The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #44138

Patterns of Retention and Persistence Rates in a Student-Centered Engineering Design Graphics Course

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Abstract

Engineering design graphics educational environments incorporating elements of active learning and associated supplementary resources promote students' engagement in applying course content and potentially student retention and persistence in engineering degree programs. An NSF Improving Undergraduate STEM Education (IUSE) study conducted at a large land grant institution in the southeast United States within an engaging student-centered introductory engineering design graphics course identifies that using active learning components with supplemental material supports increases in student self-efficacy in three-dimensional modeling along with academic success, including mental rotation ability. Additionally, the course structure allows learners to practice elements of self-regulated learning within engineering design graphics, which is critical to students' success in engineering and engineering technology programs.

While the IUSE study presents findings from three semesters of an introductory engineering graphics course, there remains an opportunity to conduct a longitudinal study analyzing the three semesters worth of data for patterns of retention and persistence of students in engineering degree programs, including engineering and engineering technology degree programs. Results from this study will act as a stepping stone for comparing retention and persistence rates at other institutions. Furthermore, the results of this study can support engineering design graphics programs to utilize student-centered learning environments that incorporate active learning and expose students to supplemental resources that can deepen their engagement with course content. This in-depth engagement with applying course content prepares students with experiences that can transfer to function within a STEM environment.

Results of this study present retention and persistence rates along with a time series pattern developed through a survival analysis on a sample of engineering degree program students. The STEM workforce continues to expand and requires a diverse population with proficient technological and engineering literacies to fulfill those developing needs, such as communicating through engineering design graphics. Engineering and engineering technology degree programs incorporating evidence-based student-centered strategies to promote retention and persistence can increase interest and identity within their programs. Such an increase can lead to meeting the growing needs of an expanding STEM workforce.

Introduction

Educational environments that incorporate components of student-centered learning and the content of engineering design graphics continue to grow in importance as the engineering design process gains increasing focus through STEM education [1,2,3,4]. While a National Science Foundation (NSF) Improving Undergraduate STEM Education (IUSE) study has shown the benefits of utilizing components of student-centered learning, such as increases in self-efficacy, academic success, and mental rotation ability over a semester, there is an opportunity to identify longitudinal patterns related to the retention and persistence of students in engineering degree programs [5]. Such rates are not widely reported and can vary between studies; one report identifies these rates as being between 50% and 55% for undergraduate engineering programs [6, 7]. A National Student Clearinghouse Research Center report states that the persistence rate for engineering colleges is 91% from a sample of 102,518 students [8].

There is a need to increase the persistence rates of engineering degree programs to meet the demand of an expanding STEM workforce that includes an increasing engineering and technology focus [9, 10, 11, 12]. The growing technological and engineering literacy is a need among members of society from various educational backgrounds, all of which can incorporate some aspect of engineering design graphics [3]. To support meeting this need of a growing workforce, researchers should identify patterns of retention and persistence of students to identify potential areas of focus that institutions of learning can take when developing programs and curricula [9, 10, 11, 12].

The imperative for investigating retention and persistence in engineering degree programs is evident through the high attrition rates [6, 7]. Comprehensive data on retention patterns is crucial for evidence-based comparisons and the development of supportive learning environments. Traditional pedagogical practices, particularly those rooted in instructivism, present challenges to fostering student-centered approaches to teaching [13]. Institutions aiming to cultivate students' interest and identity in engineering face obstacles such as lengthy lectures, large class sizes, and a lack of guided practice [13]. These challenges hinder the establishment of engaging learning environments [13]. Overcoming these obstacles to improve persistence is vital for nurturing a prepared STEM workforce, including those in the engineering and technology fields [3,13].

Retention and Persistence through Student-Centered Learning

While definitions vary in detail, persistence generally refers to students continuing education from one term to the next with the expectation of graduation [13, 14]. Retention, too, has a variety of definitions but generally refers to students remaining in the same degree program from one semester to the next. Several factors play a role in a student’s retention and persistence, most of which lie outside institutional control [13, 14]. Areas that programs can alter to influence persistence rates include, but are not limited to, educational environment, interaction with faculty and staff, and access to resources [13, 14]. Learning practices that contribute highly towards academic success and encourage retention and promotion are student-centered [4, 5, 13, 14].

Components of student-centered learning environments include hands-on experience applying content in a problem-solving format with instructor guidance and readily available tools [15, 16]. Such an environment can incorporate an online environment where digital resources such as tutorials, guides, and supplemental materials are available when students need them most, whether during or outside course time [5]. Student-centered learning environments, such as in an engineering design graphics course, afford students the opportunity to collaborate with each other and the instructor and to utilize course time to apply content rather than “sit-and-get” as in the traditional lecture format of educational environments still found in several institutions [13, 16].

Components of Student-Centered Learning

Active learning is a component of student-centered learning that promotes higher-order thinking tasks, collaboration, and real-world application of course content [13, 14, 15]. Active learning strategies enhance students' technological and engineering literacy and 21st-century skills [3, 13, 14]. In this learning approach, students actively gain knowledge through engaged experiences that involve guided practice, opportunities for collaboration, and reflection on applying course content through real-world application [13,14, 15]. Active learning allows for engaging with higher-order thinking tasks, such as analyzing, synthesizing, and evaluating applied course content [15]. This practice of high-order thinking tasks occurs in formal and non-formal STEM education environments and can incorporate self-regulated learning, self-monitoring, and self-evaluation [13,14, 15, 16, 17].

Professional organizations value active learning experiences in engineering degree programs, as evidenced by ABET accreditation criteria and industry representatives Prados, Peterson, and Luttuca, 2005 statements of there being a “movement to enhance student learning in engineering and technology through more student-centered approaches” [18, 19, 20]. A reason for increasing focus is student-centered learning environments’ ability to provide hands-on experience using resources to collaboratively apply course content in a realistic situation, providing social support in the learning process [19, 20]. Collaborative engagement involves social support in reaching task-specific and domain-specific objectives that influence self-efficacy in 21st-Century Skills [16]. Engineering degree students who experience student-centered learning environments have a self-reported increase in engineering design and professional skills, including communication and collaboration [19].

Student-centered learning tools are valuable in engineering and technology degree programs. Still, barriers exist to their incorporation, such as faculty resistance due to factors like tradition, self-perception, and incentives [13, 21]. Other obstacles include time constraints, increased preparation demands, challenges in large classes, and resource limitations [21]. Instructors often cite feeling a loss of control or inadequate teaching skills when implementing active learning [21].

Academic Success in Engineering

A student's academic success in engineering degree programs involves a combination of course grades, including projects, exams, and additional course assignments that ultimately make up a GPA [20, 21]. Along with these elements of success in engineering degree programs is the critical ability of mental rotation, which underscores the significance of engineering design graphics courses. The ability to mentally rotate objects is fundamental to the engineering design process, making these courses crucial for student success so much that The Accrediting Board for Engineering and Technology (ABET) promotes that programs provide experiences in engineering graphics courses committed to strengthening students' visualization and mental rotation abilities [1, 2, 4].

As gauged by GPA, academic success significantly shapes a student's academic and social journey within an institution (13). This correlation underscores the pivotal role of academic success in influencing retention and persistence rates among students enrolled in engineering degree programs. Investigating such rates and the accompanying patterns affords evidence-based support for how student-centered learning components can be incorporated into engineering degree programs to enhance student success.

Method

This study builds upon a quasi-experimental study incorporating components of student-centered learning, including supplemental materials in the form of active learning modules, within a Foundational Engineering Graphics course at a large land-grant institute in the southeast United States [5]. Evidence demonstrates increased self-efficacy in 3D modeling, academic success, and mental rotation abilities after a semester in an engineering design graphics course. This study uses this existing data coupled with updated data points to identify potential patterns of retention and persistence in Engineering degree programs [5].

Research Questions

Q1. What are the retention and persistence rates of students in STEM degree programs with experience in an introductory engineering graphics course that utilizes elements of student-centered learning?

Q2. What are the patterns of retention and persistence rates of students of students in STEM degree programs who have experience in an introductory engineering graphics course that utilizes elements of student-centered learning?

Data Source

This study will gather and analyze existing institutional data on the retention and persistence of students enrolling in a foundation engineering graphics course. According to the 2023 institution’s admissions and enrollment tracker, the university has 24,897 undergraduate students enrolling during the 2022-2023 academic year, including at least 11,000 in some form of undergraduate STEM degree program. When taking a closer look at the colleges at the university, the institution’s 2023 admissions and enrollment tracker demonstrates fall 2022-2023 enrollment saw 7,421 undergraduate students in the college of engineering, 3,127 in the college of sciences, 765 in the college of textiles, and 221 in STEM-related education majors in the college of education.

The course, from which data arrives, builds learning objects around the foundational elements of engineering design graphics that enable communication of design information through technical sketching and computer-aided design (CAD) constraint-based solid modeling. Such an engaging course intends to enhance students' spatial visualization, modeling ability, and self-efficacy in applying related tools in the future. This sample consists of students who each enrolled in one semester from a total of three semesters of participating students exposed to components of student-centered learning between the Spring of 2018 and Spring of 2019. The course consists of up to 60 students per section.

The data for this study comes from an NSF IUSE study measuring student self-efficacy in 3D modeling and academic success, including course grades and spatial visualization skills [5]. The sample size is 590 engineering degree program students enrolled in an engineering graphics course, whose distribution among grade levels is in Table 1. Data for the sample arrives from the existing IUSE project and the university Office of Institutional Research and Planning (OIRP).

Table 1
Distribution of Students by Grade Level (n=590)

Grade Level	f	%	Grade Level	f	%
Freshman	132	22.37	**Junior**	111	18.81
Sophomore	297	50.34	**Senior**	50	8.47

Table 2 describes the dependent variables that will undergo a descriptive analysis and survival analysis to identify rates and potential patterns related to retention and persistence within the sample. Independent variables are described in Table 3 and include a mix of continuous and categorical variables that will apply to each statistical analysis in the study.

Table 2
List of Dependent Variable

Variable	Type	Range
Retention	Categorical	Coded as 1 or 0 (1 = remained in degree program)
Persistence	Categorical	Coded as 1 or 0 (1 = remained in institution)

Table 3
List of Factors For Analyses

Factor	Type	Levels
Semester enrolled in Engineering Graphics Course	Categorical	Values range from Fall of 2018 to Spring of 2019 to Fall of 2019
GPA during semester of Engineering Graphics Course	Continuous	Values range from 0.0 to 4.0
Degree program during Engineering Graphics Course	Categorical	Coded numerically to identify engineering degree program
Number of semesters enrolled	Continuous	Values will range from 1 and higher
Year student graduated	Continuous	Values will range from Fall of 2018 to Spring of 2023
Degree program graduated	Categorical	Coded numerically to identify STEM and Non-STEM degrees including Engineering Degree Programs

Post data collection, the researcher scrubbed data, removing students not enrolled in an engineering degree program and duplicate entries. This is because the study of this paper focuses on student retention and persistence in engineering degree programs. Students who start in an engineering degree program and enroll in the engineering graphics course but then transfer out of their engineering degree program, potentially into a non-STEM degree program, remain in the sample. After scrubbing the data, the study ran descriptive and further analyses using SAS software.

Descriptive Analysis

A descriptive analysis using frequency data provides insight into the sample's retention and persistence rates [22]. In addition to the retention and persistence rates, frequency counts will inform about the degree programs students complete, the distribution of various grade levels at which students enroll, and the percentage of the total number of semesters of enrollment until degree completion. Information from the descriptive analysis will define results that answer research questions and contribute to the discussion on how to support academic success.

Survival Analysis

A survival analysis provides insight into patterns related to the time until persistence occurs. Survival analysis is a statistical method that analyzes the time until an event, such as persistence, occurs [23,24]. It provides valuable insights into the factors influencing the timing of events. It allows researchers to predict future occurrences based on the available data, especially when the time to an event is not fixed and may vary among study subjects [29, 23,24]. An event of interest can be anything with a distinct start and end point, such as in this study; the event will persist through or complete the program beyond their experience of the foundational engineering graphics course.

Results

Retention and Persistence Rates of Students in the College of Engineering

Table 4 illustrates that within this sample, the College of Engineering boasts 590 students exhibiting a persistence rate of 91.86%, alongside a retention rate of 93.17% of students continuing within the College of Engineering. In this sample, 6.83% of students transition to pursue studies in other colleges' STEM or non-STEM degree programs within the university.

Table 4
Persistence and Retention of College of Engineering Students

Persistence	f	%	Retention	f	%
No	48	8.14	**No**	37	6.83
Yes	542	91.86	**Yes**	505	93.17
	590	100		542	100

Because the above analysis involves upperclassmen who already demonstrate a commitment to a pathway, Table 5 details the persistence and retention rates of first and second-year students (lowerclassmen) enrolled in the College of Engineering. Among the 429 lowerclassmen examined, 91.14% exhibited persistence, signifying their continuous enrollment at the university until degree completion, while 8.86% did not persist. Retention rates show that 91.56% of lowerclassmen remain within the College of Engineering, while 8.44% transferred to another college to continue their degree pursuit.

Table 5
Persistence and Retention of Lowerclassmen College of Engineering (All Majors)

Persistence	f	%	Retention	f	%
No	38	8.86	No	33	8.44
Yes	391	91.14	Yes	358	91.56
	429	100		391	100

Survival Analysis on Total Semester of Enrollment for Degree Completion

A Survival Analysis summary for the time variable of “total semesters” to persist in completing a degree program shows that Quartile estimates in Table 6 indicate that the 75th percentile estimate is 12 semesters, with a 95% confidence interval between 11 to 12 semesters. The 50th percentile estimate is ten semesters, and the 25th percentile estimate is nine semesters. Additional information in these results states that the mean number of total semesters to persist in completing a degree program is 10.39. The number of censored and uncensored values is present, with 705 observations, of which 653 persist (uncensored), and 52 do not persist (censored). This data communicates that approximately 7.38% of the observations experience censoring, meaning that the exact time to event (persisting) is unknown for these cases.

Table 6
Summary Statistics for Time Variable Total Semesters

Quartile Estimates				
%	**Point Estimate**	**95% Confidence Interval**		
		Transform	**Lower**	**Upper**
75	12	LOGLOG	11	12
50	10	LOGLOG	**Mean**	**SE**
25	9	LOGLOG	10.3921	0.0887

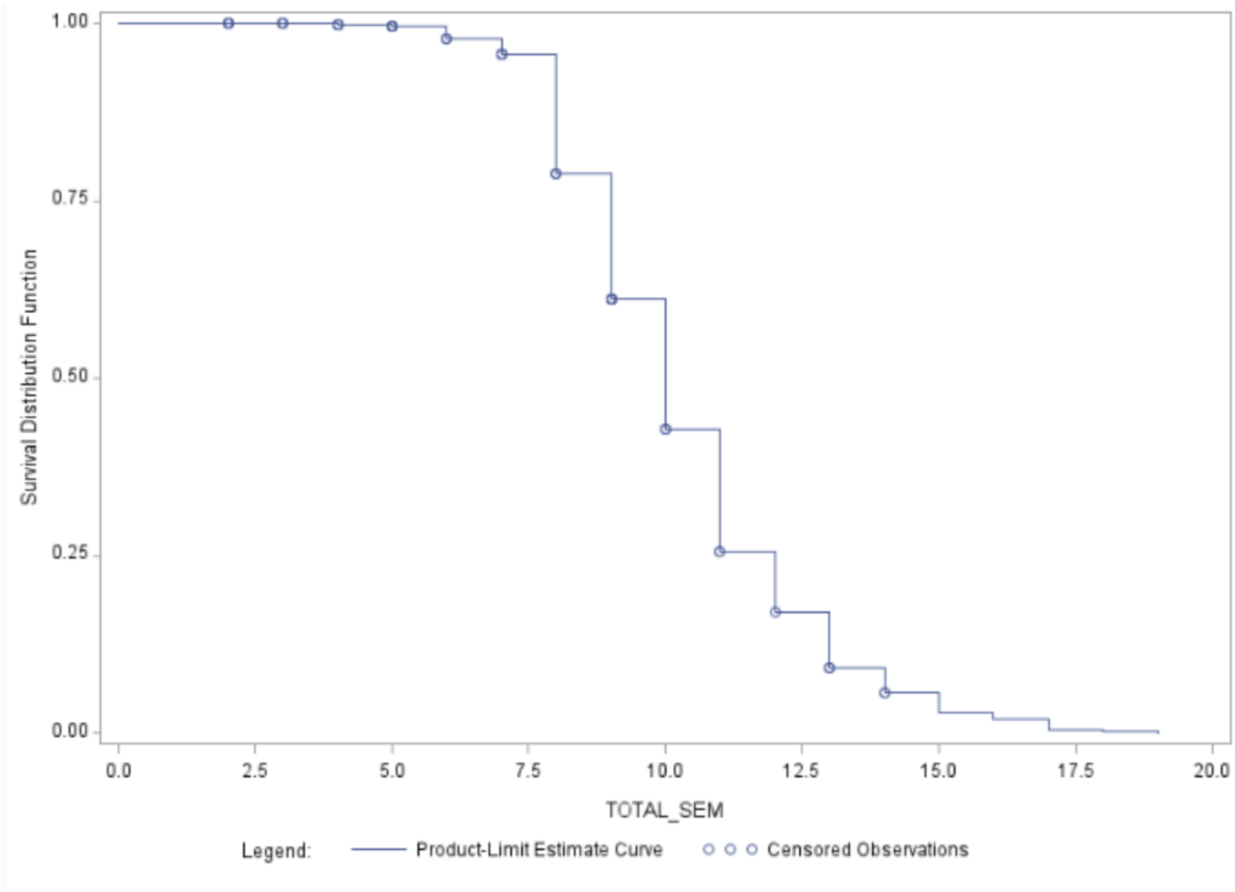
Summary of Censored and Uncensored Values			
Total	**Failed**	**Censored**	**% Censored**
705	653	52	7.38

A Survival Curve provides a visual of the results from Table 6, which appears in Figure 3 and illustrates the percentage of students who persist in completing their degrees over a time of several semesters. This curve is constructed using Kaplan-Meier estimates and depicts step functions as the time between events. The x-axis is the time of total semesters to degree completion, while the y-axis is the proportion of students persisting to the point of degree completion. Each step in the curve represents a time when persistence to degree completion occurs, decreasing the proportion of students over time.

The shape and slope of the curve provide a visual indication of the timing and proportion of persistence to degree completion of students in this sample. The presence of censored data points, denoted by circles on the curve, indicates individuals who did not experience the event of interest during the study period. The survival curve in Figure

3 shows that over 50% of students take over eight semesters to graduate, with about 40% taking more than ten semesters to complete a degree program.

Figure 3
Survival Analysis of Total Semesters on Student Persistence



Discussion

Restatement of Problem

The attrition of students from engineering degree programs poses a challenge to developing a proficient STEM workforce, which is crucial for societal success. Recognizing its significance, the United States government has prioritized efforts to mitigate attrition in engineering degree programs to maintain global competitiveness [6, 25]. However, there remains a notable gap in research concerning the rates and patterns of retention and persistence in STEM degree programs. This lack of information hampers evidence-based comparisons of retention and persistence rates and impedes progress in establishing supportive learning environments within engineering degree programs. Delays in studying and enhancing engineering degree programs can limit the preparation of a STEM-literate workforce.

Restatement of Purpose

This study aims to present a comprehensive data analysis of the retention and persistence rates and patterns among a substantial sample of engineering degree program students who have completed an introductory engineering graphics course incorporating aspects of student-centered learning. The resulting data and analysis are foundational longitudinal evidence for comparing retention and persistence rates across different institutions, degree programs, and learning environments.

Research Questions

Q1. What are the retention and persistence rates of students in STEM degree programs with experience in an introductory engineering graphics course that utilizes elements of student-centered learning?

Q2. What are the patterns of retention and persistence rates of students of students in STEM degree programs who have experience in an introductory engineering graphics course that utilizes elements of student-centered learning?

Retention and Persistence Rates

The resulting rates of 91.86% for all College of Engineering students in this sample align closely with reported persistence rates of engineering degree programs from the National Student Clearing House Research Center, which reports persistence rates for engineering degree programs as 91% [8]. The resulting rates are over the reported 75% rate for all degree-seeking students at a public 4-year institute [8]. Results for lowerclassman persistence rates of 91.14% also align with reported rates from the National Student Clearing House Research Center [8].

The retention rate of the whole sample of students who persist is 93.17%, while it is only 91.56% when examining only lowerclassmen. Such a difference in the rates can act as evidence that lowerclassmen are facing challenges when initially enrolling in engineering degree programs and are departing the College of Engineering for other STEM or non-STEM degree programs within the university. Both rates mentioned above are over the National Student Clearing House Research Center's reported retention rate of 84.4% for engineering colleges [8].

It is critical that degree programs require or strongly encourage students to take Engineering Design Graphics Courses because the rates of persistence of 91.86% and a retention rate of 91.56% show that at some point, some students depart engineering programs or an institution entirely. Due to the importance of developing vital STEM-related skills of mental rotation ability, communication through graphics, and the wide breadth of application that graphics have within problem-solving in a variety of fields, institutions need to be offering engineering design graphics courses as early as possible to establish a foundation of support for academic success. Students first entering the

College of Engineering are resulting in various degree pathways, all of which, in some capacity, can incorporate engineering design graphics.

Length of Enrollment in Completing Degree Pathways

The survival analysis for persistence to degree completion shows a time series pattern that only 25% of students complete a degree program within nine semesters, with a mean timeframe of 10 semesters, and 75% of the sample complete it by 12 semesters. Some of these semesters may be summer semesters; however, many students, including the university of this study, are shown 4-year plans that arrange eight semesters with no summer semesters. The results may include program transfers that increase the number of semesters students have to enroll.

Results from this study support literature that states undergraduate STEM degree programs advertising as four-year programs can take over ten semesters and up to an average of six years [26, 27]. A study conducted by Main et al. investigated a sample size of 5,819 students and included their length of time to graduate [26]. The study shows that even without a co-op or internship-type program, students in engineering degree programs enroll in a mean total of 9.44 semesters until graduation [26]. With co-op experiences, their total number of enrolled semesters increased to almost 14 [26]. Institutional data shows that six-year graduation rates in the College of Engineering have risen from 54.8% to 71% for Males and 57% to 70.3% for Females between 2008 and 2017, which aligns with the timeframe of students graduating within this study that shows 75% of the sample completing their degree within 12 semesters equating to six years at two semesters a year.

How an institution arranges its curricula and program structure plays a role in the institutional commitment identified as contributing to retention and persistence [14]. A traditional idea still presented to students is that STEM degree programs are set up as a four-year pathway. Such practice is so prevalent in society that several institutions lay out their degree pathways with semester loads that fit within four years or eight semesters. Requirements for degree programs have grown so much that policies have been written to encourage that unless there are compelling reasons and approval by a board of trustees, public universities' bachelor's degree programs can be at most 120 credit hours [28]. Such plans average to eight semesters of 15 credit hours. However, this sample of engineering students shows that it can take an average of 10 semesters to complete. Such actions may be due to students struggling or even leaving one program to begin another, which can add time to persistence in completing a degree program. Rather than reduce requirements, institutions can portray pathways along multiple timelines or in a layout that reduces pressure on students.

Supporting Retention and Persistence with Student-Centered Learning

When initiating engineering pathways, students need early experience within environments utilizing components of student-centered learning, such as those used in engineering design graphics courses, to establish a foundational level of academic success that can potentially promote their retention in engineering degree programs and persistence to degree completion. Students arriving at engineering degree programs need academic and social support through institutional commitment that encourages student success, as defined in Braxton et al.'s revision of Tinto's Theory of Institutional Departure [14]. This sample shows that the majority of the students who are taking engineering design graphics courses have already spent at least two semesters at the institution, as the majority of enrolled students in this study are sophomores or higher. In STEM fields, where communication via graphics is heavily dependent, students need as early experiences as possible to develop spatial visualization skills that contribute to academic success [29]. Such a program setup supports an institutional commitment to student success.

Spatial visualization skill development through engineering design graphics applies to fields outside of engineering and other STEM disciplines [29]. The likelihood of students departing an engineering program exists, and offering early experiences in engineering design graphics may encourage students who transfer to other STEM programs to bring enhanced communication skills. With the knowledge that engineering design graphics is a widely applicable tool, engineering or other STEM degree programs students should experience such practice as early as possible.

Limitations and Future Research

It is essential to remember that several external factors impact student retention and persistence as this study identifies patterns of a single large sample size of STEM degree students from a single institution who possess experience in an introductory engineering graphics course incorporating elements of student-centered learning. Studies and models defining factors contributing to student persistence consist of several factors, with most outside institutional control. This acts as a limitation in the study as the ability to control for these external influences is nonexistent, and such external influences play a significant role in students' persistence. This means that students in the sample who did not persist likely experienced external influences contributing to their attrition.

Another strong limitation of this study is that the majority of students are sophomore level or greater, so the study is not seeing true sense rates and patterns from within a student-centered learning environment. Resolving this involves partnering with other introductory courses that utilize student-centered approaches for foundational STEM knowledge. In addition to these limitations is the element of retention and persistence, which have multiple definitions, making it difficult to use in comparisons where definitions may vary greatly.

Future studies involve investigating strictly freshmen-level engineering design graphics courses or similar courses that house only freshmen-level courses to get a true sense of how students with early student-centered learning experiences may perform longitudinally. Additional studies can focus on different educational environments, different institutions, and potentially other STEM colleges or programs.

Conclusion

The attrition of students from engineering degree programs presents a significant challenge to fulfilling a growing STEM workforce, vital for societal advancement and global competitiveness. To address this issue, this study addresses a gap in research concerning retention and persistence rates in engineering degree programs. This study presents valuable insights into retention and persistence rates among engineering students, particularly those enrolled in introductory engineering graphics courses utilizing student-centered learning approaches. The findings reveal retention and persistence rates aligning with national and institutional reports' findings among students exposed in at least one such course, underscoring the importance of early experiences in fostering academic success and promoting degree completion. Furthermore, the study highlights the timeframe of degree completion that can support the development and communication of planned pathways for students pursuing engineering degrees. Such support structure promotes the need for institutional commitment to encouraging student success through program structures and early exposure to experiences in engineering design graphics. By prioritizing student-centered learning and providing opportunities, institutions can potentially enhance retention and persistence rates, ultimately contributing to developing a proficient STEM workforce and societal success.

References

[1] Accreditation Board for Engineering & Technology (U.S.). Engineering Accreditation Commission & Accreditation Board for Engineering & Technology (2019). *Criteria for Accrediting Engineering Programs.* The Commission.

[2]Accreditation Board for Engineering & Technology (U.S.). Engineering Accreditation Commission & Accreditation Board for Engineering & Technology (2021). *Criteria for Accrediting Engineering Programs.* The Commission.

[3] International Technology and Engineering Educators Association (ITEEA). (2020). Standards for technological and engineering literacy: The role of technology and engineering in STEM education. http://www.iteea.org/STEL

[4] Sorby, S. A. (2007). Developing 3D spatial skills for engineering students. Australasian Journal of Engineering Education, 13(1), 1–11. https://doi.org/10.1080/22054952.2007.11463998

[5] Clark, A. C., Schettig, E., Ernst, J. V., & Kelly, D. P. (2023, June). Supporting Student Persistence in Engineering Graphics Through Active Learning Modules. In 2023 ASEE Annual Conference & Exposition.

[6] Chen, X., & Soldner, M. (2013). STEM attrition: College students' paths into and out of STEM fields (NCES 2014-001). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, US Department of Education. Institute for Education Sciences, US Department of Education.

[7] Christe, B., & Feldhaus, C. (2013). Exploring Engineering Technology Persistence and Institutional Interventions: A Review of the Literature. Journal of Engineering Technology, 30(2).

[8] Gardner, A. (June 2022), Persistence and Retention Fall 2020 Beginning Postsecondary Student Cohort, Herndon, VA: National Student Clearinghouse Research Center.

[9] King, B. (2015). Changing college majors: Does it happen more in STEM and do grades matter?. Journal of College Science Teaching, 44(3), 44-51.

[10] Patrick, A. D., & Prybutok, A. N. (2018). Predicting persistence in engineering through an engineering identity scale. International journal of engineering education, 34(2a).

[11] Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A. B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. Science, 341(6153), 1455-1456.

[12] Lisberg, A., & Woods, B. (2018). Mentorship, mindset and learning strategies: An integrative approach to increasing underrepresented minority student retention in a STEM undergraduate program. Journal of STEM education, 19(3).

[13] Robbins, S., Bloom, J. L., & Habley, W. R. (2012). Increasing Persistence: Research-based Strategies for College Student success. https://www.amazon.com/Increasing-Persistence-Research-based-Strategies-College/dp/0470888431

[14] Braxton, J. M., Doyle, W. R., Hartley, H. V., Hirschy, A. S., Jones, W. A., & McLendon, M. K. (2013). Rethinking college student retention. http://ci.nii.ac.jp/ncid/BB17394375

[15] Doolittle, P., Wojdak, K., & Walters, A. (2023). Defining Active Learning: A Restricted Systemic Review. Teaching and Learning Inquiry, 11.

[16] González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks: Systematic review. Sustainability, 14(3), 1493. https://doi.org/10.3390/su14031493

[17] Stephen, J. S., & Rockinson-Szapkiw, A. J. (2021). A high-impact practice for online students: the use of a first-semester seminar course to promote self-regulation, self-direction, online learning self-efficacy. *Smart Learning Environments*, *8*(1). https://doi.org/10.1186/s40561-021-00151-0

[18] Prados, J. W., Peterson, G. D., & Lattuca, L. R. (2005). Quality assurance of engineering education through accreditation: The impact of Engineering Criteria 2000 and its global influence. Journal of engineering education, 94(1), 165-184.

[19] Webster, Rustin. (2019). A Learning-Centered Paradigm for Engineering Graphics and Design: Engineering Technology Students' Skill Gains and Sapstone Preparation. Journal of Engineering Technology. 37. 36-46.

[20] Spezia, C. J. (2009). A task-oriented design project for improving student performance. Journal of Engineering Technology, 26(1), 24-30. Retrieved from https://proxying.lib.ncsu.edu/index.php/login?url=https://www.proquest.com/scholarly-journals/task-oriented-design-project-improving-student/docview/1367095944/se-2

[21] Bonwell, C. C. & Eison, J. A. (1991). Active learning: Creating excitement in the classroom. ASHE-ERIC Higher Education Report No. 1. Washington, D.C.: The George Washington University, School of Education and Human Development.

[22] Gravetter, F. J., & Wallnau, L. B. (2018). *Essentials of statistics for the Behavioral Sciences*. http://ndl.ethernet.edu.et/bitstream/123456789/35021/1/24.pdf.pdf

[23] Min, Y., Zhang, G., Long, R. A., Anderson, T. J., & Ohland, M. W. (2011). Nonparametric survival analysis of the loss rate of undergraduate engineering students. Journal of Engineering Education, 100(2), 349-373.

[24] Zhuhadar, L., Daday, J., Marklin, S., Kessler, B., & Helbig, T. (2019). Using survival analysis to discovering pathways to success in mathematics. Computers in Human Behavior, 92, 487-495.

[25] President's Council of Advisors on Science and Technology (U.S.) & United States. Executive Office of the President. (2012). Report to the president, engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Executive Office of the President, President's Council of Advisors on Science and Technology.

[26] Main, J. B., Johnson, B. N., Ramirez, N. M., Ebrahiminejad, H., Ohland, M. W., & Groll, E. A. (2020). A case for disaggregating engineering majors in engineering education research: The relationship between co-op participation and student academic outcomes. International Journal of Engineering Education, 36(1), 170-185.

[27] Aiken, J. M., De Bin, R., Hjorth-Jensen, M., & Caballero, M. D. (2020). Predicting time to graduation at a large enrollment American university. PLOS ONE, 15(11), e0242334. https://doi.org/10.1371/journal.pone.0242334

[28] University of North Carolina. (2022). The UNC Policy Manual 400.1.5: Regulation Related to Fostering Undergraduate Student Success. Retrieved from https://www.northcarolina.edu/apps/policy/doc.php?id=157

[29] Sorby, S. A., & Baartmans, B. J. (2000). The development and assessment of a course for enhancing the 3-d spatial visualization skills of first year engineering students. Journal of Engineering Education, 89(3), 301–307. https://doi.org/10.1002/j.2168-9830.2000.tb00529.x