Abstract

To examine the relationship of participation in a research-based academic first-year seminar (FYS) with first-year achievement of science, technology, engineering, and mathematics (STEM) students, university data sets were collected from four cohorts ($N = 2543$) of entering STEM students of which 581 were FYS participants over the four years. Chi-square tests of homogeneity were used to compare persistence and Welch's t-test assessed differences in first-term grade point average (GPA) for females, males, conditionally-admitted students, and first-generation students between FYS and non-FYS groups. Analyses revealed significant differences in one-year persistence (some as much as 13% higher) between FYS and non-FYS participants among all groups excluding females. Additionally, first-term GPA was significantly higher for all FYS STEM students (some as much as 0.4 points higher on a 4.0 scale). Due to these results, recommendations are suggested for first-year STEM majors to participate in 3-credit research-based academic FYS in their first semester.

Keywords

First-generation students, STEM, conditionally-admitted students, first-year seminar (FYS), persistence, academic achievement, higher education

First-Year Seminars: Supporting STEM College Student Academic Success and Persistence

The globalization of markets and the transition of advanced economies from manufacturing industries to that of knowledge economies has increased the market demand for science, technology, engineering, and mathematics (STEM) graduates (Lu, 2015; Wallerstein, 2005). Even though there is high demand among employers for STEM graduates, the low interest level in the STEM fields among students entering college and the poor achievement rates of first-year college students has resulted in an insufficient number of STEM graduates (Morrison et al., 2011). Lu (2015) warns that the supply of a STEM workforce will not meet demand, manifesting a significant barrier to the United States maintaining its position as an economic global leader. The need for expansion of STEM graduates and universities' desire to increase enrollment has posed the question of how STEM students can be recruited and retained.

Nationally, the completion rates for students in STEM majors can be significantly lower than non-STEM majors with differences as much as 20% percent lower with an overall 6-year graduation rate less than 40% (Higher Education Research Institute, 2010; President's Council of Advisors, 2012). Furthermore, in an effort to bolster enrollment, researchers have looked to underrepresented groups in the STEM fields (Thompson et al., 2016; Yerdelen, Kahraman, & Tas, 2016). These students can include first-generation, conditionally-admitted, and female students. Yet, these students tend to leave STEM majors and/or not complete their degrees at even higher rates than their non-underrepresented STEM peers (Anderson & Kim, 2006; Chen, 2013; Griffith, 2010; National Academy of Sciences, 2011; Rask, 2010; Shaw & Barbuti, 2010).

This should not be surprising as many of these underrepresented students are at additional risk and tend to struggle across disciplines. According to Engle and Tinto, "nearly half (43 percent) of low-income, first-generation students had left college without earning their degrees.

Among those who left, nearly two-thirds (60 percent) did so after the first year" (2008, p. 2). First-generation students comprise a large number of the overall college population, and yet they have significantly lower retention rates when compared to other demographic groups (Schademan & Thompson, 2016). The stark reality is, even though enrollment numbers for this population of students keep rising, first-generation students "continue to earn lower grades and graduate at lower rates than their middle and upper-class peers" (Yee, 2016, p. 831). Couple the additional challenges first-generation students face in the transition to college with the typical intense coursework and expectations of STEM majors, these students are at even greater risk for attrition in absence of suitable resources.

That said, first-generation learners are not the only demographic often considered "at-risk" in terms of attrition among undergraduates. Conditional Acceptance/ Admissions Programs (CAP) have become increasingly common among mid-sized U.S. institutions in the last several decades (Caplan & Stevens, 2017; Laskey & Heztel, 2011). Although this provides additional opportunities for increasing STEM enrollment, there are several considerations when accepting and then supporting these students. Students offered provisional acceptance "are characterized not only by low scores but are also more likely than the general student population to be low income, first-generation college students, and/or ethnic minorities" potentially further complicating their academic experience (Stewart & Heaney, 2013 p. 27).

Conditional acceptance models do not expect students to surmount the often-intimidating gaps in skills and knowledge alone. However, in order to assist CAP students with the transition process, conditional admits must engage in requisite services, some of which include basic "reading, writing or math[ematics]" coursework (Stewart & Heaney, 2013 p. 27), tutoring, a "Freshman Year Experience" class (Laskey & Heztel, 2011, p. 32), and/or English language proficiency programming (Caplan & Stevens, 2017, p. 15; Fischer, 2010; Fischer, 2013). These resources and coursework become even more critical when these students seek out STEM majors that typically require more difficult curriculum.

Although female students are another underrepresented demographic in the STEM field, there are mixed findings about their achievement in these majors. Generally, the trend over the past several decades is that female students are enrolling at higher rates and earning more degrees than their male counterparts (Ewert, 2010). Within STEM, women are earning more STEM-related degrees than they have previously (Weber, 2012), but yet in the big picture, they are still leaving STEM majors at substantially higher rates than males (President's Council of Advisors, 2012). This is true even when considering that some studies have shown that women have performed at an equal level to men in STEM courses (Weber, 2012). Whether it is varying academic achievement or interest that drives decisions to remain or leave STEM fields, it is clear that female students require appropriate resources that will be effective in retaining them in STEM majors.

While male students tend to be the majority within STEM majors, as described previously, they are quickly becoming an "at-risk" population in post-secondary education. In addition to lower enrollment and graduation rates (Ewert, 2010; Pike, Hansen, & Childress, 2014; U.S. Department of Education, 2014), male students are also likely to take longer to complete their degrees (King, 2006). Conger and Long (2010) has suggested that male students immediately struggle as soon as they enter college. From the beginning, males tend to earn lower grades and have higher rates of suspension and academic probation (Courtenay, 2004). It is predicted that the gaps between male and female students will continue to grow unless something is specifically done to support the needs of male students (Hussar & Bailey, 2009). As with the other identified students, effective first-year programs are required to promote the long-term retention of male students, otherwise, the largest current pool of STEM majors will continue to dwindle.

Supporting STEM Students

Current research provides interventions that help STEM students persist to graduation (Eagan et al., 2013; Sweeder & Strong, 2013); however, studies targeting how FYS courses may aid STEM student success is lacking . Despite this limitation, other research has demonstrated that implementing meaningful, research-based academic instruction that is both challenging and supporting, may impact positive outcomes in terms of both matriculation and persistence (Longerbeam, 2016). When students are given quality instruction, challenges and rigor, they develop stronger cognitive strategies and have greater persistence to graduation (Blaich, Wise, Pascarella, & Roksa, 2016; Olson, 2017; Padgett, Keup, & Pascarella, 2013; Pascarella, Salisbury, & Blaich, 2011; Pascarella, Wang, Trolian, & Blaich, 2013; Wang, Pascarella, Nelson Laird, & Ribera, 2015). It can be assumed that interventions such as these may also be beneficial to students in academically rigorous STEM coursework.

The transition of students from high school to college involves numerous adjustments to different academic and social challenges that extend beyond the greater academic demands that characterize higher education (Permzadian & Credé, 2016). First-year seminars (FYS) are an intervention that has been used widely at universities for decades to help students with this transition. The literature consistently provides evidence that first-year seminars are beneficial for colleges and students as they have been related to increases in retention rates, GPA, graduation rates (Black, Terry, & Buhler, 2016; Permzadian & Credé, 2016), feelings of community (Boyer, 1990), and engagement of students within colleges (Kuh, Cruce, Shoup, & Kinzie, 2008).

There are several different FYS models ranging from one-credit extended orientation courses that focus on campus resources and study strategies to three-credit research-based academic courses that tend to emphasize and build students' abilities on college-level academic tasks. While enhancing general study skills is important for first-year students, it is likely they need more challenging tasks and assignments to grow personally and professionally. According to Jessup-Anger (2011), first-year seminars, which are one-credit and pass/fail courses, can be barriers to motivate the class. According to Swanson, Vaughan, and Wilkinson (2017), a three credit, full semester, first-year seminar course, with a curriculum grounded in educational psychology principles, would allow students to experience demanding college-level work in their first semester. Through the experience of tackling challenging assignments, students have opportunities to understand their strengths and weaknesses and feel satisfaction when completing their work with instructors' individual care. Students can learn to believe in themselves through challenging tasks and can increase self-efficacy, which is a vital element of students' academic performance and retention (Robbins et al., 2004). Similarly, Vaughan, Parra, and Lalonde's (2014) research assessed the relationship of student achievement with research-based first-year seminars that included peer-reviewed research readings, written assignments (including a research project), and exams with frequent interaction with instructors. This curriculum was also based on theories and research from the educational psychology domain. The students who took this course had higher first-term GPAs and were more likely to persist than were those students who did not take the course. Although there is still limited research about this type of model, the findings from these recent studies provide beginning evidence that challenging academic tasks and a research-based academic FYS could be more useful in preparing students for the next semester than the basic knowledge style of many first-year seminars.

Purpose

There is continued evidence that FYS should be designed as a research-based academic model; however, the previous literature does not specifically address how well this type of FYS model would benefit first-year STEM students including students who are potentially at additional risk (Swanson, Vaughan, & Wilkinson, 2017; Vaughan, Parra, & Lalonde, 2014). Therefore, the purpose of this research is to examine the relationship of a research-based academic FYS with the first-year achievement (i.e., first-term GPA and one-year persistence) of STEM students including students who may be more at risk (e.g., first-generation and conditionally-admitted students). Additionally, this study assesses the relationship of FYS participation with both female and male students' achievement. As described previously, the literature suggests that female students tend to achieve in college at higher rates than male students (Pike, Hansen, & Childress, 2014); however, within the STEM fields this does not always seem to be the case (President's Council of Advisors, 2012). Even though male students seem to outperform female students within STEM majors, across disciplines, male students have been increasingly identified at greater risk (U. S. Department of Education, 2014). As a result, it is important to assess the relationship of participation in this FYS model with male and female genders.

Research Questions

1. Is participation in a research-based academic FYS related to higher first-year achievement (i.e., first-term GPA and one-year persistence) for first-time STEM students including those students who are at additional risk (i.e., first-generation and conditionally-admitted students)?

2. Is participation in a research-based academic FYS related to higher first-year achievement (i.e., first-term GPA and one-year persistence) for first-time male and female STEM students?

Methods

Participants

After receiving approval from the Institutional Review Board, information from university data sets were collected from four cohorts (*N* = 2543) of entering first-time, full-time STEM students in Fall 2013 (*n* = 621), Fall 2014 (*n* = 586), Fall 2015 (*n* = 668), and Fall 2016 (*n* = 668). The number of FYS participants over the four years were 581 students (see Table 1). STEM majors at this institution refer to the following majors: athletic training, audiology, biology, chemistry, dietetics, earth science, mathematics, nursing, nutrition, physics, pre-engineering, pre-medicine, exercise science, and software engineering. This institution was selected for several reasons. First, the researchers had access to the longitudinal data that included a research-based academic FYS that has remained relatively consistent over the four years. Additionally, the curriculum was highly coordinated across sections with comprehensive instructor training each semester to help ensure fidelity of delivery (see description below). Each of these characteristics helped strengthen the research design.

Demographic data (i.e., gender, first-generation status, and conditional admittance status) and first-term GPA were collected at the end of each first semester. Credit loads were collected at the census date (add/drop period was concluded) during each of the following fall semesters (beginning of students' second year) to show continued enrollment at the university. This institution is a medium-sized, public four-year research university where approximately 30% of students are first-generation and/or students of color.

FYS Program

The philosophy of this FYS is to provide the opportunity for students to attempt and complete rigorous college-level academic tasks with the scaffolded support of highly trained instructors. With a small class size (i.e., between 20 – 25 students), there is a focus on building community and social networks both within the class and on campus. It is a 3-credit course that helps students fulfill a portion of the 40-credit general education requirements. Information about the seminar is shared during new student orientation in the summer and then students can make the decision to self-select into the course.

The course is based on the educational psychology discipline and includes topics such as goal, information processing, and motivation theories. Students first learn about the theories and the research that provides the foundation for these constructs and then learn about the short- and long-term applications. Additionally, the course includes time management, wellness topics, and major and career planning. It is also a writing intensive course that includes a research project with a presentation to the university community.

There is a coordinated curriculum where all sections have the same syllabus, course schedule and major assignments. Instructors are doctoral students in specific disciplines (e.g., psychology, education, and counseling) with expertise in educational psychology concepts and selected through a competitive process. At this university, availability, interest and expertise led to selecting doctoral students as the instructor team for the program. Before teaching, the entire instructor team completes a week-long comprehensive training in the summer and then two hours every week concurrently during the semester. Ongoing and concurrent training is essential to ensuring similar delivery of course content to all students.

Unlike other FYS courses that are more of an extended orientation model where grades tend to be either an “A” for attending and participating or an “F” for non-attendance, this research-based academic FYS tends to have a normal distribution of course grades similar to most other college-level academic courses.

Data Analysis

Due to students’ self-selection into the program, an initial analysis compared the population numbers of all FYS participants and non-FYS participants to determine if the groups were similar or different in terms of percentage of first-generation students and students of color as well as average index score. Index score represents a combination of high school GPA and college entrance exams (e.g., ACT) calculated by the state and is used by institutions state-wide to assess entering academic preparedness.

For the percentage of first-generation students and students of color, a chi-square test of homogeneity was used to assess differences between the proportions in the two groups. A one-way between subjects ANOVA was conducted to assess differences in average index score. These analyses were included to provide more information about the program as a whole. The results could potentially have different meaning if FYS participants were more academically prepared (i.e., higher index scores) or included fewer at-risk students.

The next set of analyses compared the proportion of STEM students who persisted to the following fall semester (i.e., one-year persistence rate) based on whether they participated in the FYS in their entering fall semester. For the percentage of students who persisted, a chi-square test of homogeneity was again used to assess differences in persistence between the proportions in the two groups (i.e., FYS and non-FYS group). Analyses were conducted for all students, first-generation students, conditionally-admitted students, and female and male students.

The last set of analyses used an independent samples t-test to assess the differences in STEM students' first-term GPA between the FYS and non-FYS group. The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p < .05$); therefore, the decision was made to use the Welch's t-test. Analyses were again conducted for all students, first-generation students, conditionally-admitted students, and female and male students.

Results

In the initial analysis, all assumptions for the chi-square test of homogeneity were met including that all expected cell counts were greater than five. The chi-square test of homogeneity showed significant differences in proportion of first-generation students ($p = .002$) and students of color ($p < .001$) between FYS participants and nonparticipants where the FYS program included a higher proportion of students who are typically at greater risk for academic success. See Table 2 for each of the proportions.

When assessing differences in index score (i.e., entering academic preparedness) between the two groups, there was also a significant main effect for FYS participation [$F(1, 7779) = 21.67$, $p < .001$]. FYS participants had on average a lower index score representing poorer entering academic preparedness as compared to nonparticipants. See Table 2 for average scores.

For the next set of analyses, all assumptions again were met. The chi-square test of homogeneity showed significant differences in proportion of students who persisted to their second year between the FYS and non-FYS groups except for female students. The greatest difference occurred for conditionally-admitted students where there was a 13% difference in persistence to the second year. Although the results for female students were not significant, there was still a positive 4% difference for FYS participants. See Table 3 for all of the results.

In the last analyses assessing differences in first-term GPA, assumptions were first tested for the independent samples t-test. There were no outliers and the data was normally distributed for each group, as assessed by boxplot and Normal Q-Q Plot, respectively. Homogeneity of variances was violated, as assessed by Levene's Test of Homogeneity of Variance ($p < .05$); therefore, the decision was made to use Welch's t-test to assess the differences. First-term GPA was significantly higher for all STEM students who participated in the FYS their first semester. Both first-generation and conditionally-admitted students had the greatest difference with an average GPA 0.4 points higher (on a 4-point scale) for FYS participants. See Table 4 for the results for all groups.

Discussion

There is a distressing and researched phenomenon noting significantly decreased persistence for students in the STEM fields, especially for underrepresented populations (Griffith, 2010). As a result of this lowered persistence rate across vulnerable populations (such as first-generation college students, conditional admits, and the larger categories across gender), the futures of scientific advancements, new technologies and the global position of science in the U.S. are in question as they are intimately entwined with the number of quality graduates in these essential fields of study.

Increasingly, students initially interested in pursuing a science, technology, engineering or mathematics field during their post-secondary tenure are either switching majors or dropping out of higher education altogether. The end result being they do not earn a major in one of the scientific fields and the respective and beneficial disciplines of STEM have begun to decline (Morrison et al., 2011). This persistence reduction is strongly seen across gender and underrepresented students such as the populations discussed above. These unique and indispensable populations are less likely to enter college with the intention to major in a STEM field; however, should they declare as a STEM major, they are more likely to switch from these major prior to earning a degree (Griffith, 2010).

This study examined how demographic and academic/support elements, such as the implementation of a research-based academic FYS, affect student persistence and academic achievement in STEM students' first year. The findings of this study showed significant differences in the proportion of students who persisted to their second year between those who enrolled and completed the FYS and those who did not. This finding was true for all groups except for female students; however, absent of statistical significance, females who took the course still showed higher persistence to those who did not. Through the next analysis, which assessed the differences in STEM students' first-term GPA between the FYS and non-FYS groups, the findings showed that first-term GPA was significantly higher for all STEM students who participated in the FYS their first semester. Some of these differences were close to half a GPA point (0.4 on a 4-point scale) between the two groups. In fact for the conditionally-admitted students who did not participate in the FYS, the average earned GPA for this group would have placed students on academic probation after one semester (GPA < 2.0). These findings occurred even though the FYS program as a whole included student participants who had significantly lower index scores potentially representing decreased entering academic preparedness.

If STEM programs were to view FYS courses as increasing student workload, it is reasonable to believe then that these programs may discourage FYS enrollment in order to better enable STEM students to focus on the high demands of core classes. Studies suggest, however, FYS may provide STEM students academic and social skills that promote success in this challenging field of study (Swanson, Vaughan, & Wilkinson, 2017; Vaughan, Parra, & Lalonde, 2014). FYS facilitates this by supplying skills that extend beyond academics, teaching students to be proactive and introducing them to a strong, supportive community via small class sizes and highly-accessible instructors, emphasizing for students the importance of seeking assistance at early stages when encountering challenges or setbacks in their academic career.

This study contributes to existing literature, highlighting the value of academic, research-based FYS programs by increasing persistence and academic success for all students and underrepresented populations in STEM programs. Additionally, by helping student success through FYS programs, future students could be encouraged by the example presented by past student accomplishments. When students recognize individuals of similar backgrounds as capable of excelling academically, it stimulates their belief that they can be successful as well (Bandura, 1997).

Limitations and Future Research

Findings of this study are limited to the institution in which the study was conducted. However, it is notable that this mid-sized university is similar in representation of other mid-sized universities with regards to the number of first-generation and conditionally-admitted students and students of color. Additionally, it is beyond the scope of this study to ascertain the factors within the FYS program that specifically contributed to student persistence and GPA.

Although analyses were provided to show that the FYS program had a significantly higher proportion of students at additional risk (i.e., first-generation and conditionally-admitted students) and had significantly lower average index scores than nonparticipants, there is still a potential limitation due to students' self-selection into the course. Another limitation to the findings is that the study did not examine the influence of FYS courses upon student grades for STEM specific courses.

Future studies would provide useful information by exploring the relationship of this type of seminar with multiple STEM outcomes. These could include achievement in STEM-related coursework, persistence in STEM majors both in the short and long term including students who graduate with a STEM degree. Additional research designs could also provide different information as well as more rigorous analysis. These include mixed-methods designs to understand how and why this type of seminar is effective and quasi-experimental designs that include data from multiple universities to strengthen the study.

Conclusion

Considering the urgent and growing need for STEM graduates to fill positions as demanded by technological advancement and changing markets, universities have come to focus on the inclusion of underrepresented populations (i.e., female, conditionally-admitted, and first-generation students) in STEM programs. Traditionally these populations have faced challenges in persistence and academic success, making it an ethical responsibility for universities to provide necessary assistance for these students. The literature provides evidence that institutions achieving student success in STEM majors invest in programs that provide inclusive and affirming environments with quality academics, purposeful faculty contact and help, as well as campus social engagement and experiences (Kuh et al., 2006; Xu, 2018). Academically challenging, research-based FYS programs can help fulfill these goals and should be considered in combination with STEM programs.

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Table 1

Demographic Information for All Students and the Two Groups, FYS and Non-FYS Participants

	Combined Fall 2013 – Fall 2016		
	All	FYS	Non-FYS
All students	2543 (100%)	581 (23%)	1962 (77%)
First-generation students	1295 (51%)	291 (50%)	1004 (51%)
Conditionally-admitted students	496 (20%)	122 (21%)	374 (19%)
Female students	1800 (71%)	443 (76%)	1357 (69%)
Male students	743 (29%)	138 (24%)	605 (31%)

Table 2

Proportion (%) of Students and Average Index Scores in FYS and Non-FYS Group

	FYS (%)	Non-FYS (%)	*p-value*
First-generation students	50.4	46.1	.002
Students of color	42.4	34.7	< .001
Average index scores	104.1	106.1	< .001

Table 3

Chi-Square Results for One-Year Persistence for All STEM Student Groups

	N	Persisted	*p-value*
All			
FYS	581	427 (74%)	.004
Non-FYS	1962	1318 (67%)	
First-generation students			
FYS	291	209 (72%)	< .001
Non-FYS	1004	598 (60%)	
Conditionally-admitted students			
FYS	122	81 (66%)	.011
Non-FYS	374	199 (53%)	
Females			
FYS	443	320 (72%)	.085
Non-FYS	1357	921 (68%)	
Males			
FYS	138	107 (78%)	.007
Non-FYS	605	397 (66%)	

Table 4

Results of Welch's T-Test to Measure Differences in First-Term GPA for All STEM Groups

	n	*M*	*M* difference	*SE* difference	*95% CI of difference*	*p*-value
All						
FYS	581	2.77	0.28	0.045	[0.19, 0.37]	< .001
Non-FYS	1962	2.48				
First-generation students						
FYS	291	2.62	0.40	0.065	[0.27, 0.53]	< .001
Non-FYS	1004	2.22				
Conditionally-admitted students						
FYS	122	2.09	0.40	0.092	[0.22, 0.58]	< .001
Non-FYS	374	1.69				
Females						
FYS	443	2.86	0.26	0.051	[0.16, 0.36]	< .001
Non-FYS	1357	2.60				
Males						
FYS	138	2.47	0.25	0.092	[0.06, 0.43]	.008
Non-FYS	605	2.22				