the domain of students being more able to see themselves as being able to achieve a STEM career. There is some evidence that this is at work in the SPRING program (Sweeder and Strong, 2012, 2013). This boost in self-efficacy may occur by the student's developing a self-identify as a scientist. Specifically, the external recognition of being a scientist (by being selected to participate), maintaining a sense of community, and actively envisioning their future selves in specific careers may assist students in internalizing the label of scientist (Carlone and Johnson 2007; Aschbacher, Li, & Roth, 2010).

However, providing a more robust analysis of the potential mechanisms for these positive impacts would be highly beneficial. It may be simply that interacting with a cohort of peers who are 'in the same boat' has the intuitive effect of making students feel less alone in their struggles (Astin, 1997). It may also be that SPRING helps the students connect with resources (both financial and academic) that enable them to overcome the barriers associated with earning a STEM degree. Through the examination of annual interviews with the students, we anticipate being able to explore these underlying mechanisms to better inform the thoughtful development of future programs designed to support students' success.

Acknowledgements

The authors thank the students and faculty participants who have made the SPRING program possible. They also thank Lyman Briggs College and the Scholarship of Undergraduate Teaching and Learning program for support. The SPRING program was made possible by the support of the National Science Foundation through awards DUE-0849911, 1153778, and 1564745. The research was supported as part of NSF award number DUE -1564745.

References

Anderson, E., and Kim, D. (2006). *Increasing the Success of Minority Students in Science and Technology.* Washington, DC: American Council on Education.

Arbona, C. & Novy, D. M. (1990). Noncognitive dimensions as predictors of college success among black, Mexican-American, and white students. *Journal of College Student Development, 31*, 415–422

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582.

Astin, A. W. (1997). *What Matters in College? Four Critical Years Revisited* (1st edition). San Francisco: Jossey-Bass.

Astin, A.W., and Astin, H.S. (1992). *Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences.* Los Angeles: The Higher Education Research Institute, University of California, Los Angeles.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218.

Cataldi, E. F., Bennett, C. T., & Chen, X. (2018). First-generation students: College access, persistence, and postbachelor's outcomes. Retrieved from https://nces.ed.gov/ pubs2018/2018421.pdf

Chen, X. (2013). *STEM Attrition: College Students' Paths Into and Out of STEM Fields* (NCES 2014- 001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Darling-Hammond, L., Barron, B., Pearson, D., Schoenfeld, A.H., Stage, E.K., Zimmerman, T.D., Cervetti, G.N., & Tilson, J.L. (2009). *Powerful learning: What we know about teaching for understanding*. San Francisco: Jossey-Bass.

Dee, T. S., & Jackson, L. A. (1999). Who loses HOPE? Attrition from Georgia's college scholarship program. *Southern Economic Journal, 66*(2), 379.

D'Souza, M. J., Shuman, K. E., Wentzien, D. E., & Roeske, K. P. (2018). Working with the Wesley College Cannon Scholar Program: improving retention, persistence, and success. *Journal of STEM education: innovations and research, 19*(1), 31.

Eagan, K., Herrera, F.A., Sharkness, J., Hurtado, S., and Chang, M. (2011b). *Crashing the Gate: Identifying Alternative Measures of Student Learning in Introductory Science, Technology, Engineering, and Mathematics Courses*. Los Angeles: Higher Education Research Institute.

Fenske, R.H., Porter, J.D., and DuBrock, C.P. (2000). Tracking Financial Aid and Persistence of Women, Minority, and Needy Students in Science, Engineering, and Mathematics. *Research in Higher Education, 41*(1): 67–94.

Fry, R., & Gonzales, F. (2008). *One-in-five and growing fast: A profile of Hispanic public school children.* Washington, DC: Pew Hispanic Center.

Griffith, A. (2010). Persistence of Women and Minorities in STEM Field Majors: Is It the School That Matters? *Economics of Education Review, 29*(6): 911–922.

Hernandez, J. C. (2000). Understanding the retention of Latino college students. *Journal of College Student Development, 41*, 575–584.

Hernandez, J. C. (2002). A qualitative exploration of the first-year experience of Latino college students. *Journal of Student Affairs Research and Practice, 40*, 69–84.

Hill, C., Corbett, C., and Rose, A.S. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC: American Association of University Women.

Huang, G., Taddese, N., and Walter, E. (2000). *Entry and Persistence of Women and Minorities in College Science and Engineering Education* (NCES 2000-601). National Center for Education Statistics, U.S. Department of Education. Washington, DC.

IBM SPSS (Version 25). (2017). Retrieved from https://www.ibm.com/products/spss-statistics Jeschke, M.; Johnson, K.E.; and Williams, J.R. (2001). Comparison of Intrusive and Prescriptive Advising of Psychology Majors at an Urban Comprehensive University. *NACADA Journal, 21* (1/2): 46–58.

Kalevitch, M., Maurer, C., Badger, P., Holdan, G., Iannelli, J., Sirinterlikci, A., & Bernauer, J. (2012). Building a community of scholars: one University's story of students engaged in learning science, mathematics, and engineering through a NSF S-STEM grant. Journal of STEM Education, 13(4), 34-42.

Kokkelenberg, E.C., and Sinha, E. (2010). Who Succeeds in STEM Studies? An Analysis of Binghamton University. *Economics of Education Review, 29*(6): 935– 946.

Lowell, B.L., Salzman, H., Bernstein, H., and Henderson, E. (2009, November 7). *Steady as She Goes? Three Generations of Students Through the Science and Engineering Pipeline.* Paper presented at the Annual Meetings of the Association for Public Policy Analysis and Management, Washington, DC.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education, 101*(1), 6-27.

Mendez, G., Buskirk, T.D., Lohr, S., and Haag, S. (2008). Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests. *Journal of Engineering Education, 97*(1): 57–70.

Michigan State University. (2019). Internal Report: STEM Graduation Rate.

Morgan, T., Ness, D., & Robinson, M. (2003). Students' Help-Seeking Behaviours by Gender, Racial Background, and Student Status *Canadian Journal of Counselling, 37*(2), 151-166.

National Science Foundation, National Center for Science and Engineering Statistics. (2020). NSF Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM). Special Report NSF 20-526. Alexandria, VA. Available at www.nsf.gov/pubs/2017/nsf17527/nsf17527.htm.

National Science Teachers Association (2016). *Building STEM Education on a Sound Mathematical Foundation.* Position Statement. Retrieved from https://www.nctm.org/uploadedFiles/Standards_and_Positions/

Olson, S., & Riordan, D. G. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President.*

Phelan, J. C., & Link, B. G. (2015). Is racism a fundamental cause of inequalities in health? *Annual Review of Sociology, 41*, 311-330.

President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC.

Queveda-Garcia, E. L. (1987). Facilitating the development of Hispanic college students. In D. J. Wright (ed.), *Responding to the Needs of Today's Minority Students*. San Francisco: Jossey-Bass.

Reid, L. (2016). Does population health have an intrinsically distributional dimension? *Public Health Ethics, 9*(1), 24–36.

Scott-Clayton, J. (2015). The role of financial aid in promoting college access and success: Research evidence and proposals for reform. *Journal of Student Financial Aid, 45*, 7–22.

Shapiro, D., Dundar, A., Huie, F., Wakhungu, P., Yuan, X., Nathan, A., & Hwang, Y. A. (2017). *A national view of student attainment rates by race and ethnicity – Fall 2010 cohort* (Signature Report No. 12b). Herndon, VA: National Student Clearinghouse Research Center.

Shapiro, D., Dundar, A., Wakhungu, P.K., Yuan, X., Nathan, A, & Hwang, Y. (2016). *Time to Degree—2016.* Retrieved from https://nscresearchcenter.org/signaturereport11/

Shaw, E.J., and Barbuti, S. (2010). Patterns of Persistence in Intended College Major With a Focus on STEM Majors. *The National Academic Advising Association Journal, 30*(2): 19–34. Seymour, E., & Hewitt, N. (1994). Talking about leaving: Factors contributing to high attrition rates among science, math, and engineering undergraduate engineering majors. Boulder, CO: University of Colorado.

Seymour, E., & Hewitt, N.M. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, CO: Westview Press.

Simmons, E. H., & Sweeder, R. D. (2016), "Lyman Briggs College: An Environment Supporting Change" in *Improving Undergraduate STEM Education at Research Universities: A Collection of Case Studies.* Research Corporation for Science Advancement. Washington, DC.

Sorenson, S. B., & Telles, C. A. (1991). Self-reports of spousal violence in a Mexican American and a non- Hispanic White population. *Violence and Victims, 6*, 3–16.

Student Success Annual Report. (2018). Michigan State University. Retrieved from https://undergrad.msu.edu/uploads/2018-StudentSuccessAnnualReport2.pdf, Accessed Jan 12, 2021.

Sweeder, R. D., Jeffery, K. A., & McCright, A. M. (2012). Lyman Briggs College: An innovative living-learning community for STEM education. *Quality Approaches in Higher Education, 3*(2), 7–14.

Sweeder, R. D., & Strong, P. E. (2012). Impact of a Sophomore Seminar on STEM Majors Desire to Pursue a Science Career. *Journal of STEM Education: Innovations and Research, 13*(3). http://www.jstem.org/index.php/JSTEM/article/view/1623

Sweeder, R., Kursav, M., Cass, S., & Matz, R. (2019). Understanding the Impact of Learning Community Support for STEM students with Low Mathematics Placement. *Learning Communities Research and Practice, 7*(2). https://washingtoncenter.evergreen.edu/lcrpjournal/vol7/iss2/2

Sweeder, R., & Strong, P. E. (2013). Supporting Undergraduate Students in Earning a STEM Degree. *International Journal of Learning in Higher Education, 19*(3), 83–90. https://doi.org/10.18848/2327-7955/CGP/v19i03/48657

Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition*, 2nd ed. Chicago: University of Chicago Press.

Tinto, V. (1997). Colleges as communities: Exploring the educational character of student persistence. *Journal of Higher Education, 68*, 599-623.

Tinto, V. (2017). Reflections on student persistence. Student Success, 8(2), 1–8.

U.S. Department of Homeland Security. (2016). *STEM Designated Degree Program List*. Retrieved from https://www.ice.gov/sites/default/files/documents/Document/2016/stem-list.pdf

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching, 42*(5), 36-41.

Whalen, D.F., and Shelley, M.C. (2010). Academic Success for STEM and Non- STEM Majors. *Journal of STEM Education, 11*(1,2): 45—60.

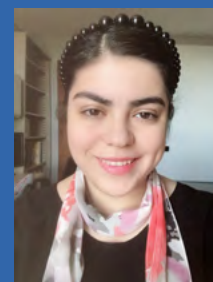
Williams, J., Phillips, K. W., & Hall, E. V. (2014). *Double jeopardy? Gender bias against women of color* in *science.* Hastings College of the Law, Center for WorkLife Law.

Vickers, Roberts J. (1994). HOPE freshman's fund in jeopardy, Atlanta Journal –Constitution, 18 June, p. B/04.

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. Annual Review of Sociology, 41(1), 331–357.

Ryan D. Sweeder is a Professor of Chemistry in the Lyman Briggs College (a residential science program) and the Hub for Innovation in Learning and Technology at Michigan State University. He received his Ph.D. at the University of Michigan in inorganic chemistry and chemistry education and completed his postdoctoral studies at Cornell University. He and his research group study the undergraduate science student experience to better understand student retention with and focus on diversity and equity. He also investigates the impact of curricular interventions promoting undergraduate learning in chemistry including through the use of technology.

Merve N. Kursav is a Ph.D. student in Mathematics Education at Michigan State University (MSU), serving as a research assistant for the Connected Mathematics Project (CMP), and was an instructor of record in Mathematics. She is a Fulbright Alumni and has been a fellow in the Scholarship of Undergraduate Teaching and Learning program in Lyman Briggs College at MSU. Her research focuses on students' engagement when using collaborative STEM curriculum in diverse mathematics classrooms and establishing and promoting quantitative and qualitative methods to enhance teachers' and students' outcomes in the areas of mathematical engagement and achievement by using innovative tools.



Sean A. Valles is a philosopher of health specializing in the ethical and evidentiary complexities of how social contexts–everything from one's local food options to the presence/absence of exposure to violent policing practices–combine to create inequitable health disparities. His work includes studying the challenges of responsibly using race and ethnicity concepts in monitoring health disparities, scrutinizing the rhetoric of the COVID-19 pandemic as an 'unprecedented' problem that could not be prepared for, and examining how biomedicine meshes with public health. He is author of the 2018 book, Philosophy of Population Health: Philosophy for a New Public Health Era.