2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #52703

Expanding Engineering Graduate Pathways: Tracking Outcomes for Students from Non-Engineering Undergraduate Majors

Dr. Cynthia Howard-Reed, The Pennsylvania State University

Cindy Howard Reed is the Director of Graduate and Postdoc Equity and an Associate Teaching Professor in the College of Engineering at Penn State. She has a MS in Environmental Health Engineering and PhD in Civil Engineering from The University of Texas at Austin and received her BS in Civil Engineering from North Carolina State University. Prior to her position at Penn State, Dr. Reed conducted research in the field of indoor air quality at the Environmental Progection Agency and National Institute of Standards and Technology.

Dr. Jennifer X Wu, Pennsylvania State University

Jennifer Wu is the Chief Engineering Analytics Officer and Professor of Practice in the College of Engineering at Penn State. She has a PhD in Educational Administration from the University of Minnesota, Twin Cities. She has 30 years of experience in higher education, including managing student engagement programs, academic advising, and currently leading the College's analytics team. Jennifer leads the development and exploration of applied research questions that are fundamental to student success and institutional effectiveness in engineering education. Her office collaborates with stakeholders at all levels to provide data and insight that guide the day-to-day operations and support the strategic priorities of the College. She is also tasked by the university leadership to collaborate with the central institutional research office to provide consultation on data analytics for the academic deans.

Chenying Wang, Pennsylvania State University
Dr. Enrique D Gomez

Expanding Engineering Graduate Pathways: Tracking Outcomes for Students from Non-Engineering Undergraduate Majors

Abstract

A potential strategy to grow and diversify engineering graduate programs is to recruit prospective graduate students from non-engineering disciplines, particularly from institutions without undergraduate engineering degrees. Despite concerns about these students' quantitative preparation in mathematics and physical sciences, limited data exists on their graduate completion rates compared to peers with engineering undergraduate degrees. Tracking such outcomes is notoriously difficult due to the nonlinear nature of graduate education and the scarcity of comprehensive university data. For example, students may be graduating but with a master's degree instead of their intended PhD, or they started graduate school in engineering but completed their degree in a different field. To address this gap, we developed a custom dashboard tool that enables dynamic tracking and benchmarking of graduate student completion rates. The dashboard data includes cohorts of incoming graduate students from 2007 to present. A key feature of this dashboard is its ability to follow student pathways (e.g., capturing transitions between degree programs and departments) and disaggregate data by identity markers such as gender, race/ethnicity, age, and citizenship status. This capability allows us to analyze the trajectories of students entering engineering graduate programs from non-engineering majors and compare their outcomes (e.g., milestone completion rate, time to graduation, etc.) to those with traditional engineering preparation. Preliminary findings from this tool offer insights into student success patterns and inform targeted interventions. Ultimately, this work supports the strategic expansion of engineering graduate recruitment to include non-engineering students, with the goal of broadening participation in engineering graduate programs and related careers.

Introduction

Recent reports indicate that the supply of U.S. engineers is lagging behind the expected need for the workforce to maintain economic competitiveness [1], [2]. According to a report for SAE International, the U.S. needs 400,000 new engineers every year [3], a number that far exceeds the approximate 200,000 undergraduate and graduate students completing their degrees in engineering on an annual basis [4]. Compounding this deficit is the number of currently unfilled engineering jobs. A recent check of the website Adzuna revealed that there are over 750,000 open engineering opportunities in the United States [5].

There are several different strategies being tried to boost the supply of engineers in this country. A high priority academic strategy is to put more students on this path starting with K-12 outreach as well as targeting the recruitment of groups historically underrepresented in the engineering workforce (e.g., women and minoritized racial groups) [6]. However, these efforts can take many years to yield meaningful results and have been insufficient to meet the expanding demands of industry and manufacturing. And despite the extensive efforts to attract students to engineering degree programs, the "pipeline leaks" at the point of graduation, with over half of U.S. engineering graduates going on to pursue roles in other disciplines [3].

Another way universities can help address the need for more career engineers is to recruit undergraduate students from non-engineering majors into engineering graduate programs. As suggested by Corneal et al. [7], the juncture between undergraduate and graduate studies is a feasible time for students to switch majors. Factors motivating students to pursue an alternative path include difficulty in finding a job in their undergraduate major field and potentially increased salaries [8]. In addition, this recruiting approach might not only help grow engineering graduate programs, but help to diversify the engineering workforce as well. For example, there are over 700 Minority Serving Institutions (MSIs) in the United States, whose student population represents over 40% of all undergraduate students of color [9]. Not all MSIs offer bachelor's degrees in engineering, representing a lucrative graduate school recruitment opportunity.

A potential barrier to recruiting prospective graduate students without engineering undergraduate degrees is the perception that graduating with an engineering major is a requirement to pursue a master's or doctoral degree in engineering. In reality, most engineering schools do not require students to have a bachelor's degree in engineering in order to apply for their advanced degree programs. That being said, engineering graduate programs typically have an expectation that students will have strong quantitative training in mathematics and the physical sciences and may be reluctant to admit students from non-engineering backgrounds. However, there is little to no data comparing the retention and graduation rates of engineering graduate students based on their undergraduate degree major. In fact, tracking such outcomes is challenging due to the nonlinear nature of graduate education and inconsistencies across graduate departments [10]. For example, students may be graduating with a master's degree instead of their intended PhD, or they started graduate school in engineering but completed their degree in a different field.

To address this gap, the data team in the College of Engineering at Penn State recently developed a novel dashboard that has the capability of following students from their first semester in a specific graduate degree program to the point when they exit that particular path, either through graduation or attrition. By tracking student progress this way, we gain insights into several program and degree metrics, including retention and graduation rates. Example uses of the database include revealing equity gaps, "mastering out" trends, department timeline variations, etc. [11]. For this paper, we implemented the dashboard to answer the question of whether a graduate student's undergraduate major impacts retention in the graduate degree program they start in, graduation rates from that program, and time to graduation.

Methods

To determine the impact of undergraduate major on graduate school outcomes, we linked applicant information for enrolled students to their trajectory through graduate school as compiled in an existing database.

Graduate Student Retention and Graduation Dashboard

The Power BI platform was used to visualize the graduate student database with an interactive dashboard organized by student identity, program and degree enrollment, and outcomes. Student data was grouped into cohorts according to the semester they started their graduate degree. There are multiple pathways to track students based on their major and degree track. For example, it is possible to follow a student's trajectory that starts on a specific graduate degree track (MS, MEng or PhD) in a college of engineering department and ends up on a different degree track in any major at the university. The data used for this paper's question includes cohorts starting in Fall 2016 to Fall 2024, for a total of 9 cohorts.

The size of the cohort is based on all the different college of engineering major/degree counts of the students for the corresponding levels. So, it is possible for a single student to be included in multiple cohorts if they begin new degrees (e.g., MS and then a PhD) or switch to a new engineering major within their degree (e.g., PhD in mechanical engineering to a PhD in nuclear engineering). The dashboard also provides filters to allow users to disaggregate cohort data according to many different factors, including previous enrollments, milestone exam status, gender, race/ethnicity, citizenship, and engineering department.

While the literature identifies a range of factors that influence student persistence, such as financial support, mentoring, research experience, academic integration, sense of belonging, and socialization [12], [13], these data are not systematically captured in existing university data systems and thus cannot be incorporated into the dashboard or this analysis. As a result, the observed differences in outcomes should be interpreted as descriptive patterns, with underlying mechanisms inferred rather than directly measured.

Once the cohort characteristics are defined, the user can see the associated retention rates, graduation rates and time to degree for a given major/degree track pathway. A student is considered retained if they are still enrolled in their graduate program or successfully completed their graduate degree. The associated retention rate for a specific cohort is the number of retained students in that cohort divided by the cohort size. Similarly, the graduation rate is the number of students who obtain their graduate degree divided by the associated cohort size. Time-to-degree is based on the number of academic semesters it takes a student to graduate (summer semesters are not included in the count). If a student started their MS degree in the Fall of 2020 and graduated in the Summer of 2022, then their time to degree is 4 semesters. If it takes that student an additional semester such that they finish in Fall 2022, then their time to degree is counted as 5 semesters.

Undergraduate Major Data

For this paper, we pulled undergraduate major (UGM) information from graduate school applications submitted by the graduate students enrolled in the applicable cohorts. For new graduate students enrolled between Fall 2016 and Fall 2024, there were 371 unique undergraduate majors listed on their graduate school applications. To classify a UGM as an engineering major or not, we used the 2020 Classification of Instructional Programs taxonomic scheme [14] and grouped majors in the following four categories: "Engineering," "STEM," "STEM Education," and "Non-STEM." Majors from international institutions were manually added to the most appropriate category. If the UGM was missing from the student's application, their major was classified as "N/A" and not included in the analysis. Due to relatively small numbers in the Non-STEM and STEM Education categories, we pooled their values with those in the STEM category and created a combined category called "Non-Engineering." Table 1 provides a distribution of the unique majors included, as well as the associated student head count and cohort sizes.

Table 1. Undergraduate Major (UGM) grouping of graduate students for cohorts from 2016 – 2024

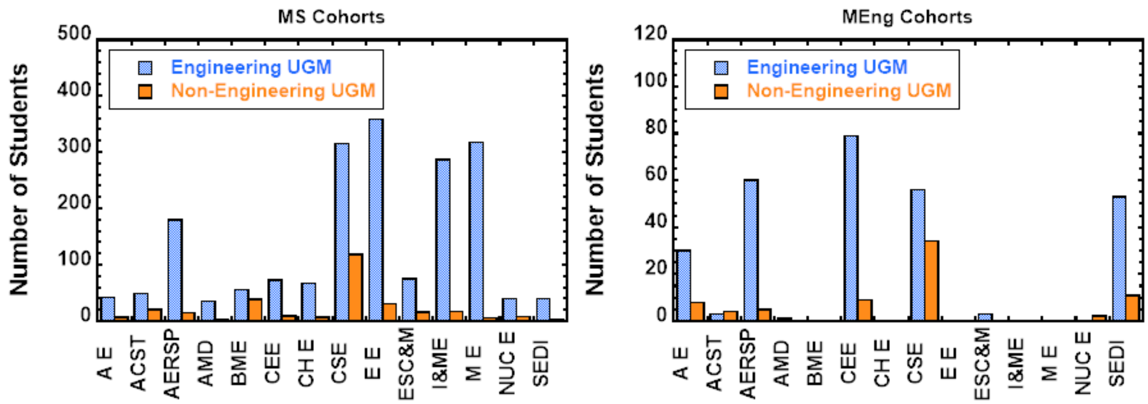
UGM Grouping	Unique Major Count	Student Head Count	PhD Cohort Size	Masters Cohort Size
Engineering	231	3,414	1,911	2,220
Non-Engineering	140	598	325	368
STEM	*97*	*521*	*285*	*321*
Non-STEM	*41*	*75*	*39*	*46*
STEM Education	*2*	*2*	*1*	*1*
TOTAL	**371**	**4,012**	**2,236**	**2,588**

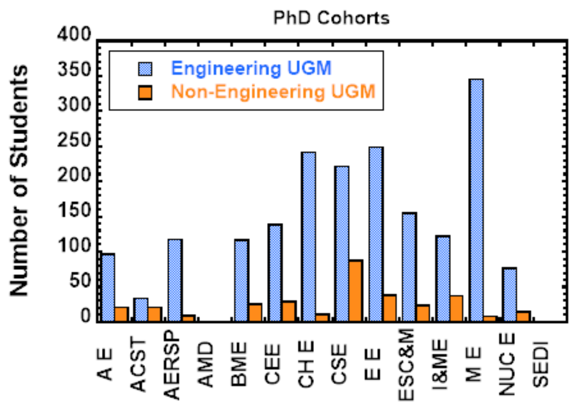
The student enrollment data for Fall 2016 – Fall 2024 were matched with their application data allowing for a separate filter in the dashboard to disaggregate outcomes based on type of undergraduate major. For this paper, we applied the most conservative definition of retention and tracked student's paths for the degree and discipline that they started in. For example, if a student started in a PhD program but graduated with a master's degree, they would not be considered retained for the PhD program. Similarly, if a student started in a Biomedical Engineering PhD program but switched to Mechanical Engineering or Biology to finish their PhD degree, they, too, would not be counted as a successful graduate.

Results

To determine the extent to which engineering disciplines at the university are already enrolling graduate students with non-engineering UGMs, we disaggregated each cohort by graduate department/program. As shown in Figure 1, some departments/programs at Penn State are more likely to already admit students with non-engineering backgrounds. For example, biomedical engineering, acoustics and computer science MS enrollments between Fall 2016 and Fall 2024 consisted of more than 25% students with non-engineering undergraduate degrees. In contrast, mechanical engineering, industrial & manufacturing engineering, and additive manufacturing design enrolled fewer than 6% of their MS students with non-engineering UGMs. A similar trend is seen for PhD cohorts with acoustics and computer science accommodating more non-engineering students, especially compared to mechanical engineering, chemical engineering and aerospace engineering.

To compare outcomes for students with engineering UGMs vs. non-engineering UGMs, the cohorts were separated based on degree track (MS, MEng and PhD). Figure 2 shows the retention and graduation rates for MS students during the first 5 years after a cohort start. Each data point represents the average retention or graduation rate across the applicable cohorts. Therefore, nine cohorts (2016 – 2024) were used to determine the average one-year retention or graduation rate, and five cohorts (2016 – 2020) were used to determine the average retention and graduation rates at five years.





Department/Program Abbreviations:
AE = Architectural Engineering
ACST = Acoustics
AERSP = Aerospace Engineering
AMD = Additive Manufacturing Design
BME = Biomedical Engineering
CEE = Civil and Environmental Engineering
CHE = Chemical Engineering
CSE = Computer Science and Engineering
EE = Electrical Engineering
ESC&M = Engineering Science and Mechanics
I&ME = Industrial and Manufacturing Engineering
ME = Mechanical Engineering
NUCE = Nuclear Engineering
SEDI = School of Engineering Design and Innovation

Figure 1. Department/Program cohorts disaggregated by degree track, department and UGM.

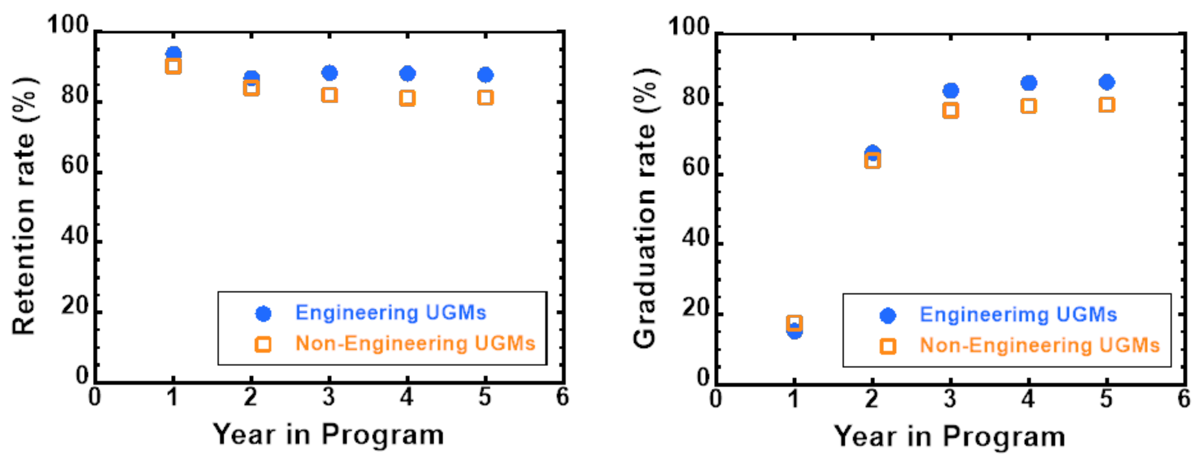


Figure 2. Average retention and graduation rates for MS students who stayed in same degree track and major.

On average, MS students with traditional engineering preparation were retained at a higher rate than their non-engineering counterparts, with the largest difference seen in years 3 to 5 after starting. Similarly, students with engineering backgrounds tended to graduate at a higher rate than students who started with a non-engineering UGM. The four-year completion rates for both UGM groups exceed the reported national average completion rate for engineering MS degrees of 65% [15].

We conducted a similar analysis for MEng students whose cohort size at Penn State represents a smaller population than MS. In general, the difference between the two types of master's degrees is a research thesis. The MS degree typically requires a thesis whereas the MEng degree is usually based on coursework and designed to be completed in about one year. Not all departments at Penn State offer an MEng option (see Figure 1). As shown in Figure 3, the retention and graduation rates for MEng students are similar for engineering and non-engineering UGMs. Compared to MS values, the MEng graduation rates for years 3 to 5 after starting the program reach higher percentages.

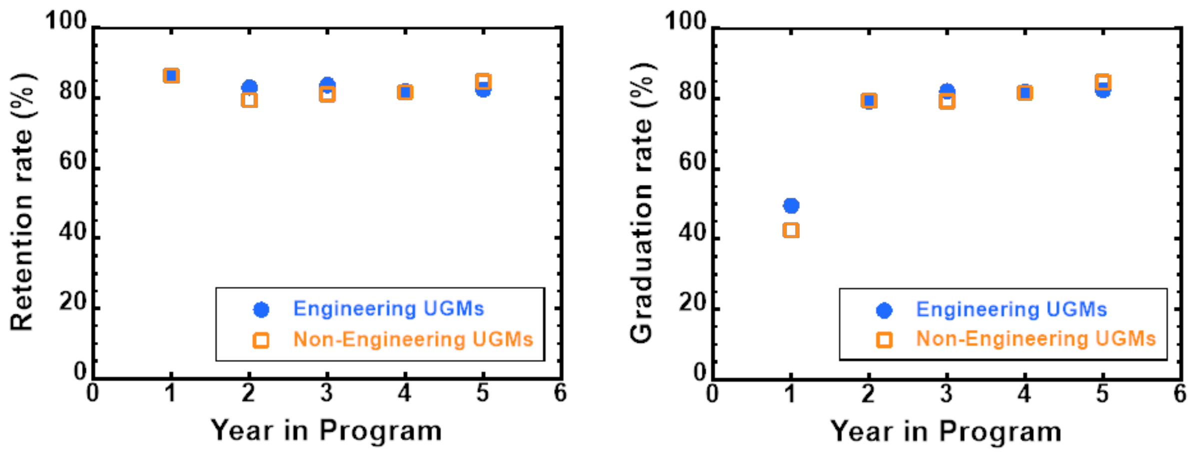


Figure 3. Average retention and graduation rates for MEng students who stayed in same degree track and major.

For PhD students, we compared retention and graduation rates up to 7 years after the cohort started (see Figure 4). So, only three cohorts (2016 – 2018) were averaged for the data points at 7 years. In general, average PhD retention rates were higher for students with engineering backgrounds with the most noticeable difference at 3 and 5 years after program start. Students with non-engineering backgrounds also tended to graduate at a lower rate than students with engineering backgrounds for a given year after program start. As seen with the Master's cohorts, the seven-year PhD completion rates for both groups track higher than those reported in the Ph.D. completion project (< 60% at seven years) [16].

To determine if any of the noted differences in retention and graduation rates shown in Figures 2 to 4 are statistically significant for a given cohort year, we used a two-proportion z-test with a significance level of 0.05. The null hypothesis stated that the proportions are equal such that there is not a significant difference between the retention and graduation rates for students coming to graduate school with a background in engineering vs. students who do not. Therefore, for differences with a p-value < 0.05, the null hypothesis is rejected, and the proportions are not considered to be equal making the difference in rate statistically significant. The statistical analysis is summarized in Tables 2 to 7.

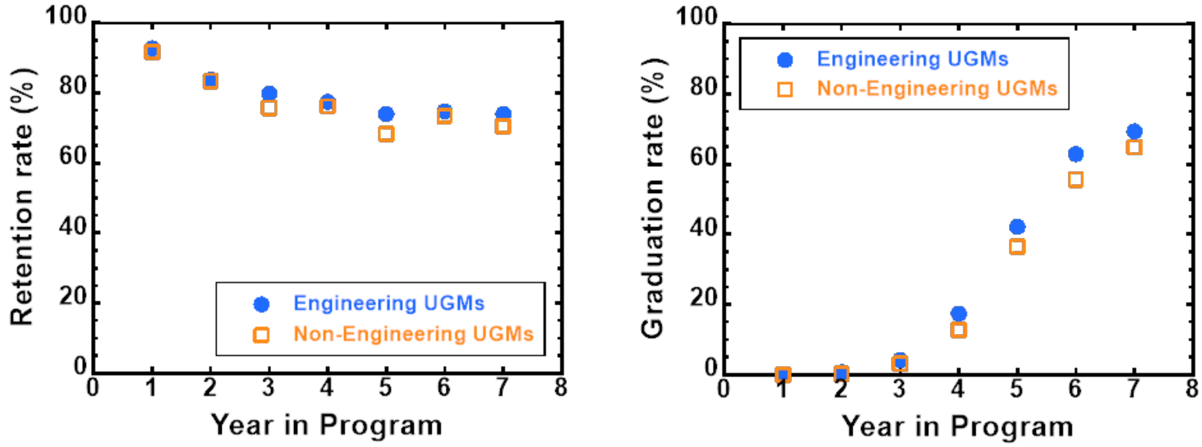


Figure 4. Average retention and graduation rates for PhD students who stayed in same degree track and major.

For all three degree tracks, the only one with a significant difference in outcomes based on UGM is the MS track. As shown in Table 2, the difference in retention rate for Engineering UGM MS students is significantly higher than the non-Engineering UGM students for each year except after year 2. The MS graduation rate curve also peaks at a significantly higher value for engineering UGM students compared to those with non-engineering UGMs. The lack of significance detected for MEng students may be at least partially attributed to the smaller pooled populations.

Table 2. MS retention rates based on undergraduate majors

Enrolled Year after Starting	Engineering UGM (#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
1	93.6% (1935)	90.2% (295)	2.15	0.031*
2	86.8% (1729)	83.9% (254)	1.26	0.208
3	88.3% (1494)	81.9% (215)	2.65	0.008*
4	88.1% (1273)	81.1% (180)	2.63	0.008*
5	87.7% (1030)	81.2% (138)	2.13	0.033*

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Table 3. MS graduation rates based on undergraduate majors

Graduation Year after Starting	Engineering UGM (#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
1	15.3% (1935)	17.6% (295)	1.01	0.311
2	66.1% (1729)	63.8% (254)	0.72	0.471
3	83.8% (1494)	78.1% (215)	2.08	0.037*
4	86.0% (1273)	79.4% (180)	2.33	0.020*
5	86.2% (1030)	79.7% (138)	2.03	0.042*

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Table 4. MEng retention rates based on undergraduate majors

Enrolled Year after Starting	Engineering UGM (#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
1	86.3% (285)	86.3% (73)	0	1.0
2	83.0% (259)	79.4% (63)	0.67	0.502
3	83.7% (233)	81.0% (58)	0.49	0.623
4	81.9% (210)	81.6% (49)	0.049	0.961
5	82.4% (176)	84.6% (39)	0.33	0.742

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Table 5. MEng graduation rates based on undergraduate majors

Graduation Year after Starting	Engineering UGM (#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
1	49.5% (285)	42.5% (73)	1.07	0.285
2	79.2% (259)	79.4% (63)	0.035	0.972
3	82.0% (233)	79.3% (58)	0.47	0.636
4	81.9% (210)	81.6% (49)	0.049	0.961
5	82.4% (176)	84.6% (39)	0.33	0.742

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Table 6. PhD retention rates based on undergraduate majors

Enrolled Year after Starting	Engineering UGM(#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
1	92.7% (1911)	91.7% (325)	0.63	0.526
2	83.7% (1721)	83.3% (294)	0.17	0.864
3	79.7% (1528)	75.7% (259)	1.46	0.143
4	77.4% (1257)	76.1% (213)	0.42	0.676
5	74.0% (979)	68.3% (167)	1.54	0.124
6	74.7% (731)	73.4% (124)	0.31	0.759
7	74.0% (512)	70.5% (88)	0.69	0.492

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Table 7. PhD graduation rates based on undergraduate majors

Graduation Year after Starting	Engineering UGM (#)	Non-Engineering UGM (#)	z-statistic	p-value[a]
4	17.4% (1257)	12.7% (213)	1.7	0.089
5	42.1% (979)	36.5% (167)	1.36	0.174
6	62.9% (731)	55.6% (124)	1.55	0.122
7	69.3% (512)	64.8% (88)	0.84	0.401

[a]Significance level determined with two-proportion z-test ($p<0.05$)*

Although the differences in PhD retention rates between engineering and non-engineering undergraduate majors are not statistically significant at the 0.05 level, a consistent pattern emerges at specific time points. As shown in Table 6, the largest differences occur at years 3, 5, and 7 after program start. These time points align with key transition phases in doctoral education including progression to candidacy, advancement into the dissertation stage, and latestage degree completion. Prior research has shown that doctoral persistence is not uniform across time, but instead varies by stage, with different factors influencing student progression at different phases of the PhD pathway [12], [17].

This pattern suggests that differences in undergraduate preparation may not meaningfully impact early persistence, which is typically structured around coursework and program requirements, but may instead manifest during later stages when students are expected to operate with greater independence. At these points, factors such as research preparedness, advisor alignment and access to sustained funding may play a more critical role in shaping student trajectories. Existing literature highlights the importance of academic integration, mentoring relationships, and disciplinary socialization in supporting doctoral persistence, particularly during the transition from structured coursework to independent research [13], [18].

It is also important to note that the smaller sample size for non-engineering undergraduate majors, particularly in later years (e.g., year 7), reduces statistical power and limits the ability to detect significance even when moderate differences are observed. Therefore, while these findings should be interpreted with caution, the consistency of the pattern across multiple transition points suggests a meaningful directional trend that warrants further investigation.

The final graduate school outcome that we compared based on undergraduate majors is the number of semesters to degree completion (see Figure 5). Across all nine cohorts, students with Engineering UGMs completed an MS degree in an average of 4 semesters, which was the same average time to a MS degree for students with non-engineering majors. The non-engineering UGM cohorts showed greater variability in time to degree with an interquartile range (IQR) of 2 semesters compared to 1 semester for engineering UGM cohorts. Both major types had 95th percentile completion values of 6 semesters.

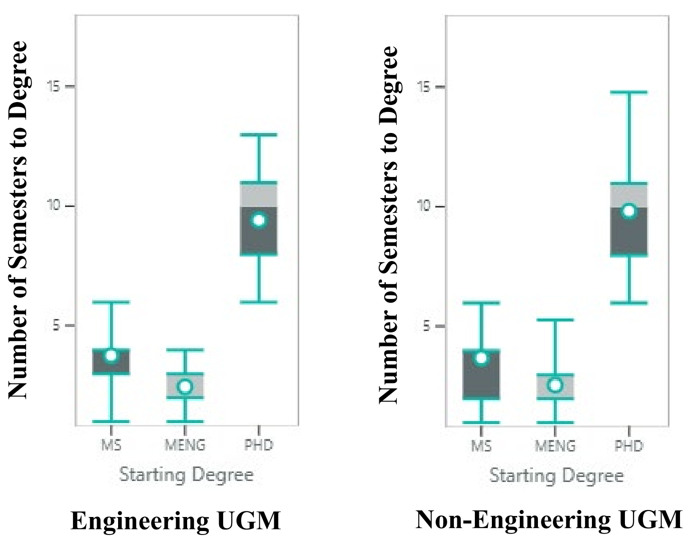


Figure 5. Number of semesters to degree by starting degree track and cohort for students with engineering UGMs compared to those with non-engineering UGMs.

For MEng cohorts, it took the non-engineering UGMs an average of 3 semesters to complete their degree, which is one more semester than the average time to completion for students starting with an engineering background. Although the IQR for MEng students across both incoming major types was 1 semester, the 95th percentile completion rate for non-engineering UGM students was 5 semesters compared to 4 semesters for students with engineering UGMs.

Finally, PhD students with engineering UGMs completed their PhD in an average of 9 semesters across all cohorts with a 95th percentile completion rate of 13 semesters. In general, PhD students with non-engineering UGMs took longer to complete their degrees with an average time to graduation of 10 semesters and a 95th percentile completion rate of 15 semesters. One possible interpretation is that students from non-engineering undergraduate backgrounds may require additional time to fully integrate into the research environment or adapt to discipline-specific expectations, particularly in less structured phases of the PhD.

Conclusions

Students who start engineering graduate programs with non-engineering undergraduate degrees will likely experience different outcomes than students starting with a traditional engineering background. Our university's data show that significantly fewer students with a non-engineering UGM will complete a MS engineering degree than students starting with engineering UGMs. It will also take about a semester longer for students with a non-engineering degree to complete a MEng or PhD than their engineering counterparts. Notably, differences in PhD retention appear to emerge at key transition points in the doctoral pathway rather than in the early years, suggesting that targeted interventions at these stages may be more effective than broad early-stage support alone.

Although these differences exist, it may not preclude the enrollment of graduate students to engineering programs with non-engineering UGMs. The overall graduate school completion rates of students with non-engineering UGMs at our university is similar to rates observed in literature, as we see about 78% of MS students complete their degree within 3 years and 65% finish their PhD degree within 7 years. The comparable graduate degree completion rate among students with non-engineering UGMs may be explained by the additional semester they typically require to complete the program. Their slightly longer time-to-degree may simply reflect the additional coursework or skill-building needed to bridge foundational gaps.

There are also proven strategies to improve the outcomes for students starting engineering programs with non-engineering UGMs. For example, other universities have used summer bridge programs to aid the transition from undergraduate to graduate schools [7], [19]. Adopting similar models within engineering graduate programs could help close preparation gaps and increase enrollment of students without engineering UGMs while still maintaining academic rigor.

Future work may examine whether certain engineering disciplines are especially well-suited to recruiting students from non-engineering backgrounds. These insights will inform more strategic, data-informed recruitment and advising practices, thereby helping engineering graduate programs expand their talent pipelines, diversify academic pathways, and open doors to students whose previous academic experiences may enrich the engineering profession.

References

[1] American Council of Engineering Companies, "The Workforce Reality Check Engineering Can't Afford to Ignore," 4 November 2025. [Online]. Available: https://engineeringinc.acec.org/last-word-blog/. [Accessed January 2026].

[2] RS Group, "The 2024 RS engineering talent shortage report," 18 October 2024. [Online]. Available: https://us.rs-online.com/expert/category/expert-advice/. [Accessed January 2026].

[3] Boston Consulting Group, "The US Needs More Engineers. What's the Solution?," *BCG Featured Insights,* pp. 1 - 11, 13 December 2023.

[4] National Center for Education Statistics, "Integrated Postsecondary Education Data System," NCES, 2026. [Online]. Available: https://nces.ed.gov/ipeds/. [Accessed 2026].

[5] Adzuna, "Job Search - Find Every Job, Everywhere with Adzuna," [Online]. Available: https://www.adzuna.com/. [Accessed January 2026].

[6] J. M. Valla and W. M. Williams, "Increasing Achievement and Higher-Education Representation of Under-Represented Groups in Science, Technology, Engineering, and Mathematics Fields: A Review of Current K-12 Intervention Programs," *Journal of Women and Minorities in Science and Engineering,* vol. 18, no. 1, pp. 21 - 53, 2012.

[7] L. Corneal, S. Manoharan and S. Rhodes, "Onboarding Engineering Graduate Students from Non-Engineering Undergraduate Majors," in *2024 ASEE Annual Conference & Exposition*, Portland, 2024.

[8] U.S. Bureau of Labor Statistics, "Occupational Employment and Wage Statistics," May 2024. [Online]. Available: https://data.bls.gov/oes/#/industry/000000.

[9] M. Gasman and T.-H. Nguyen, "Historically Black Colleges and Universities as Leaders in STEM," Penn Center for Minority Serving Institutions, Philadelphia, 2016.

[10] M. E. Young, M. Miller, C. Urban and C. Petrescu, "Tracking Student Progress through Graduate Programs," *Discover Education,* vol. 3, no. 43, 2024.

[11] E. Gomez and C. G. P. Berdanier, "Introducing a Virtual Dashboard to Benchmark and Monitor Engineering Graduate Degree Retention Trends at Penn State," in *2025*

Collaborative Network for Engineering & Computing Diversity (CoNECD), San Antonio, 2025.

[12] F. D. Ampaw and A. J. Jaeger, "Compleing the Three Stages of Doctoral Education: An Event History Analysis," *Research in Higher Education,* vol. 53, no. 6, pp. 640-660, 2012.

[13] S. K. Gardner, "Faculty Perspectives on Doctoral Student Socialization in Five Disciplines," *International Journal of Doctoral Studies,* vol. 5, pp. 39-53, 2010.

[14] National Center for Education Statistics, "The Classification of Instructional Programs," 2020. [Online]. Available: https://nces.ed.gov/ipeds/cipcode/Default.aspx?y=56.

[15] Council of Graduate Schools, "Completion and Attrition in STEM Master's Programs: Pilot Study Findings," Council of Graduate Schools, Washington, D.C., 2013.

[16] R. Sowell, T. Zhang, N. Bell and K. Redd, "Ph.D. Completion and Attrition: Analysis of Baseline Demographic Data from the Ph.D. Completion Project," Council of Graduate Schools, Washington, D.C., 2008.

[17] Council of Graduate Schools, "Ph.D. Completion and Attrition: Analysis of Baseline Demographic Data from the Ph.D. Completion Project," Washington, D.C. , 2008.

[18] C. Golde, "The Role of the Department and Discipline in Docotroal Student Attrition: Lessons from Four Departments," *The Journal of Higher Education,* vol. 76, no. 6, pp. 669-700, 2005.

[19] University of Maryland, Baltimore County, "Meyerhoff Graduate Fellows Program," [Online]. Available: https://meyerhoffgrad.umbc.edu/program-benefits/summer-bridge-program/?msclkid=232f4f73d4a81f74ba802603e357ac59. [Accessed January 2026].