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Improving Recruitment and Retention: A Management Framework to Utilize DMAIC and Kaizen for Student Support in Engineering Education

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Abstract: The Clay N. Hixson Student Success Center within the College of Engineering at Tennessee Tech University has undergone a transformative upgrade by integrating the Define, Measure, Analyze, Improve, and Control (DMAIC) framework with select Kaizen principles for continuous improvement to enhance student support services. Key performance indicators (KPIs) have been employed to assess the achievement of core goals, significantly advancing recruitment, retention, and overall student success. Implementing the DMAIC framework has streamlined processes such as a unified degree map and a math bridge program, resulting in a 53% increase in incoming first-year students and broadening the College of Engineering's outreach. These efforts have also contributed to a 10% increase in first-to-second-year retention rates. Through the utilization of DMAIC, the regular redistribution of advisor caseloads and cross-training has been facilitated, ensuring timely student support without overburdening advisors. Additionally, targeted academic support initiatives have reduced the at-risk student population from 19% to 11%. These management techniques extend to multiple initiatives, including enhancements to high school summer camps, advisor listening sessions, and student surveys designed to meet evolving student needs. Creating specialized areas for academic advisors has also supported their professional growth, contributing to better student outcomes. This paper comprehensively analyzes these strategies and provides valuable insights for institutions seeking to apply DMAIC and continuous improvement models to strengthen student support systems.

Keywords: DMAIC; engineering education; engineering management; recruitment; retention; student success

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1. Introduction

The challenge of student success in engineering undergraduate education has long been a focal point due to the field's historically high attrition rates [1]. This issue is increasingly critical as the U.S. Department of Labor forecasts a growth of 11% in STEM occupations by 2031 [2], while data from the National Center for Education Statistics reveal a concerningly high attrition rate among engineering and computing majors [3–5]. Addressing these challenges involves exploring effective strategies for enhancing student retention, recruitment, and overall engineering and higher education support. A broad array of research has examined the underlying factors contributing to attrition [6,7] and analyzed specific success tools [8]. In this context, universities must tackle the essential question: "What actions can be taken to support engineering students in persisting toward

their degree within the unique framework of their programs?" It is crucial to recognize that "retention is a campus-wide effort" [9].

At Tennessee Tech University, the College of Engineering (CoE) has responded to this challenge by significantly enhancing its student support services, driven by the Student Success Center (SSC). Established in 2015, the SSC has evolved from a modest team focused on at-risk advising and student professional development to a robust unit with two Directors, seven academic advisors, and a comprehensive array of programs. These initiatives are strategically aligned with its mission to advance recruitment, retention, and student success, which supports the state's objective to boost higher education enrollment [10] and address the growing demand for STEM education [11]. The SSC's mission also complements Tennessee Tech University's strategic goals of increasing freshmen-to-sophomore retention rates from 75% to 82% and achieving a 50% four-year graduation rate by 2025 [12].

In recent years, the SSC has experienced substantial growth, intensifying its recruitment efforts, implementing evidence-based retention practices, and fostering professional development among staff. This paper examines the transformative integration of engineering management principles, specifically the Define, Measure, Analyze, Improve, and Control (DMAIC) framework and Kaizen which incorporate Lean Six Sigma concepts, into the SSC's operations. DMAIC is a data-driven methodology used to optimize processes and solve problems systematically, while Kaizen emphasizes continuous improvement through small, incremental changes involving all stakeholders. The SSC has advanced its core goals by employing key performance indicators (KPIs). The application of these methodologies has streamlined processes. This paper provides a comprehensive analysis of these initiatives, offering insights into how institutions can leverage the DMAIC framework and continuous improvement principles to elevate their student support services.

2. Systematic Approach and Engineering Methodology in Improving Education and Engineering Education

Adopting a systematic and engineering-based approach in engineering education is essential for addressing complex challenges and driving continuous improvement. The engineering-based approach to organization discussed in this paper emphasizes structured methodologies, such as DMAIC and Kaizen, for improving recruitment and retention in higher education. DMAIC is a structured, linear framework used to improve processes by focusing on five key steps. First, it encourages clearly defining the problem or goal (Define), followed by gathering and analyzing data to understand current performance (Measure and Analyze). The framework then moves to implementing improvements based on the data analysis (Improve), and finally, it involves monitoring the process to ensure the improvements are sustained (Control). This evidence-based approach helps to ensure that changes are data-driven and aligned with institutional objectives. Kaizen, on the other hand, complements DMAIC by offering a cyclical process that emphasizes small, incremental improvements over time. In Kaizen, solutions are tested and refined through repeated cycles, allowing for continuous adaptation and adjustment. The focus is on fostering a culture of ongoing improvement, where problems are regularly identified and solved to create better, more efficient processes. While DMAIC provides a structured framework for problem-solving, Kaizen offers a methodology to maintain continuous momentum toward improvement. Together, DMAIC and Kaizen help institutionalize systematic thinking in education. These methodologies encourage data-driven decision-making, process optimization, and iterative problem-solving. By using both frameworks, educational institutions can continuously enhance their processes, ensuring that interventions are effective, sustainable, and aligned with their broader goals.

This approach aligns with Weber's Bureaucratic Rationalism, relying on efficiency, clear processes, and rational structures. However, it extends these principles by integrating contemporary engineering tools to address dynamic challenges in educational settings. Systematic thinking involves applying such methodologies to analyze and enhance educational processes, ensuring that interventions are effective and aligned with institutional goals. This approach emphasizes the importance of data-driven decision-making, process optimization, and iterative problem-solving. Weber's foundational work on organizational theory [13], emphasizing bureaucratic principles such as efficiency and rational structures, and Balzer's research on applying process improvement methodologies like Lean to higher education [14] provide a foundational framework for this discussion. These works illustrate how process-oriented strategies can enhance institutional performance and inform the adoption of systematic methodologies such as DMAIC and Kaizen in addressing challenges in higher education. Engineering thinking brings a discipline of rigorous analysis and methodical planning to educational practices. It involves breaking down complex problems into manageable components, identifying root causes, and applying engineering principles to develop and implement solutions. By leveraging these methodologies, educational institutions can systematically improve recruitment, retention, and overall student support, ultimately fostering a more effective and responsive educational environment.

DMAIC and Kaizen have been shown to offer various benefits across sectors; in particular, engineering education stands to gain significantly from these systematic approaches, especially when addressing specific challenges related to curricula, teaching techniques, and educational tools. Higher education institutions, including CoEs, often operate as loosely coupled systems [15] and exhibit resistance to rational, process-oriented frameworks [16]. These complexities highlight the need to balance systematic approaches with an understanding of institutional dynamics. By integrating structured engineering methodologies, such as DMAIC and Kaizen, within this context, institutions can achieve targeted improvements while navigating higher education's broader, less predictable environment.

Engineering education in the US has historically emphasized "weeding out" students based on perceived ability, influenced by factors like family background and access to resources [17]. This traditional approach reflects outdated practices that prioritize strict performance criteria over potential. To address these issues, engineering education must adopt a more student-centered approach, similar to modern practices focusing on development and personalized support by creating flexible pathways, offering targeted resources, and fostering a culture of continuous learning and adaptability. Zhang et al. [15] underscore the variability in the Internal Rate of Return (IRR) across different college majors, revealing that engineering and computer science fields offer the highest IRRs, exceeding 13%. This IRR is calculated by including lifetime costs and discounting future costs and benefits to their present value [18]. The findings highlight the importance of aligning educational investments with market demands, echoing engineering management principles, such as optimizing resource allocation and maximizing value.

Lifelong learning is essential for engineering educators in today's dynamic global environment, aligning with continuous improvement and engineering management principles. A study by Lantad and Nunez [19] systematically identifies challenges and proposes strategies to enhance the professional development of educators, emphasizing student-centered approaches and educational innovation. These strategies support the ongoing refinement of teaching methodologies by fostering increased faculty–student interactions and adopting iterative improvement practices. These efforts mirror engineering management's focus on optimizing processes and outcomes through structured, continuous enhancement. The findings highlight the importance of adopting a continuous improvement mindset, as found in the DMAIC framework in educational settings, to prepare future engineers effectively.

This approach benefits educators and students and contributes to the overall excellence and adaptability of universities worldwide.

Continuous Quality Improvement (CQI), a core component of Lean, is also a tool that can be used in engineering education to meet evolving job market demands and technological advancements [20]. Ihsan and O. Khalifa [20] discuss the role of CQI in enhancing educational processes through innovation, evidence-based practices, and regular evaluations. Their paper presents a model for assessing student learning outcomes and integrating CQI with outcome-based approaches, highlighting its importance in maintaining relevance and quality in engineering programs. Lean principles, such as CQI, facilitate knowledge sharing and continuous improvement by visually representing problem-solving methods and communication strategies [21].

Six Sigma, which uses DMAIC, is a methodology that can be adapted to education. Hoerl and Snee [22] describe Six Sigma as a data-driven quality improvement methodology that reduces process variations, enhances efficiency, and increases effectiveness. While originally developed for manufacturing, its studying and minimizing variation principles can offer value when carefully adapted to educational contexts, such as recruitment, retention, and student support services [23]. The successful application of Six Sigma in education requires recognizing the unique characteristics of educational processes, including the complexity of human interactions and the difficulty in quantifying qualitative outcomes like learning and personal growth. Previous studies [24] emphasize the importance of defining clear performance measures tailored to the educational context and focusing on improvement opportunities that align with institutional goals. The application of Six Sigma tools in research and development (R&D) settings requires a different approach than in the manufacturing industry [25]. Nasseri et al. [26] review existing Lean models in education, identify key elements for a new model, and propose a framework based on Lean World-Class Manufacturing (LWCM) and Lean Six Sigma. The model aims to reduce waste in academic settings, enhancing retention, graduation rates, and overall student success.

What applies to Lean Six Sigma in the service sector, including education and engineering education institutions, also applies to other engineering management concepts like 5S and Kaizen. Successful implementation leads to improved organization, efficiency, and a better work environment, fostering team spirit, employee morale, and job satisfaction through continuous, low-cost improvements [27]. Kaizen in education should align with the institution's strategic direction for effective implementation, focusing on creating value for students through simplicity, quality, speed, and cost efficiency. A culture of excellence rooted in Kaizen principles can sustain continuous improvement efforts, overcoming past failures in education with committed leadership and a focus on breaking down resistance to change [28].

Once primarily used in industrial contexts, engineering management methodologies [28–31] can be adapted to enhance engineering higher education. A study by Platis and Fragouli [32] examines the application of the European Foundation for Quality Management (EFQM) model, a key tool in Total Quality Management (TQM), to enhance administrative structures in higher education. By using interviews and statistical analysis, the research identifies the key TQM elements and their impact on service quality. The findings highlight strong positive relationships between the EFQM model's enabler criteria—such as human resources, processes, leadership, and cooperation—and the result criteria of educational institutions. The study underscores the EFQM model's potential for achieving organizational excellence and suggests that improvements in leadership, strategy, and other enablers will positively influence overall performance and service quality.

There is much evidence that engineering management techniques have had a positive impact on education and education support practices in a variety of contexts, and this paper

will focus on a methodology of how DMAIC and Kaizen can be utilized for student support in recruitment, retention, and readiness. Sections 3–5 provide an overview of the SSC's goals, objectives, and activities pertaining to recruitment, retention, and academic advising, respectively. The DMAIC and Kaizen frameworks are applied to the various activities.

3. Student Recruitment and Stakeholder Management

Recruiting skilled and diverse students is a focus for the CoE, aligning with the university's strategic plan to increase enrollment by 18% in 5 years. The Clay N. Hixson SSC promotes student success via community outreach and involvement. It prioritizes stakeholder needs and collaborates to drive its projects and to improve recruitment, retention, and readiness while ensuring continuous improvement.

The university's Office of Admissions sponsors several activities and events in which the SSC participates, including the VIP Program, Preview Day, and Spring Showcase. The VIP Program, managed by the CoE's SSC, is an entryway for potential students and their families to experience the university's dynamic environment. The KPIs used to evaluate these recruitment efforts include the number of potential students reached and the number of VIP visits conducted for stakeholder identification, the number of attendees at Preview Day for engagement and communication, the enrollment conversion rate of Spring Showcase attendees and satisfaction survey results from event attendees for measuring satisfaction and feedback, and the increase in transfer student enrollment rates for relationship management and process improvement. In integrating stakeholder management principles into student recruitment, the SSC employs the strategies described below.

3.1. Identification of Stakeholders

Identifying and involving key stakeholders, such as prospective students, current students, faculty, staff, and community partners, is not limited to one program or event but is an ongoing practice with planning, communication, and evaluation across the SSC's multiple outreach efforts. For VIP visits, the admissions office coordinates with the CoE's SSC to create a personalized experience for each visitor. Working with academic departments, the SSC carefully plans tours that include thorough explorations of program facilities, introductions to notable faculty, and meaningful interactions with current students. These tours offer more than just a view of the campus; they provide an immersive glimpse into the academic experience, helping prospective students picture themselves as part of Tech's vibrant learning community. Faculty members typically lead these visits, presenting overviews of their departmental offerings. Through efficient organization, the SSC was able to inform over 850 potential students in 2023 alone.

3.2. Engagement and Communication

Actively engaging stakeholders in the planning and execution of events and initiatives ensures that their needs and expectations are met. In addition to the weekly campus visit program, the SSC leads the college-level planning, organization, and execution of Preview Day. This event targets students who have yet to apply to Tennessee Tech University and are exploring other universities and programs. Preview Day involves extensive collaboration among faculty, staff, and students from various departments, with the SSC serving as the central coordinator. This role includes identifying volunteers, developing itineraries, and ensuring seamless communication with the Office of Admissions, highlighting the importance of effective stakeholder management.

Preview Day showcases the CoE's majors, concentrations, and labs through the efforts of faculty, staff, and students. Running from 8:00 a.m. to 2:00 p.m., this event features the following: an academic tent where all college majors are represented; a student organization

fair with tables set up by engineering student groups such as the Baja, Formula, SAE aero design, Steel bridge, IEEE, Tau Beta Pi, All Ladies in Civil Engineering, Women in Cybersecurity, and National Society of Black Engineers; and departmental tours and open houses. In 2023, 382 high school students showed interest in engineering, with over 120 engineering faculty, staff, and students contributing to this event.

3.3. Satisfaction and Feedback

Maintaining clear and open communication channels among all stakeholders facilitates collaboration and coordination. The Spring Showcase is designed to assist admitted students in deciding whether to enroll at Tennessee Tech University. It fosters meaningful interactions that enhance stakeholder satisfaction by involving faculty, current students, and staff. The high enrollment rate of event attendees and the positive feedback from satisfaction surveys highlight the success of this stakeholder-centered approach. The Spring Showcase, held in the spring for incoming first-year students admitted for the upcoming academic year, is aimed at individuals still debating between numerous universities. Unlike new student orientation, which comes after students have committed, the Spring Showcase allows prospective students to engage with faculty members, existing students, and peers in their desired fields.

The SSC has been essential since the Tennessee Tech University Spring Showcase's founding. The CoE departments start planning the event every fall. The event starts with a welcome speech by the engineering dean, followed by a parent session with a panel of current students, major-specific breakout sessions for admitted students, and open houses where families and students can learn more about every major offered by the college. It has proven highly effective in encouraging students to choose Tennessee Tech University, with over 80% of attendees enrolling over the past two years. A follow-up satisfaction survey from the Office of Admissions indicates that 98% of respondents were satisfied with their experience.

3.4. Relationship Management and Process Improvement

Gathering stakeholder feedback is essential for continuously improving processes and enhancing stakeholder satisfaction. Attracting transfer students involves close collaboration with community colleges and the development of clear transfer guides. The SSC's proactive engagement with community college administrators and faculty ensures that transfer pathways are both transparent and efficient. The CoE prioritizes the recruitment of high-caliber students from community colleges. However, the complexities associated with course equivalencies and transfer pathways can present significant challenges, potentially deterring qualified applicants. The SSC implemented a two-pronged approach to facilitate the transfer process. Firstly, it collaborated with regional community colleges to develop comprehensive transfer guides that include detailed outlines of equivalent courses, offering students clear academic pathways and mitigating confusion regarding credit transfer. This enables students to progress in engineering with increased confidence and clarity. Secondly, it established and cultivated robust relationships with community college leadership. This open line of communication facilitated collaborative endeavors to optimize the transfer process. Through the implementation of articulation agreements, both institutions have worked in concert to ensure a seamless transition for engineering students, effectively eliminating superfluous obstacles and enhancing their prospects for academic success.

3.5. Improving Recruitment Using DMAIC

Integrating DMAIC and Kaizen principles into CoE recruitment efforts has driven a systematic and continuous improvement process. The SSC has successfully optimized recruitment strategies to meet enrollment goals by focusing on data-driven decision-making

and iterative refinements. The DMAIC framework is a systematic, data-driven approach traditionally used in Six Sigma and Lean methodologies. As shown in Figure 1, this structured approach not only addresses immediate challenges but also builds a foundation for continuous improvement and long-term success in student retention. Figure 1 provides explanations for each of the steps in the DMAIC framework. First, a program must be clearly defined; second, data are collected; third, data are analyzed; fourth, the analysis is utilized to inform improvement; and finally, monitoring is implemented to ensure continuous improvement.

DEFINE	Clearly outline the program's goals and objectives, focusing on retention rates, student preparedness, and diversity within engineering disciplines.
MEASURE	Collect data on student performance, retention rates, and placement test results before and after participation in these programs.
ANALYZE	Analyze the collected data to identify trends and areas for improvement, focusing on the effectiveness of each program component.
IMPROVE	Implement evidence-based changes to the programs based on data analysis and participant feedback.
CONTROL	Establish monitoring processes to ensure that improvements are sustained and the programs remain effective.

Figure 1. DMAIC framework steps for enhancing student retention.

Define—Establish Clear Recruitment Objectives: In this phase, the SSC collaborated with the Office of Admissions and academic departments to establish clear, measurable recruitment goals in line with the university's strategic objective to increase first-year student enrollment from 561 to 661 in five years. A thorough stakeholder analysis was conducted, identifying key groups such as prospective students, parents, community colleges, faculty, and industry partners. Specific recruitment goals were set, focusing on increasing the enrollment of diverse, talented students across engineering, engineering technology, and computer science programs.

Measure—Track Recruitment Metrics: This phase involved the identification and tracking of KPIs to assess the effectiveness of recruitment strategies. Metrics such as campus visit attendance, application rates following events (e.g., VIP visits, Preview Day), and first-year student enrollment were consistently monitored. A significant KPI introduced was the "First-Year Student Enrollment Growth Rate", which quantifies the annual percentage increase in first-year student enrollment. These metrics provided actionable data, enabling the SSC to measure the impact of targeted recruitment efforts.

Analyze—Identify Barriers and Opportunities: The SSC comprehensively analyzed the data collected during recruitment events. This analysis revealed areas of success, such as a high conversion rate of VIP visit attendees to applicants, and opportunities for improvement, including better outreach to community colleges. Data indicated that students who engaged directly with faculty and current students during visits were likelier to apply, underscoring the importance of personalized, immersive experiences. Additionally, survey feedback from prospective students and parents highlighted the need for information on financial aid and scholarships.

Improve—Recruitment Initiatives: Kaizen principles of continuous, incremental improvements were applied during the Improve phase to refine recruitment strategies. A few

key enhancements include personalized campus tours, targeted outreach to community colleges, and enhanced communication channels.

Control—Ensure Sustained Success: In this phase, mechanisms were put in place to ensure the sustainability of improvements. The SSC continued to monitor KPIs, adjusting as needed to respond to evolving student and stakeholder needs. Ongoing feedback from students, faculty, and admissions staff ensured that recruitment strategies remained agile and effective. Additionally, a standardized process for collecting post-event surveys allowed for the real-time evaluation of recruitment events, ensuring continuous refinement.

After applying the DMAIC and Kaizen, the CoE has seen improvements in its recruitment processes. These efforts have driven a notable increase in first-year student enrollment. Specifically, the percentage of first-time freshman (FTF) students relative to the total undergraduate population rose from 23% in 2023 to 27% in 2024. A one-tailed hypothesis test for population proportions at a 5% significance level confirmed that this increase is statistically significant, demonstrating the efficacy of these methods. The iterative nature of this approach guarantees that recruitment efforts will continue to evolve, positioning the CoE to meet its long-term enrollment objectives while maintaining a student-centered focus. Overall, not only is the SSC involved in Office of Admissions-sponsored events, such as campus visits, but the staff have also developed programming and built relationships, including summer camps, a math bridge program, a streamlined first-year course degree map, and relationship-building with regional schools and community college faculty and staff.

4. Initiatives and Strategies for Enhancing First-to-Second-Year Retention

Incoming first-year students frequently encounter challenges, including inadequate preparation in mathematics courses, rigorous academic demands, unfamiliarity with the university environment, and new experiences. If left unaddressed, these obstacles may precipitate disengagement and, ultimately, attrition. The CoE has instituted a comprehensive support framework spearheaded by SSC professionals. This approach transcends traditional academic assistance, offering a holistic array of services tailored to address the diverse needs of first-year students. These extensive first-year retention initiatives are strategically aligned with the university's overarching objective of increasing the freshman-to-sophomore retention rate from 75% to 82% with an incoming class of 2000 students, increasing the four-year graduation rate from 34% to 50%, and increasing the six-year graduation rate from 55% to 60%.

The current first-year retention rate achieved is 83.3%, exceeding the target (82%), but is not statistically significant at $\alpha = 0.05$. However, through the use of a one-tailed population proportion hypothesis test at $\alpha = 0.05$, the retention rate calculated is significantly higher than the university target of 76%. Programming has been selected to address specific challenges that empirical evidence has identified as unique to engineering education and our college's particular context. These challenges include, but are not limited to, inadequate mathematical preparation, insufficient college readiness, and a diminished sense of belonging within the academic community.

The KPIs for evaluating these initiatives include math placement improvement rates, assessed through the math bridge program (RAMP); academic progression consistency, measured via degree maps; academic support engagement, reflected in tutoring participation; faculty–student interaction, evaluated through mentoring programs; student involvement levels, monitored via participation in student organizations; and career readiness outcomes, measured by internship and co-op placements. Additionally, first-year retention rates are tracked as a primary metric for student success, placement test results assess the effectiveness of preparatory programs, and student surveys capture feedback on key initiatives like the Spring Showcase and PACE program to gauge satisfaction and impact.

4.1. Math Bridge Program

The Reinforce Advanced Math Placement (RAMP) program has been instituted to address critical mathematical proficiency challenges encountered by incoming first-year students in engineering, engineering technology, and computer science majors, particularly those demonstrating proficiency levels at or below Calculus I. Historical data from Tennessee Tech University indicate that approximately 50% of incoming freshmen are initially placed in College Algebra or Pre-Calculus courses. Moreover, a comparable proportion of students initially placed in Calculus I failed to complete the course. These factors have contributed to a suboptimal first-year retention rate of 63% and an extended time to degree completion. In response to this identified academic challenge, the CoE initiated the RAMP first-year bridge program in 2022. This initiative aligns with established educational research and practice, as bridge programs have been extensively utilized to mitigate student attrition [33] and to equip students with the requisite skills for college-level mathematics [34] and broader collegiate academic preparedness [35].

The RAMP program was developed and implemented through a collaborative effort between the CoE and the Department of Mathematics. Structured as a one-week residential program, RAMP is designed to prepare students for mathematics and engineering coursework, provide opportunities for retaking math placement tests, facilitate social team-building activities, familiarize students with available academic support resources, and offer an early introduction to college life. The outcomes of the RAMP program over its three years of implementation are presented in Table 1 and Figure 2.

Table 1. RAMP program outcomes.

Year	No. Student Participants	No. Students Who Took Accuplacer	% Moved Down	% No Change	% Moved Up
2022	83	74	12%	21%	67%
2023	147	103	7%	30%	63%
2024	148	95	9%	27%	64%
Average			9.3%	26%	64.6%

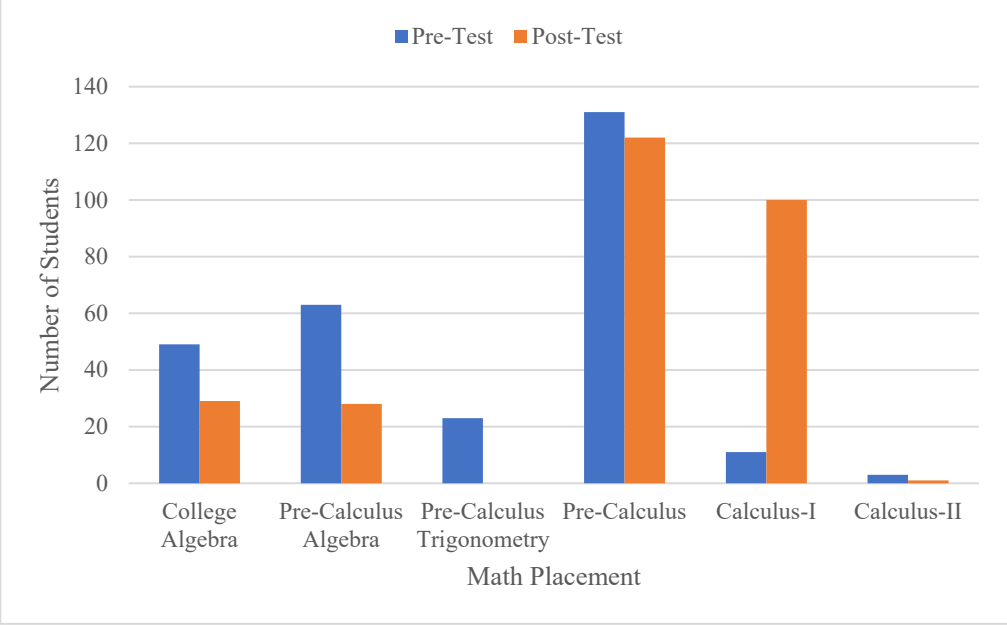

Figure 2. Math placement of students pre and post RAMP program.

Table 1 provides RAMP program outcomes for the past three years. Once students completed the program, they were encouraged but not required to take a placement exam called the Accuplacer. As Table 1 indicates, each year saw two-thirds or nearly two-thirds of the students opting to take the exam move up into a higher math course than their original placement based on ACT or SAT scores. As stated, since 2022, two-thirds advanced in math placement. After these students enrolled in a higher-level math course, their performances were compared to those of students who did not participate in the RAMP program, with no significant difference found. This is a critical gain since students with a higher initial math placement level were directly enrolled in advanced math courses rather than the more basic ones, had improved first-year retention rates, and were expected to graduate in less time.

Figure 2 shows the specific math placements for RAMP participants pre and post RAMP. A two-sample *t*-test with equal variances was further performed on these data. This *t*-test compared the students' math placement levels before and after the RAMP program and revealed a statistically significant improvement. The large negative t-value ($t = -8.81$) indicated that the pre-test placement mean was substantially lower than the post-test mean. The extremely small *p*-values (approximately 10^{-17}) suggested that this difference was almost certainly not due to random chance. Statistically, it can be inferred that the RAMP program had a positive effect on students' math placement.

4.2. Degree Maps

Degree maps offer an organized roadmap detailing the courses needed to complete degree requirements. Before 2021, department-specific degree maps were the only available options due to the lack of standardized degree maps within the CoE. These versions were inflexible and could not adapt to students changing their majors after starting their studies. These random course schedules frequently forced students to change their majors midstream and enroll in classes out of order, prolonging their time to graduation.

However, an important change happened after all programs adopted a single, comprehensive degree map in 2021. A template for every major and concentration was given to departments within the CoE, encouraging them to create a concise four-year plan. A coherent course schedule was guaranteed by this standardized plan, particularly in the first year of study. Accordingly, an academic setting was created in which first-year students could seamlessly switch between majors without falling behind. Furthermore, degree maps were also developed for 2 + 2 programs so that community college transfer students know how their courses will transfer. Since implementation, it has been found that fewer students have deviated from the structured degree maps and that students are making faster progress toward graduation.

4.3. Professional Academic Advising

Tennessee Tech has implemented a bifurcated student success strategy to provide consistent and targeted support for CoE students throughout their academic tenure. This model represents a significant departure from the previous paradigm, where academic advisors and faculty members provided academic advisement across all student cohorts. Recognizing the distinct needs of first-year students, Tennessee Tech established a specialized advisement unit dedicated exclusively to incoming first-year students, the "Launchpad". Upon attaining sophomore status, students transition to the CoE SSC, where academic advisors possess specialized knowledge about engineering students' unique needs and curricular requirements. This transition fosters more in-depth, program-specific mentorship as students progress in their chosen disciplines. CoE SSC advisors maintain close collaboration with their Launchpad counterparts throughout the students' inaugural year to ensure the continuity of support, facilitating a seamless transition between advisement structures.

CoE SSC administration and advisors have engaged in extensive collaboration with Launchpad personnel to develop a comprehensive understanding of the challenges encountered by first-year students and to co-create initiatives aimed at enhancing student engagement and integration. This collaborative effort has manifested in various modalities, including joint participation in orientation programs, the implementation of "Lunch and Learn" sessions providing an open forum for dialog, the establishment of clear communication channels between the freshman advisement center and college advisors, the solicitation of feedback to elucidate the specific and unique challenges faced by engineering first-year students, and the co-development of a transition event for students migrating to college-level advisement.

The initial collaborative endeavor occurred during the mandatory orientation program, which spanned two days before the commencement of the autumn semester. CoE advisors worked with Launchpad advisors and college faculty to ensure that incoming freshmen had the requisite information for academic success. This encompassed informational sessions on engineering disciplines, access to degree maps for various majors, and hands-on registration sessions facilitating course schedule modifications.

A "Lunch and Learn" initiative was established in the fall of 2023 to allow advisors from both units to engage in open dialog regarding optimal student support strategies. The inaugural session shared insights into first-year student challenges, best practices for student support and transition management, and effective communication techniques. The conference culminated in actionable items, including collaborative efforts on student success workshops and transition events and the inclusion of first-year advisors in campus-wide communications. This collaboration between the two units culminates in a spring transition event designed to facilitate introductions between freshmen and their future CoE SSC advisors. Moreover, the event fosters a sense of belonging among first-year students, strengthening their connection to the broader engineering community. By fostering cross-functional collaboration and knowledge sharing, the institution aims to create a more cohesive and responsive advisement ecosystem that addresses the evolving needs of engineering students throughout their academic careers.

4.4. Cross-Training Academic Advisors

In the past, each advisor was allocated advisees within a single major. However, it was judged necessary to broaden the advisers' knowledge set. The change from discipline-specific academic advisors to a more diverse and cross-trained advising team in 2022 marked a big step forward in student support at the CoE. Before this shift, there were constraints to relying on discipline-centric advisers, especially when enrollments and advising loads increased. As the number of students increased, it became more difficult to schedule timely advising meetings, particularly during critical pre-registration periods. This resulted in some students having delays in receiving critical academic help, potentially impeding their ability to plan their courses adequately. The transition to cross-training academic advisors across several engineering disciplines resulted in significant beneficial effects. The equitable distribution of advising loads ensured that students had better access to assistance and support. This strategy provided students with rapid support, minimizing delays in seeking counsel and allowing them to make educated judgments about their academic paths. Students were assured of comprehensive and timely guidance through the creation of an environment where academic advisors possessed knowledge across various engineering disciplines, contributing significantly to their ability to navigate their academic journey smoothly and stay on track toward their educational goals.

4.5. Tutoring and Supplemental Instruction

To assist with student concerns related to specific courses, the university offers free resources, such as tutoring, to help students with their academics; however, the CoE's Student Success Center determined that more services could be offered at the college level. Thus, the CoE SS offered tutoring, supplemental instruction, and peer mentors. One example of this is the tutoring program, which began in 2021 with a small number of four undergraduate tutors located at the center's physical location and five tutors located at both the center and the engineering residential hall. In addition to meeting students where they are, the tutoring program has expanded the number of engineering classes it tutors. In the fall of 2021, appointments totaled 378, while in the academic year of 2023–2024, there were a total of 948 appointments. This increase can be attributed both to the effort to hire tutors for specifically identified classes and to a centralized approach to providing information about tutoring services.

In addition to tutoring, the CoE SSC offers supplemental instruction, a program created by the University of Missouri—Kansas City, for courses that impact students' time to graduation. Since 2021, the program has expanded from programming classes to Pre-Calculus, Calculus, and Physics-1. These courses were chosen due to their traditionally high percentage of D or F grades or withdrawal from class (DFW) rates. The program hires undergraduate students who have previously taken the courses in question and plans and facilitates active-learning and collaborative study sessions for students currently enrolled in the class. These sessions help students by allowing them to ask questions about the course content, apply what they are learning, and learn effective study skills from their near-peers. Between 2021 and 2023, data show that students who attended SI sessions had a 28.5% DFW rate, whereas students who did not attend sessions had a 35.3% DFW rate. The SI program has thus been shown to be an effective retention tool by helping students avoid failing and retaking courses.

4.6. Peer Mentors

The CoE SSC has also developed a peer mentor program. Peer mentors are upper-classmen who work with incoming freshmen to provide them with guidance, mentorship, and resources geared toward helping new students become acclimated to college. To support these efforts, the SSC has written a peer mentor handbook; the peer mentors have been assigned to specific freshmen-level engineering courses, and these peer mentors hold regular meetings for the students in those courses. The goal of rapport building between peer mentors and incoming freshmen is invaluable for them to help new students feel a sense of belonging, build relationships, and develop as college students.

4.7. Professional Academic Coaching

In the CoE at Tennessee Tech University, the retention of academically at-risk students is a concern. Between 2012 and 2020, the number of academically at-risk students, defined as students on warning, probation, or suspension, rose from 15% to 19%, with an average of 18% among all CoE undergraduates. Due to this alarming trend, the Professional Academic Coaching for Engineers (PACE) program has been developed. Following NACADA'S best practices for "intrusive" and "proactive" advisement, the academic advisors reach out to and set up individual meetings with students who are on warning, probation, or return from suspension to thoroughly review the student's academic, personal, professional, and social barriers to academic success and to trouble-shoot strategies and resources to help them overcome these challenges and improve their academic standing [36,37].

An important aspect of the PACE program is an Academic Success Form that the student fills out with their advisor. This form allows the student and advisor to review

various factors that may impact student success, such as a lack of preparedness for classes, poor time management and study skills, and mental health challenges. The CoE SSC team has identified common barriers, thus assisting in creating a more supportive environment and targeted workshops, such as a "Registration Trouble-Shooting" workshop for students. Figure 3 illustrates how the number of at-risk students lowered from 19% in 2020 to 11% in 2024.

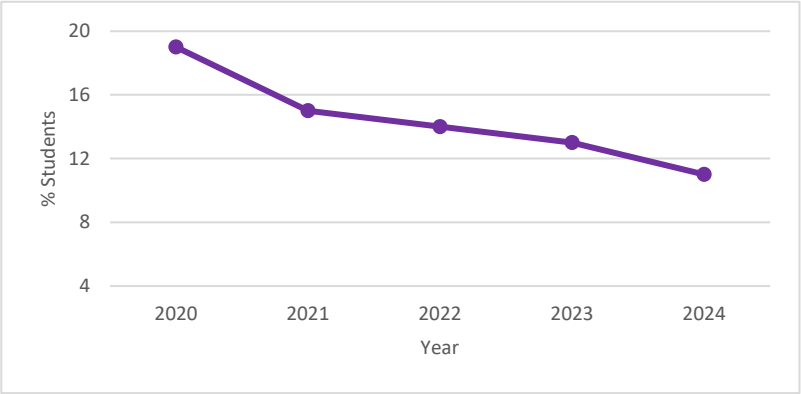

Figure 3. Trend of decline in the percentage of students at academic risk.

The continuous decrease in at-risk students from 2020 onward follows a statistically robust linear trend, with an Adjusted R^2 value of 0.894. The intercept is statistically significant at 19.8 (p-value = 0.0003), and the slope is −1.8 (p-value = 0.0098), indicating a meaningful downward trend. Using this linear model, we predict the percentage of at-risk students in 2025 and 2026 to be approximately 9% and 7.2%, respectively, assuming the trend persists.

4.8. Listening Sessions

Several opportunities have been created to empower students to provide the CoE administration, faculty, and staff with candid feedback about their experiences. The goal is to build a student-centered culture where students are unafraid of speaking up and offering their perspectives. First, the CoE has set up a "Donut Stop" initiative once per month. Students can interact with the associate dean and an academic advisor in a relaxed and informal atmosphere where students are encouraged to talk to the leadership and to one another about both positive and negative aspects of their experiences in the CoE. This initiative has helped foster a culture of openness and student engagement by showing students that the leadership is willing to listen to their successes and concerns and to engage in open dialog. In addition, the CoE SSC has developed a program entitled "Fuel to Fly", conducted once per month. This is another informal, student-centered opportunity wherein students can stop by the physical location of the SSC and have coffee and pastries. The program's outcomes have been very helpful for the CoE; through the holding of the event at the center, students interact with engineering tutors and become more aware of the academic resources provided by the SSC. Moreover, advisors engage and assist these students in this informal environment.

Drawing on the success of "Fuel to Fly", advisors set up a monthly "Roaming Advisor" advising session at the SSC with drop-in appointments. This allows students to drop by and speak to an advisor without making a formal appointment, making the advisor more accessible. The idea behind this initiative is based on the literature suggesting that advisors and students benefit from this type of informal, relationship-building interaction [38–40]. The program provides students with a chance to have their questions immediately addressed, and the overall effect is one of supporting students.

For more in-depth discussion between administration and students, the CoE SSC has implemented focus groups for specific student populations, including students who changed majors out of engineering and first-time freshmen. The focus groups have allowed the leadership team to uncover important information about why students have chosen another major and how first-time freshmen perceive the climate in the college. With the former group, the findings showed that a key reason for students leaving engineering was that they did not feel they belonged in that major, nor did they feel confident about seeking assistance. Based on this information, the CoE SSC introduced activities to help build students' sense of belonging and create an environment where they felt more comfortable seeking help. With the latter group, information also provided insight into students' sense of belonging and their perception of support systems available to first-year students in engineering.

4.9. Enhancing First-to-Second-Year Retention with DMAIC

In higher education's dynamic and competitive landscape, improving student retention, particularly in the critical first year, is a significant challenge. Retention is vital not only for the academic success of students but also for the financial health and reputation of educational institutions. Through applying the DMAIC framework, Tennessee Tech University's CoE created a robust, data-informed strategy for improving the retention of first-year students. As shown in Section 3.5, DMAIC follows five steps: Define, Measure, Analyze, Improve, and Control. In the context of this paper, each of these steps is defined according to the SSC's goals for recruitment, retention, and readiness. Clearly outlining the program's goals and objectives for the Define step of the DMAIC framework, focusing on retention rates, student preparedness, and diversity within engineering disciplines, requires a structured approach. The main primary goals include increasing retention rates, enhancing math preparedness, and improving diversity within the engineering student body. Specific, measurable goals must be set, the target population and their needs identified, and success criteria clearly defined. Tables 2 and 3 summarize these goals, objectives, specific measurable goals, target populations, and success criteria.

Table 2 outlines the specific objectives and goals that the SSC has determined for improving students' experiences and success rates. By clearly defining measurable goals and success rates, the SSC staff will have the tools they need to ensure that they are working toward improvement. For example, by specifying a retention rate of 82%, the SSC will be able to record progress, note tools that have helped reach successful goals, and move benchmarks or goals as needed. Table 3 highlights important aspects of the Measure step, which involves identifying key metrics such as retention rates, performance in core courses (e.g., math and engineering fundamentals), placement test results, and demographic data. These metrics provide insights into areas like student engagement, diversity, and academic challenges. By collecting comprehensive data, institutions establish a foundation for identifying improvement areas and setting measurable goals.

Statistical analysis plays a pivotal role in interpreting collected data. Methods such as trend analysis and correlation studies help uncover the patterns and root causes of attrition. For instance, poor performance in foundational courses like math is often linked to higher dropout rates, suggesting the need for targeted academic support. Similarly, analyzing retention data across demographic groups can reveal disparities, prompting tailored interventions to address specific challenges. The Analyze step builds on these data to explore trends and identify opportunities for intervention. For example, institutions might find that major migration—students transferring between engineering disciplines—highlights the need for enhanced advising and orientation programs. Understanding these patterns allows institutions to refine strategies such as academic advising, curricular adjustments,

or supplemental instruction to improve retention. General principles derived from the data include the importance of identifying predictive metrics, such as performance in critical courses, and monitoring trends over time to ensure stability. Furthermore, evaluating the effectiveness of preparatory programs, like placement tests or bridge initiatives, is vital. Institutions can apply DMAIC to address their unique retention challenges and enhance student success by focusing on these foundational methods.

Table 2. Define step in the DMAIC process.

Goal	Objective	Measurable Goals	Target Population	Success Criteria
Increase Retention	Improve first-year retention rate to 82%	Year-over-year retention increase of 7% for all participants	Incoming freshmen in the CoE	Retaining 82% of participants into their second year
Enhance Preparedness	Increase percentage of students advancing in math and coursework	70% of RAMP participants moving up a math level after retesting; increase in successful course completion rates	Students in College Algebra, Pre-Calculus, Calculus I, and other key courses	At least 70% of RAMP participants improving their math placement level; reduced DFW rates
Increase Underrepresented Minority (URM) Students	Attract and retain a diverse group of students	10% annual increase in underrepresented minority and female participants	Incoming first-year students from URM backgrounds	Achieving year-over-year increase in URM metrics of participants
Academic Support	Provide comprehensive tutoring and supplemental instruction	Reduction in DFW rates in targeted courses	Students enrolled in high-DFW-rate courses	Demonstrated decrease in DFW rates and improved academic performance
Guidance and Advising	Ensure tailored academic advising and coaching through degree maps and First-Year Professional Academic Advising	High satisfaction rates with advising; improved academic progress	All CoE students, with a focus on first-year students	Positive feedback from student surveys; academic progress tracking
Advisor Development	Enhance advisor skills through cross-training academic advisors	Increased advisor competency and student satisfaction	Academic advisors in the CoE	Positive feedback from advisor evaluations and student satisfaction surveys
Sense of Belonging	Foster community through peer mentorship, listening sessions, and engagement	Increased participation in mentorship and social activities	First-year CoE students	High participation rates and positive feedback on mentorship experiences
Career Readiness	Prepare students for professional success through Professional Academic Coaching	Increased internship and co-op placements; career readiness workshops	CoE students in their sophomore year and beyond	Higher rates of internship and co-op participation; positive feedback on career readiness programs

Table 3. Key metrics, KPIs, targets, and baselines for the Measure step in the DMAIC process for student retention.

Metric	KPI	Target	Current Baseline
First-Year Retention Rates	Percentage of first-year students retained into the second year	82% freshman-to-sophomore retention rate	83.0% (2024)
Placement Test Results	Percentage of students moving up a level after participating in preparatory programs (e.g., RAMP)	65% improvement rate	2022: 67% 2023: 63% 2024: 64%
Student Surveys and Feedback	Satisfaction and impact from key initiatives (Spring Showcase, PACE program)	Achieving high satisfaction rates and significant impact on student success, maintaining or improving current trends	Spring Showcase: 98% satisfaction (2023)

Finally, student surveys and feedback offer qualitative insights into student satisfaction and the impact of key initiatives like the Spring Showcase and PACE program. Analyzing trends in feedback from these programs can provide valuable information on which aspects are working well and which areas might need further improvement. Cross-referencing this feedback with retention and performance data can also help determine if these programs directly influence student success and persistence.

Figure 4 reveals significant major changes within the first year, which could indicate students not receiving adequate guidance during their initial major selection. It provides a visual of engineering education's first two years at Tennessee Tech. Notice that the largest majors, mechanical engineering and computer science, remain relatively stable; however, quite a lot of students from all majors leave the university altogether or move to other majors within engineering. These data support the finding that when students begin their studies, they may lack sufficient guidance about what major will be a good fit for them.

Meanwhile, Figure 5 shows a 21% increase in first-year enrollment and a 22% increase in total undergraduate enrollment. While these trends are positive, they also necessitate further analysis to ensure that the growth in student numbers is matched by sufficient resources and support services, thereby maintaining or improving retention rates. By combining these insights from the Measure and Analyze steps, the CoE can refine its strategies to address the root causes of student attrition, ultimately leading to improved retention rates and a more successful transition from the first to the second year for engineering students. In the Improve step, specific strategies are implemented to enhance student retention.

Once improvements are successfully implemented, the DMAIC process moves into the Control step, where mechanisms are established to sustain these gains over the long term. In the Control step, the CoE could establish monitoring systems to ensure that the interventions continue to produce the desired results. This could involve the regular tracking of retention rates, student performance in core courses, and feedback from students on the effectiveness of the new support systems. For example, if the analysis reveals that enhanced advising has led to a significant reduction in major changes, the college would want to ensure that this practice becomes a permanent part of the student experience. This might involve formalizing new advising protocols, training advisors on best practices, and incorporating feedback mechanisms to continually assess the effectiveness of the advising process. Similarly, if the introduction of supplemental instruction in challenging courses

leads to improved student performance, these sessions should be made a regular part of the curriculum, with ongoing evaluation to ensure that they continue to meet students' needs.

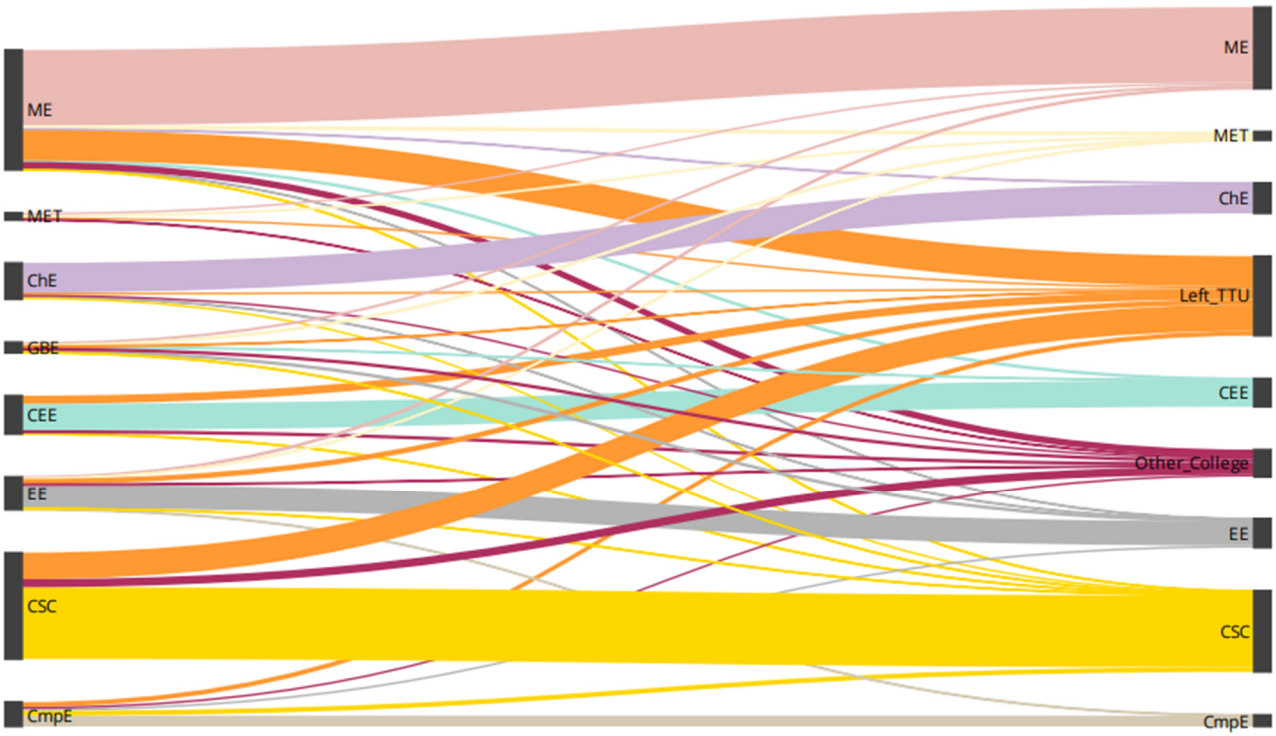

Figure 4. Student major migration: movement between majors within the first two years.

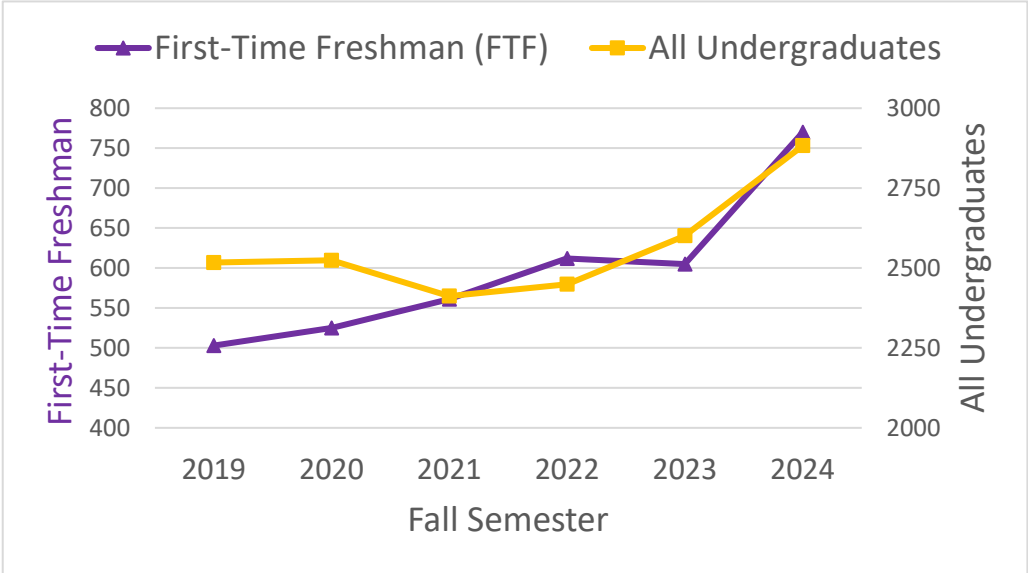

Figure 5. Increasing enrollment between 2019 and 2024.

The Control step also includes establishing clear KPIs to measure the ongoing success of these interventions, as well as defining accountability structures to ensure that these measures are maintained. Regular review meetings, continuous professional development for staff involved in these initiatives, and periodic student surveys can all be part of the control process to keep improvements on track. Ultimately, the goal of the Control step is to institutionalize successful practices, ensuring that they become an integral part of the college's approach to student retention, thus securing the long-term success of the initiatives developed through the DMAIC process.

5. Cultivating Leadership and Continuous Improvement in Academic Advising

The institution has implemented a bifurcated model of academic advisement, wherein first-year students initially engage with advisors in a centralized facility, designated as the Launchpad, before transitioning to discipline-specific advisors within the CoE SSC. The CoE SSC employs a cadre of seven advisors, each specializing in a particular engineering discipline while maintaining proficiency in a secondary field. This structure ensures the continuity of advisement, with students retaining their assigned college advisor throughout their academic tenure. While specific KPIs are being developed for the ongoing evaluation of these advisement strategies, the aim is to track advisor effectiveness, student retention, and progression. Future assessments will focus on measuring student satisfaction, academic performance, and the impact of advisor specialization on student success. These metrics will be critical in evaluating the success of this approach as it evolves.

5.1. Continuous Improvement Through Brainstorming Sessions

In alignment with its continuous improvement strategy, the CoE has instituted monthly colloquiums for academic advisors. These forums serve as a nexus for collaborative discourse and open communication channels. The primary objective is facilitating the articulation of pressing student-related issues to college leadership, thereby enabling a proactive and systematic approach to enhancing student outcomes. Since their inception in 2021, these deliberations have precipitated significant policy and curricular modifications. These insights have catalyzed the development of novel on-ramp programs designed to support academically challenged students. Furthermore, advisor feedback regarding course-specific impediments within required sequences has prompted comprehensive curriculum redesigns to facilitate fluid academic progression for students.

Through active engagement with department chairs and faculty, the associate dean has leveraged the insights gleaned from these sessions to refine curricular offerings and implement targeted interventions. This process aligns closely with the continuous improvement paradigm inherent in engineering management principles, where iterative feedback loops and data-driven decision-making drive ongoing enhancements. This approach exemplifies the application of systems thinking to academic administration, where the holistic consideration of student experiences informs strategic decision-making and resource allocation.

5.2. Leadership Development Through Niche Specialization

The CoE's initiative to foster leadership among academic advisors through niche specialization exemplifies an innovative approach to professional development and student support. This program operationalizes the concept of distributed leadership by empowering advisors to identify and cultivate expertise in areas that align with their individual competencies, interests, and professional trajectories. Advisors allocate 5% of their weekly workload to these specialized domains, supplemented by targeted professional development opportunities and mentorship. In its inaugural year, the focus areas were advancing equity and inclusion initiatives, strengthening residential learning communities, facilitating the integration of transfer students, and promoting STEM education through K-12 outreach programs.

By positioning advisors as resident experts and champions within their respective niches, the CoE has effectively established a network of change agents. These individuals are poised to drive innovation and enhance the student experience across critical academic and personal development dimensions. This approach aligns with the principles of distributed cognition in organizational theory, leveraging collective expertise to address

complex challenges in higher education. This initiative represents a paradigm shift in the conceptualization of academic advising roles, moving beyond traditional models of generalist support to a more nuanced, expertise-driven approach. By integrating principles of engineering management with academic advising practices, the CoE has created a synergistic model that has the potential to significantly enhance both advisor professional development and student outcomes.

6. Conclusions

The CoE at Tennessee Tech University has effectively applied engineering management principles to enhance its recruitment and stakeholder management strategies, with significant contributions from the Clay N. Hixson SSC. Personalized outreach programs and strong community college partnerships have bolstered recruitment efforts, streamlined transfer processes, and improved retention rates. By utilizing KPIs, the SSC has ensured a continuous cycle of improvement that aligns with the university's strategic goals. The DMAIC process has been instrumental in refining strategies to boost student retention. In the Improve phase, targeted initiatives such as personalized advising, enhanced support for core courses, and the RAMP program have been implemented and tested to confirm their effectiveness. The Control phase then established mechanisms to maintain these improvements, including continuous monitoring and feedback systems that help sustain long-term retention gains within the CoE.

The commitment to fostering a supportive academic environment has led to noteworthy achievements. The first-to-second-year retention rate has steadily increased, exceeding the target of 82% by 2025, with a notable 83.3% retention rate in 2023. This success is attributed to a comprehensive approach that includes academic preparedness, robust support services, and open communication. Initiatives like the RAMP program, standardized degree maps, and cross-trained academic advisors have been crucial in helping students navigate their academic paths, while tutoring, supplemental instruction, and peer mentoring programs have provided essential support and fostered a sense of community.

The CoE's dedication to student feedback and open dialog is evident in programs such as Donut Stop, Fuel to Fly, and roaming advisor hours, which create opportunities for meaningful interactions and allow the leadership team to address concerns promptly.

Overall, the CoE's multi-faceted approach to promoting student success through engineering management principles provides a robust framework for fostering continuous improvement in engineering education. The combined efforts of various programs have suggested a path to increase first-year enrollment, improve retention rates, and improve at-risk students' academic standing.

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