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Assessing Academic Progress in First-Year Engineering and First-Generation College Students Through Engineering Design Graphics Courses

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Abstract:

Engineering design graphics courses provide essential opportunities for students beginning their engineering or technology degree programs to build foundational knowledge and skills. Students entering such STEM fields come from a wide range of academic backgrounds, affecting their college preparedness level and potential for success in a degree program. First-year and first-generation college students, in particular, require early academic support to enhance their success, retention, and persistence in STEM degree programs.

This paper will describe a study that identified retention and persistence rates of first-year engineering and first-generation students enrolled in a foundational engineering design graphics course, as part of an NSF Improving Undergraduate STEM Education (IUSE) study conducted at a large land-grant institution in the southeastern United States. Previous analyses of this sample from three semesters' students have demonstrated improvements in self-efficacy with solid modeling, 3D mental rotation ability, and overall academic success. This longitudinal study using descriptive analysis highlights the retention and persistence rates among 312 first-year engineering students and 218 first-generation college students from that sample, focusing on their continued enrollment and progress toward degree completion.

The findings reinforce the importance of structured support systems for first-year students, including first-generation college students, who often lack sufficient resources and arrive from underrepresented populations. The study further emphasizes the value of engineering design graphics courses in offering early exposure to critical skills that contribute to long-term success in engineering and technology programs. These insights underscore the role of targeted interventions in enhancing student outcomes and supporting diverse learners in STEM fields.

Introduction

The success of first-year and first-generation students in engineering programs hinges on providing effective support structures that foster increased retention and persistence. Retention refers to students remaining in their chosen degree programs, while persistence focuses on continued progress along an academic pathway year-to-year [1, 2]. First-year engineering program students and first-generation college students in engineering programs face challenges related to a lack of experience in higher education and a lack of knowledge of resources that, unless support structures are in place, can impact elements pertaining to students' success.

To gain insight into how these demographics of students perform longitudinally, and how potential changes in future environments can impact retention and persistence, this study investigates the retention and persistence of students from an Engineering Design Graphics course to establish a baseline of information. Addressing the unique needs of first-year and first-generation students in engineering programs is essential for fostering retention and persistence. Through intentional instructional strategies and supportive learning environments, these students can achieve academic success, ultimately contributing to a stronger and more diverse STEM workforce.

Literature Review

Engaging and supportive learning environments are vital for student success in engineering, particularly in foundational courses like Engineering Design Graphics. Such foundational courses develop critical skills, such as spatial visualization and problem-solving collaboration, which contribute to academic performance and self-efficacy in applying content [2]. Research has shown that student-centered learning environments, where students actively engage with course materials and apply concepts to real-world problems, positively impact retention and persistence [3, 4]. This is especially important for first-year engineering and first-generation college students, who can greatly benefit from early experiences in their academic journey.

Traditional instructional practices often prioritize lectures and independent assignments, which can diminish engagement and increase attrition [5]. Such environments are still found in many institutions of higher education and can put inexperienced students, such as first-year or first-generation college students, at a disadvantage. For these students, a lack of institutional knowledge and support systems exacerbates feelings of isolation, reducing their likelihood of persisting in their chosen degree pathway [6].

Tracking retention and persistence patterns is essential for identifying factors that influence students' decisions to remain in their programs or progress through academic milestones [2]. The National Student Clearing House Research Center study reports persistence rates for engineering degree programs as 91%, measuring persistence as progressing from one year to the next [7]. They also report a persistence rate for engineering programs of 84.4%. PRISM journal from The American Society For Engineering Education (ASEE) reports a national first-year persistence for engineering bachelor’s degree at 92.8% and a retention rate of 86.4% [8] Factors such as academic self-efficacy, access to resources, and the ability to apply course concepts to real-world scenarios are crucial predictors of success, particularly for first-generation students [3]. Programs designed to enhance self-regulation and reduce anxiety are especially beneficial for this demographic, providing a foundation for their academic and professional growth.

Evidence from Engineering Design Graphics Courses

Engineering graphic courses offer early exposure to critical skills that contribute to long-term success in engineering and technology by supporting student spatial visualization development in addition to hands-on experience with engineering-related tools [2]. An NSF-funded study on active learning in Engineering Design Graphics highlights the positive impact of incorporating a supplemental curriculum with an environment that utilizes elements of student-centered learning. A curriculum focused on real-world applications saw improvements in student engagement, self-efficacy, mental rotation skills, and academic performance [9]. These findings underscore the value of intentional, evidence-based interventions in fostering supportive structures that can influence retention and persistence among students, including those at greater risk of attrition.

Need for Improved Retention and Persistence

The demand for a skilled STEM workforce continues to rise, with STEM occupations growing by 20% from 2011 to 2021 [10]. Meeting this demand requires educational programs that prepare diverse students to succeed in technologically and engineering-intensive roles. By improving learning environments and incorporating support structures that involve student-centered approaches, institutions can better support first-year engineering and first-generation students as well as expand the pipeline of STEM professionals equipped to address global challenges [11].

Significance of Supporting First-Year and First-Generation Students

Improving retention and persistence among first-generation and first-year students in engineering programs is critical for building a more inclusive and capable workforce. Retention and persistence in STEM programs are pivotal to addressing the growing demand for a skilled, technologically literate workforce. Retention refers to students staying enrolled in their chosen programs, while persistence tracks their progress toward graduation over time [1, 2].

Student-centered learning strategies, emphasizing engagement, real-world applications, and academic support, have demonstrated positive effects in overcoming challenges related to student engagement [12, 13]. By establishing baseline data and implementing evidence-based practices, institutions can construct environments where more students, regardless of background, have the opportunity to thrive.

Addressing Retention Challenges for First-Year and First-Generation Students

Student-centered learning approaches, such as active learning modules and performance-based assessments, have been shown to improve retention and persistence in STEM programs [2]. These strategies allow students to engage deeply with course material and build skills necessary for academic and professional success. For first-year engineering students, this approach lays a solid foundation for long-term achievement, while first-generation students benefit from the personalized support that addresses their unique needs [1, 14].

Higher education institutions play a vital role in fostering inclusive environments that support diverse student populations. Programs tailored to first-year engineering students often emphasize the development of technical skills, academic readiness, and motivation to persist in STEM disciplines [15]. Similarly, initiatives designed for first-generation students must address barriers such as limited access to resources, unfamiliarity with academic systems, and systemic inequities [16, 17].

Longitudinal studies are critical for understanding the long-term impact of student-centered approaches on retention and graduation rates for both first-year engineering and first-generation students. These insights can guide the development of evidence-based interventions that empower students to overcome challenges and achieve academic and professional success. By investing in innovative, inclusive educational strategies, institutions can better prepare a diverse STEM workforce equipped to meet the demands of a rapidly evolving global landscape.

Method

This longitudinal study examines retention and persistence rates of first-generation and first-year engineering students enrolled in an introductory engineering graphics course over five years ago across three semesters of course enrollment. The sample is drawn from an NSF-funded Improving Undergraduate STEM Education (IUSE) project, which demonstrated the positive impact of active learning and student-centered approaches on academic performance and self-efficacy in 3D solid modeling [9]. Since students self-enroll in course sections, the study design does not employ randomized control and experimental groups.

Research Questions

- What are the retention and persistence rates among a subsample of Engineering First Year students and a subsample of First Generation College Students enrolled in a foundational engineering graphics course?
- How do rates among a subsample of Engineering First Year students and a subsample of First Generation College Students compare to external studies on first-generation and first-year engineering student success?

Defining Retention and Persistence

Retention refers to students maintaining their enrollment within a specific college, signifying their ability to remain engaged in an academic pathway [1, 2, 18]. In this study, persistence is measured as the continuous and determined progression toward the ultimate goal of completing a degree. These concepts, while related, capture distinct dimensions of student success.

Data Source

Institutional data from a research-intensive, land-grant university in the southeastern United States serves as the primary dataset. The GC 120 - Foundations of Graphics course curriculum was enhanced through an NSF-funded IUSE initiative, incorporating supplemental active learning modules, guided video tutorials, and real-world applications [12]. The modules cover technical sketching, orthographic projections, dimensioning, assembly modeling, and other foundational topics, integrating practical exercises and self-assessment tools to promote self-regulated learning.

The sample comprises two subsamples, one subsample of 312 first-year engineering program students and another subsample of 273 first-generation college students who enrolled in the GC 120 course during three semesters (Spring 2018, Fall 2018, and Spring 2019). This course emphasizes graphic communication skills, including technical sketching and computer-aided design (CAD) using industry-standard software. The curriculum aims to develop spatial visualization and modeling skills while enhancing self-efficacy, essential for STEM success.

Data Collection

Data collection focused on independent variables such as demographic characteristics and academic performance, and dependent variables like retention and persistence rates. Statistical analyses were conducted to assess relationships between these variables and to address the research questions. By analyzing these data, this study provides actionable insights into enhancing retention and persistence among first-generation and first-year engineering students through targeted program interventions and course design improvements in STEM education.

Factors considered for a descriptive analysis, focusing on student retention and persistence, include categorical variables such as the semester enrolled in a specific course (GC 120), the degree program during that course, and the degree program upon graduation. Continuous variables like the year of graduation, first-year engineering program status, and first-generation college student status are also included. All data is institutionally reported except for the self-reported first-generation college student status. The analysis aims to establish subgroups based on these factors and identify potential gaps in student success, particularly for first-generation college students and first-year engineering students. Retention is defined as whether a student remained in their specific degree program, while persistence indicates whether they remained enrolled at the institution. Both variables are categorical, institutionally reported, and are crucial for assessing retention and persistence within the institution.

Results

First-Year Engineering Program

Table 1 shows that among the 298 First-Year Engineering Program students analyzed, 87.25% persisted to degree completion, while 12.27% departed from the university. Retention rates reveal that of the 260 students persisting to degree completion, 88.85% of those persisting students remained within the College of Engineering, while 11.15% of the persisting students transferred to another college within the university to complete their degree.

Table 1

Persistence and Retention in First-Year Engineering Program

Persistence of Students				Retention of Persisting Students		
Persistence	Frequency	% of n		Retention	Frequency	% of n
No	38	12.75		No	29	11.15
Yes	260	87.25		Yes	231	88.85
	n=298 students	100			n=260 students	100

First-Generation College Students

Table 2 outlines the outcomes related to persistence and retention among first-generation college students. Among the overall IUSE data, 237 students self-reported as first-generation college students. From this sample, analyzed data reports that 91.98% successfully persisted in completing their degree programs. Regarding retention, 88.53% of the first-generation college students who persisted in degree completion remained enrolled within their original college, while 11.47% of the persisting first-generation college students transferred to another college within the university to complete their degrees.

Table 2
Persistence and Retention in First-Generation College Students

Persistence of Students			Retention of Persisting Students		
Persistence	Frequency	% of n	Retention	Frequency	% of n
No	19	8.02	No	25	11.47
Yes	218	91.98	Yes	193	88.53
	n=237 students	100		n=218 students	100

Discussion

Persistence and Retention in Engineering Programs

The overall persistence rate of 87.25% for the First-Year Engineering program is below other reported national rates for engineering, which are between 91%-93% [8]. This is possibly due to the differences in definitions of persistence between studies. The study's retention rate of 88.85% for First-Year Engineering is above a nationally reported retention rate of 86.4% for First-Year Engineering students, though differences in retention definitions and the timeframe of studies highlight challenges in making direct comparisons [8].

What these rates do communicate is that there is room for improvement. Studies highlight that institutional support, such as fostering student-centered learning environments and improving faculty engagement, plays a critical role in increasing retention and persistence rates, which can contribute to potential improvements [1, 19]. These factors contribute to students' sense of institutional commitment, which is essential for academic success and social integration and is something that can and should be established early in engineering programs, such as through foundational courses, such as engineering design graphics [1].

Supporting First-Generation and First-Year Engineering College Students

First-Generation College Students face unique challenges in navigating higher education, with persistence rates of 91.98% and retention rates of 88.85%. First-generation students face distinct obstacles, including limited access to academic resources, lack of parental experience in higher education, and the need to navigate unsupportive, teacher-centered learning environments [2, 6]. Bridging the challenges faced by First-Generation College Students with the broader context of workforce development, particularly in STEM fields, highlights the critical importance of fostering educational pathways that support underrepresented populations. These pathways are essential not only for improving retention and persistence rates among First-Generation College Students but also for addressing the growing demand for a diverse and skilled

Supporting Workforce Development

Building technological and engineering literacy is critical to cultivating a STEM-competent workforce that can meet these demands [13]. First-year engineering programs and the support of First-Generation College Students are key to this effort, serving as an entry point for many students pursuing STEM pathways. Examining retention and persistence trends within these foundational programs provides institutions with valuable data to refine support strategies and enhance student success. However, the limited availability of detailed, public data on these metrics hinders the ability to analyze trends and draw evidence-based comparisons. This lack of transparency restricts efforts to improve STEM education programs and strengthen the development of a skilled and diverse STEM workforce.

Enhancing Academic Success through Student-Centered Learning

Student-centered learning has been shown to improve academic outcomes and reduce attrition in STEM programs [19]. Incorporating active learning practices, research opportunities for course credit, and peer collaboration can foster engagement and promote retention. Rather than overhauling curricula, embedding such practices into existing programs supports early academic success without compromising course content or credit hours [1, 20]. Engineering design graphics courses afford the opportunity to provide early exposure to student-centered learning practices such as hands-on problem-solving, guided instruction and demonstrations with instructors, collaborative projects, and flexibility in rigor to support the development of critical skills that contribute to long-term success in engineering and technology programs [1, 19].

First-year engineering programs and the faculty within can benefit from targeted interventions and professional development that support both First-Generation College Students and broader student populations. Professional development for faculty, especially those transitioning from industry, can enhance the adoption of student-centered practices, promoting retention and persistence. Such professional development can involve collaborative efforts to identify student-centered projects or other resources that can be incorporated into existing courses. Additional professional development should involve the observation of existing student-centered learning environments to identify practices that faculty can incorporate into their work. Efforts to bolster retention and persistence rates through student-centered learning are vital to sustaining a diverse and skilled STEM workforce, ensuring that programs effectively meet the demands of an evolving labor market. Additionally, diversifying STEM pathways by informing students of various career opportunities within and beyond engineering can address workforce needs and reduce attrition in traditional programs [1, 21].

Support Within Engineering Design Graphics Courses

Engineering graphics courses provide an early opportunity to introduce student-centered learning practices that are shown to enhance student engagement, retention, and persistence. Such foundational courses not only help in developing essential spatial visualization and technical skills related to success in engineering but also serve as a platform for integrating active, student-focused pedagogies such as collaborative projects, hands-on problem-solving, guided instruction, and real-world applications. An NSF-funded study on active learning in Engineering Design Graphics demonstrated that embedding a student-centered supplemental curriculum significantly improved student engagement, self-efficacy, mental rotation skills, and academic performance [9]. These outcomes align with broader research that highlights the importance of supportive, student-centered environments in fostering institutional commitment and academic belonging, which are factors closely tied to persistence and retention [1, 19]. By embedding student-centered learning early in the engineering curriculum through courses like engineering graphics, institutions can lay the groundwork for student success and help mitigate barriers faced by underrepresented populations in STEM.

Limitations and Future Studies

This study examines retention and persistence rates among engineering students in a foundational course, focusing on students in First-Year Engineering programs and First-Generation College Students. While it identifies key factors, limitations exist, including the focus on a single institution, self-reported data on first-generation status, and variations in persistence and retention definitions across studies. The study lacks data on student departure points and transfer student experiences. While predictive analysis can guide support initiatives, it should not be used for exclusion. Future research should investigate early-stage retention, explore support structures, examine specific departure points, and analyze the experiences of transfer students to further enhance student success in engineering programs. Additionally, this sample is from a single course in engineering pathways, leading to the need to potentially investigate students in other foundational engineering courses.

Conclusion

This study highlights the need to improve retention and persistence rates within First-Year Engineering programs, particularly for First-Generation College Students retention, to strengthen the STEM workforce. While First-Generation College Students' rates align with national averages, the overall persistence and retention rates for First-Year Engineering students fall below national benchmarks for STEM programs. To address this, the study emphasizes the importance of student-centered learning approaches, faculty development programs, and targeted support for First-Generation College Students. Future research should investigate specific points of attrition, including transfer patterns, and explore how institutional factors like curriculum design and advising can be leveraged to enhance student success. Diversifying STEM pathways and supporting underrepresented students are crucial for cultivating a skilled workforce.

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