

**Using Human-Centered Design and Theory of Change to Improve Student
Access and Success in an Undergraduate Pre-Engineering Program.**

by

Aishwary Pawar

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Doctoral Committee:

**Associate Professor DeLean Tolbert Smith, Chair
Assistant Professor Fred Feng
Associate Professor David Knight, Virginia Polytechnic Institute and
State University
Assistant Professor Feng Zhou**

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List of Abbreviations and Acronyms

CECS — College of Engineering and Computer Science

FTIAC— First Time in Any College

GPA — Grade Point Average

HCD — Human Centered Design

PENG— Pre-Engineering program

START — Student Advising and Resource Team

STEM — Science Technology Engineering and Mathematics.

ToC — Theory of Change

UM-Dearborn — University of Michigan Dearborn

Abstract

College access and success are the most pressing issues confronting the United States in post-secondary education. This work focuses on declining STEM proficiency in the United States, requiring universities to focus on and understand students' needs explicitly. It explores students' learning experiences, attitudes, and challenges in Pre-Engineering (PENG) at the University of Michigan-Dearborn. The study aims to investigate the barriers students perceive while entering Pre-Engineering, understand their experiences during the program, and examine Pre-Engineering through professors' and academic advisors' lenses. Thus, focusing on the challenge framed: "How might we understand students' learning experiences, attitudes, and struggles about the support provided in Pre-Engineering?".

The study follows a three-phased mixed methods approach, utilizing a Theory of Change (ToC) framework and human-centered design (HCD) process. The ToC framework guides the planning, monitoring, and evaluation of program goals, while the HCD process ensures a user-centered approach. Key participants, including students, faculty members, and academic advisors, are actively engaged in addressing their needs and perspectives.

Phase one of the study entails a qualitative exploration of students' experiences during the Pre-Engineering admission process and throughout the program. Data is collected through surveys and interviews involving current and alumni Pre-Engineering students. The analysis is supported by a preliminary examination of students' demographic and academic data from the university. Phase two involves interviewing Pre-Engineering faculty members and advisors to

understand their perceptions and experiences related to the program. Qualitative and quantitative methodologies are employed to analyze the responses from both phases, providing a comprehensive understanding of the various perspectives. Phase three focuses on a co-design session that fosters collaboration among PENG faculty members and advisors. The aim is to generate innovative ideas to enhance/re-design the Pre-Engineering program, guided by the ToC framework. This session outlines the desired impact and intermediate steps required for effective transformation. Lastly, student evaluation and feedback surveys ensure alignment between suggested activities and resources and the desired results.

The study emphasizes the significance of orientation programs, advising services, peer mentoring, collaboration opportunities, and hands-on activities in improving the Pre-Engineering program. Data-driven approaches, and stakeholder collaborations are crucial for creating an inclusive and supportive environment for Pre-Engineering students. These findings hold practical implications for Pre-Engineering educators and policymakers, informing decision-making and program development. Additionally, the study contributes to the existing literature on engineering education, providing valuable insights into effective practices and strategies for enhancing student success in Pre-Engineering.

Chapter 1: Introduction

Background for the Study

Science, technology, engineering, and mathematics (STEM) education focuses on educating future generations to be successful in their professions. A decline in STEM proficiency has been reported in America, leading to significant regression from its position as a global leader in math and science. Debbie Myers, general manager of Discovery Communications in Science, Technology, Engineering, and Math (STEM) Diversity Symposium (2013), concluded: "International comparisons place the U.S. in the middle of the pack globally." For the United States to achieve a competitive advantage, there is a need to encourage young people to develop a passion for learning and specifically encourage minorities and females to pursue STEM careers. (Beard, 2013)

Another report from the United States National Academics (2005) named "Rising above the Gathering Storm" indicated that the U.S. is losing market share in math and science competence. College access and success are among the most pressing challenges confronting the country, where higher education attainment is a critical criterion for student achievement and economic advancement. Moreover, the United States will not achieve the required level of educational attainment without eliminating the significant inequalities across demographic groups (Perna et al., 2014). It requires explicitly focusing on the inclusion and retention of underrepresented minority (URM) groups, including women, first-generation students, and

certain racial and ethnic groups, including African American, Latino, Native American, etc. (Dika et al., 2014)

Despite effective attempts to improve college access and degree completion for students from lower socioeconomic status (SES), considerable gaps exist (Bowman et al., 2018). Enrollment is decreasing by 2.6% every year (Hanson, 2021). Students from low-income families, students who are the first in their families to attend or complete college, and students from racial and ethnic minority groups all have much lower rates of achievement than the national average (Perna, 2015). According to the Current Population Survey (CPS), roughly 2.3 million 16- to 24-year-olds were not enrolled in high school in 2016 and did not have a high school diploma or equivalency degree. These status dropouts had a rate of 5.2% for Whites, 8.6% for Hispanics, and 6.2% for Blacks (National Center for Education Statistics, 2019). Students from lower socioeconomic status backgrounds are five times more likely to drop out of high school than those from higher socioeconomic backgrounds (Hanson, 2021). These vast disparities show that effective initiatives are needed to enhance students' access to education.

To promote college access and success for low-income and first-generation students and address various barriers, particularly for students from historically underrepresented groups in higher education, there is a need for a multifaceted, systematic approach as well as involvement from a variety of stakeholders (Perna & Jones, 2013; Perna, 2015). To address this challenge, we must first understand the students' pathway from college admission to graduation and the support they require along this journey.

Students take many pathways to pursue STEM careers and sometimes face barriers to earning a degree. These barriers may include departmental, institutional, and national policies and the frequency of institutional-level engagement with students (National Academies of

Sciences, Engineering, and Medicine, 2016). One pathway includes Pre-Engineering programs, which give students the fundamental competencies, knowledge, and abilities needed to transition to an engineering bachelor's program, which significantly impacts students' careers. The Pre-Engineering program supports students in strengthening their math and science foundations and providing necessary academic help, without which students enrolling in bachelor's programs may typically end up not completing the program, repeating math subjects, and not matriculating in upper-level engineering courses.

Preliminary research findings provide a starting point to study and recognize the economic limitations faced by the students of specific ZIP codes and assist University administrators and policymakers in formulating strategies to attract and enroll more students (Pawar, 2020). The results from the preliminary work provide the researchers with additional insights into the community characteristics that admitted students represent. The current study focuses on the experiences of Pre-Engineering students at the University of Michigan Dearborn. The next section discusses the significance of the study, followed by the research questions addressed in this study.

Significance and Need for the Study

From a broad perspective, previous research shows different metrics commonly used by school officials to assess the success or failure of a Pre-Engineering program. Commonly used metrics evaluate a program's outcome based only on increased student enrollment, student grade performance, etc. However, no one has articulated/ investigated what aspects constitute an effective Pre-Engineering program that considers student learning experiences, professors' perspectives, academic advising department expectations, and school administrators. There is a need to discover characteristics contributing to program performance by identifying which

factors help the students achieve their desired results. This study was designed in such a way that it aids in building a bridge between students' needs, perceptions, experiences, and program goals.

This study examines the Pre-Engineering program by gathering information, analyzing data, and learning about the students' college access, enrollment, and success. Research related to Pre-Engineering programs, especially considering students' experiences and perspectives for program improvement, is limited. This work aims to address and investigate the barriers students perceive while entering Pre-Engineering programs and understand their experiences during the program. In addition, examine the Pre-Engineering program through professors' and academic advisors' lenses. Thus, focusing on the challenge framed: "How might we understand students' learning experiences, attitudes, and struggles about the support provided in a Pre-Engineering program?".

This research study investigates student learning experiences, attitudes, and struggles with the support provided in a Pre-Engineering program. The research employs qualitative methods, including interviews with students, to elicit their experiences within the program and examine their behavioral needs and issues. Additionally, the study aims to understand students' Pre-Engineering perceptions and identify areas where improvements are needed from an advising standpoint. This investigation also involves analyzing academic support and mentoring techniques, specifically in Pre-Engineering programs, by interviewing faculty members in the program and academic advisors, including the Student Advising and Resource Team (START), to enhance their office's tools and processes to support students better. The findings of this research provide valuable insights into the experiences of Pre-Engineering students and the support services they require to succeed.

Research Questions

The guiding research questions for this study are as follows:

[1] How do Pre-Engineering students describe their program experiences at the University of Michigan Dearborn?

[2] How can we redesign the Pre-Engineering program to support students better?

This study focuses on improving PENG student experiences at UM-Dearborn, a public school in the United States Midwest region. The study participants include PENG students, faculty members, and advisors. These guiding questions help in examining students' needs, comfort issues, and concerns about the support provided in a Pre-Engineering program and further assist higher education personnel in enhancing their office's tools and processes to support students better and use data more effectively to better track, identify, and support students.

Pre-Engineering Program at the University of Michigan-Dearborn

The Pre-Engineering program (PENG) at the University of Michigan-Dearborn was established in Fall of 2019 and is in its fourth year of operation. This program is designed to assist students in building and strengthening their math and science fundamentals to succeed in the CECS curriculum. This foundational knowledge is a significant determinant of engineering and computer science success. Thus, undergraduate students interested in Engineering or Computer Information Science can apply one of two methods to the College of Engineering and Computer Science (CECS). It includes (1) Admission directly into a CECS major or (2) Admission into the PENG program. (Table 1)

1. Admission directly into a CECS major**Freshman Requirements:**

- Students with a GPA of 3.5 or higher AND an SAT of 1200 (ACT of 25) or higher, or
- Students who have completed at least Pre-Calculus (Math 105 or equivalent) with a C grade or higher, or
- Students who place into Calculus 1 (Math 115) or higher on their placement exam or via the following automatic placements:
 - SAT math section score of 620 or higher
 - ACT math score of 26 or higher
 - 3, 4, or 5 on an AP Calculus exam
 - 5 or higher on an IB Mathematics SL exam or a 4 or higher on an IB Mathematics HL or HL Further exam

Transfer Requirements:

- Students who have completed Calculus II (Math 116 or equivalent) elsewhere with a C grade or higher AND have an overall GPA of 2.75 or higher.

2. Admission into the Pre-Engineering program**Freshman Requirements:**

- Students who satisfy the university's undergraduate admissions standards, but do not meet the above admission criteria for direct admission into CECS.

Transfer Requirements:

- Students will be required to show an overall transfer GPA of 2.75 or higher.

Table 1: Admission pathway to College of Engineering and Computer Science at UM-Dearborn

PENG students at UM-Dearborn work collaboratively with START Academic Advisors to enroll in appropriate classes, ensuring and improving their likelihood of success in the rigorous curriculum ahead. Student Advising and Resource Team (START) includes New Student Advising (START Advising), Peer Advising Learning & Success (PALS), and Health Professions Advising (HPA). START assists students in building a solid foundation for success as they begin their academic journeys at UM-Dearborn.

Students in the PENG program must complete the transition requirements (Table 2) and declare their major within one calendar year or during their first 30 credit hours at UM-Dearborn, whichever comes first

Transitioning from Pre-Engineering into a CECS Major:

- Freshmen can transition once they successfully complete Pre-Calculus (Math 105) with a C grade or higher AND complete General Chemistry I (Chem 134 or 144) with a C grade or higher.
- Transfer students can transition once they successfully complete Calculus II (Math 116) with a C grade or higher.
- All students transitioning into a CECS major are expected to be in good academic standing overall (2.0 GPA or higher).

Table 2: Transitioning from Pre-Engineering into CECS major

Chapter 2: Review of Literature

Introduction

Developed nations, including the U.S., have severe shortages of competent engineers. Recent research indicates that one factor contributing to this scarcity is low student enrollment and high retention rates, which are significant issues in higher education, particularly in STEM education (Sithole et al., 2017). There is a critical need to broaden the domestic STEM workforce (Honey et al., 2020). Also, there is a need to address challenges and barriers to the involvement of traditionally underrepresented communities in STEM fields (e.g., minorities, women, individuals with disabilities, military veterans, and individuals from lower socio-economic backgrounds). It will ensure that all citizens fully engage in a globally competitive, knowledge- and technology-intensive economy (National Science Board, 2015).

The COVID-19 epidemic made a significant impact on fall 2020 enrollments. As per data from the U.S. Department of Education's National Center for Education Statistics, college and university enrollment decreased by 651,774 students (i.e., more than 3%) from fall 2019 to fall 2020 (Weissman, 2021). Total undergraduate enrolment at degree-granting postsecondary institutions in the United States declined by 9% between the fall of 2009 and 2020. (i.e., 17.5 million to 15.9 million students) (NCES, 2022). A recent report from National Student Clearinghouse Research Center (NSCRC, 2022) showed that in spring 2022, overall

postsecondary enrollment declined by 4.1% or around 685,000 students compared to spring 2021. It includes both undergraduate and graduate students.

One direct cause for the decline in student enrollment at an undergraduate college can be explained using the pyramid effect, where PENG Programs and other engineering prerequisite courses in K–12 public schools are at the bottom of the pyramid, and university engineering graduates are at the top (McMullin, 2013). Since fewer students attend the bottom of the "pyramid," or PENG Programs, leading to fewer graduates at the top of the pyramid. This obstruction in the flow of students from PENG to college needs to be addressed. Thus, the next section of the literature review discusses the research focused on PENG Programs and the importance of collecting and analyzing students' data.

Definition, Evolution, and Types of Pre-Engineering Programs

Pre-engineering programs have long been recognized as a means to cultivate students' foundational knowledge and skills in mathematics, science, and engineering principles before they specialize in a specific engineering discipline. Pre-engineering programs encompass various approaches to prepare students for success in undergraduate engineering studies. An extensive literature on the subject explores different types of pre-engineering programs and their unique characteristics. Understanding these programs' historical development and evolution can provide valuable insights into their purpose, structure, and goals over time. Moreover, it is crucial to investigate the existing literature on pre-engineering programs to comprehensively explore the topic. This literature review aims to examine the various definitions of pre-engineering programs related to the collegiate training of engineers and understand the development and implementation of PENG programs in the United States. By delving into scholarly works, we

seek to comprehensively understand the diverse nature and objectives of pre-engineering programs.

In today's era, several institutions provide pre-college PENG programs to encourage students to pursue undergraduate degrees in STEM education. Such initiatives focus on specific goals to increase the enrollment and retention of underrepresented STEM students, including African Americans, Hispanics, Native Americans, and possibly Asian-Pacific (Lam et al., 2004).

Dunn (2019) highlights three broad definitions of pre-engineering programs in the context of college training for engineers. These pre-engineering programs exhibit distinct characteristics, varying in their aims and methodologies. Firstly, through STEM collaborations, pre-engineering programs at secondary schools introduce engineering concepts and offer college-credit courses in math, science, and general education. They enable motivated students to enter university engineering programs at the second-year level or enroll in pre-engineering programs at community colleges, typically following a two-plus three format. Secondly, pre-engineering programs available at universities target students who aspire to pursue engineering but may not meet the academic admission standards. These programs aim to improve students' academic performance for future success in engineering and provide a broad introduction to engineering concepts and principles. They typically include mathematics, physics, chemistry, and introductory engineering courses. The primary goal is to build a solid academic foundation and prepare students for further studies in specific engineering disciplines. Thirdly, pre-engineering programs are designed to enhance student awareness of the various engineering professions through career exploration and provide students with opportunities to explore different disciplines. Thus, allowing them to make informed decisions about their field of study. The

integration of STEM education, academic remediation, and career exploration collectively contributes to the overarching definition of this category of pre-engineering programs.

The historical development of engineering programs can be traced back to the mid-19th century when they began to emerge as a response to the growing need for specialized preparation in engineering studies. One notable program in this regard is the Scientific Course introduced at the Lawrence Scientific School of Harvard University in 1847. This program aimed to provide training to students who intended "to enter upon an active life as engineers or chemists, or, in general, as men of science, applying their attainments to practical purposes . . ." (Green, 1948)

Subsequently, educational programs expanded and diversified across various institutions. Another institution that significantly contributed to engineering education in the United States is the Rensselaer Polytechnic Institute (RPI) in Troy, New York. Since its establishment in the early 20th century, RPI has implemented several pre-college programs, including Tutor Time, RPI STEP (Science Technology Entry Program), PREFACE, and GE Girls at Rensselaer. These initiatives have created pathways and opportunities for students from underrepresented and economically disadvantaged backgrounds in grades K-12. The programs aim to enhance their access to and success in the Science, Technology, Engineering, and Mathematics (STEM) fields (Rensselaer Polytechnic Institute, 2023)

Over time, the structure and organization of foundational educational programs underwent significant evolution. Initially, these programs were often integrated into the curriculum of liberal arts colleges or universities. However, as the field of engineering education gained prominence, and a distinct identity, dedicated pre-engineering programs emerged to meet the specific needs of aspiring engineering students. This evolution reflects the growing recognition of the importance of providing specialized preparation and support for students

embarking on their engineering journey. For instance, the University of Maine offers a Pre-Engineering Program designed to provide a foundation in mathematics, physics, and introductory engineering coursework for students interested in pursuing engineering as their major. This program enables otherwise under-qualified students to gain admission to the university and prepares them for advanced study in engineering disciplines. It allows students to explore different engineering fields, acquire essential knowledge and skills, and receive academic advising and course selection guidance. Furthermore, successful program completion enables students to apply to specific engineering majors offered by the University of Maine, including Civil Engineering, Mechanical Engineering, Electrical Engineering, and more (University of Maine, 2023).

The structure of pre-engineering programs varies across institutions, but standard components include coursework in mathematics, physics, chemistry, and foundational engineering subjects. The curriculum is typically designed to ensure a solid understanding of core concepts and to provide students with a well-rounded education that sets the stage for more specialized engineering studies. The Pre-Engineering Instructional and Outreach Program (Pre-IOP) was developed to increase the number of skilled high-tech professionals, particularly among historically underrepresented groups (minorities and women). A thorough communication campaign promoting the benefits of careers in science, technology, engineering, and mathematics (STEM) introduced a PENG curriculum in middle and high schools to achieve this goal (Rockland et al., 2002).

The PENG program's holistic approach aims to prepare students for the technical aspects of engineering and the challenges they may encounter in their future careers. For instance, the Pre-Engineering program at UC Berkeley is a three-week summer program for incoming

Berkeley Engineering students. It offers primer seminars in crucial subjects, specifically calculus, chemistry, and programming courses. It builds professional skills (such as resume preparation) and includes a design component with hands-on projects (creating a prototype). Students connect with peers, faculty, and industry representatives, preparing them for success before starting regular classes. Thus, providing support at no cost due to corporate partnerships (Berkeley Engineering, 2023).

The integrated Teaching and Learning (ITL) Program at the University of Colorado at Boulder created a PENG outreach program for K–12 instructors and students to inspire students about the benefits of PENG topics. Program effectiveness was evaluated based on participants' feedback, long-term results, and evaluation of instruments created for teachers' classroom use (Poole et al., 1999).

PENG programs have proven quite effective in enabling students, particularly underprivileged students, to pursue an engineering degree. Mitchell (1981) created a vocational decision-making model as a foundation for the Greater Chicago Area Program (GCAP) for Minorities in Engineering, which lacked a theoretical foundation. This study investigated the issues in the minority PENG programs and the factors leading to increased minority student attrition in these programs. The factors discovered during this study are essential for completing the GCAP program. Another example is the Indiana State University PENG program, offered by the Department of Chemistry and Physics, which provides a flexible pathway for students interested in engineering where students complete a set of courses covering the initial non-engineering-specific requirements, namely mathematics, physics, chemistry, computer science, and general education. Students can apply to their preferred engineering school upon PENG

program completion. The program offers an increased likelihood of admission due to two years of successful college study (Indiana State University, 2023).

Perry (2013) discusses the development of the pre-engineering program at the joint Florida A&M University-Florida State University College of Engineering. The study indicates that students who finish the pre-engineering program are significantly more likely to graduate with an engineering degree. Furthermore, the research suggests no notable variations in graduation rates among those who complete the pre-engineering program based on their home institution, gender, or race/ethnicity.

McCharen and High (2010) analyzed the PENG students' retention rates at the College of Engineering at Oklahoma State University entering college. It includes a comparison between the retention rates of students from a developed PENG program of study from a regional career technology center and the general university students during the same period. Moreover, pre-engineering programs often emphasize developing critical skills such as problem-solving, teamwork, communication, and creativity. For instance, a minority engineering program (MEP) was developed to address African American students' non-cognitive and cognitive needs. The objective is to retain students in the College of Engineering by providing them with the fundamental skills needed to excel in their chosen major (Good et al., 2007). These programs are most often found at flagship institutions.

Fisher et al. (2001) describe the CircLES program (Circles of Learning for Entering Students) at the University of Texas at El Paso (UTEP), which is designed to support first-year students by improving their success and retention rates. It focuses on students with weak math backgrounds and provides non-credit courses to build their math skills to a college level. The program enrolls students in four courses: developmental math, English composition, university

seminar, and introduction to engineering. This clustering of courses with an interdisciplinary team of instructors creates a learning community providing students with success strategies, critical thinking skills, problem-solving abilities, and hands-on projects to explore engineering and bridge the gap between abstract math concepts and real-world engineering applications.

These programs have evolved from bridging the gap between high school and undergraduate studies to encompassing hands-on experiences and a holistic approach to skill development. By providing students with a strong foundation in mathematics, science, and engineering principles, pre-engineering programs prepare them for success in their subsequent engineering studies and future careers. Future research should focus on assessing the effectiveness of different program structures and pedagogical approaches in achieving. By examining these different types of programs, we can gain insights into the multifaceted nature of pre-engineering education.

Human-Centered Design Concept and Applications

Human-centered design (HCD) is a systematic and innovative problem-solving approach that involves a comprehensive understanding of the individuals being served, fostering empathy and insight into their unique perspectives while also considering technological feasibility and economic viability. Thus, generating innovative and effective solutions directly addresses the intended users' specific requirements (IDEO.org, 2015). The HCD philosophy advocates that when designing technical systems, the primary focus should be on placing the end-users at the core of the design process, prioritizing their needs, preferences, and experiences (Johnson, 1998). IDEO's HCD process for problem-solving consists of three key phases: inspiration, ideation, and implementation. The inspiration phase involves understanding users' experiences and pain points. The ideation phase involves designers leveraging user insights (feelings, experiences,

etc.) to generate multiple ideas for solving the problem. Finally, in the implementation phase, designers prototype and test the ideas/solutions with users to gather immediate feedback (IDEO.org, 2015; Brown & Wyatt, 2010; Brown & Martin, 2015; Chen et al., 2020).

User-centered design, another term in the literature, refers to a multi-stage problem-solving process (i.e., framework of processes). Designers analyze and envision how users interact/engage with a product and then validate their assumptions through real-world testing to understand user behavior. The difference between a "user" focus and a human-centered focus lies in how technology is designed (Gasson, 2003). Gould and Lewis (1985) describe three fundamental principles of user-centered system design. These principles include an initial and ongoing emphasis on users, using empirical measurements to assess user behavior and usage, and adopting an iterative design approach that involves modifying and testing the system in simulated prototypes or solid form in repetitive cycles. For instance, a systematic literature review conducted to examine the application of user-centered design (UCD) in developing e-Learning systems found that UCD is used in various ways, with methods such as questionnaires, interviews, prototyping, and usability testing being commonly integrated. Projects involving users in multiple development phases tended to produce e-Learning systems with good usability. Additionally, the study highlights the importance of active participation from learners and subject matter experts in the design process for achieving optimal user interfaces and facilitating practical learning experiences (Hasani et al., 2020).

Cha and Ahn (2020) utilized UCD to develop an intelligent tool to support teachers in implementing differentiated instruction (DI) in classrooms. The study emphasizes the importance of involving teachers in evaluating and making decisions about system features. The user-centered design approach includes using personas, scenarios, and iterative evaluations conducted

by teachers. The evaluations helped designers understand teachers' tasks and prioritize features. The study highlights the benefits of different evaluation methodologies in designing educational tools with future technologies. The findings confirm that intelligent technologies, like the developed innovative tool, can effectively support differentiated instruction in the real world.

Zoltowski et al. (2012) conducted a study to investigate how students perceive and engage with human-centered design. The research involved interviewing 33 student designers from various academic backgrounds. The study identified seven distinct ways in which students experienced human-centered design, with five categories showing a hierarchical relationship: "User as Information Source Input to Linear Process," "Keep Users' Needs in Mind," "Design in Context," "Commitment," and "Empathic Design." The findings highlighted the significance of immersive experiences with real clients and users in enhancing students' understanding of human-centered design principles. The study underscores the importance of incorporating user perspectives and needs throughout the design process.

Kahramana (2010) attempts to use a user-centered design approach to course design in university education to increase teaching effectiveness, student learnability, and success. This includes redesigning three elective courses in interior architecture using the user-centered design approach. Data collection involved students' input through focus groups and questionnaires to identify factors influencing student learnability and success, propose teaching methods, design course activities, evaluate student perceptions of the courses, and assess student satisfaction. The findings provide insights into the impact of the user-centered design approach on course design and student experiences.

Hadjerrouit (2010) discusses the potential of web-based learning resources (WBLRs) in improving school teaching and learning. The study acknowledges that WBLRs are currently

developed primarily by technical and software experts, lacking input from teachers and learners. This absence of user involvement often leads to a disconnect between the software and the educational needs of the users. The article suggests adopting a user-centered approach to WBLR development to address this, focusing on aligning pedagogical issues with practical learning tools. The study discusses the application of this approach in school education, including feedback and evaluation from trainee teachers, school teachers, and students. The article highlights the importance of ongoing design, implementation, and evaluation processes in different school contexts to enhance the user-centered approach.

Human-centered design (HCD) application in various domains has become increasingly important in creating user-centric solutions. In the healthcare industry, HCD can guide the design of solutions that effectively meet their requirements by understanding the needs and preferences of patients, healthcare providers, and stakeholders. Carter (2018) proposed using HCD principles in developing a training program for medical trainees, focusing on experiential learning, mentorship, and exposure to digital medicine. This study showcased a distinctive approach to fostering clinician-innovators by employing human-centered design principles, emphasizing medical trainees as the end-users. Critical steps in this approach include empathizing, defining objectives, generating solutions, creating a curriculum prototype, and testing its impact. The findings show that this training prepares trainees to contribute innovative solutions and adapt to emerging scientific and technological advancements.

One effective tool utilized within HCD is the development of personas and fictional representations of target users based on actual data (Blomkvist, 2002). Personas can be described as complex archetypical characters that represent specific groups of behaviors, goals, and motivations identified through research and observation (Cooper, 1999; Calde et al., 2002).

Miaskiewicz and Kozar (2011) explore the benefits of using personas in product design. The study mentioned that personas help design teams to focus on customer goals, prevent self-referential design, challenge assumptions, and help prioritize consumer segments. Thus, by designing for specific personas, products have a greater chance of success than a broad audience. Personas aid in understanding social and political aspects with several benefits, including establishing a strong user focus, leveraging cognitive extrapolation, making explicit assumptions, acting as a communication medium, and narrowing the target audience (Grudin & Pruitt, 2002).

Tu et al. (2010) propose combining qualitative and quantitative methods for creating personas in the interactive design process. This approach develops personas for Vtech Inc.'s target customers for a new outdoor sports earphone. User data is collected through questionnaires, interviews, and observations; cluster analysis is used to group users with similar goals. The study emphasizes that this approach aligns with the "design for goals" concept more effectively than traditional qualitative methods. Ferreira et al. (2016) introduced the PATHY technique, which combines Empathy Maps and Personas to enhance understanding of user needs in software engineering. The study evaluates the technique's usability and effectiveness, with results indicating that PATHY was considered both user-friendly and valuable. Overall, PATHY represents an innovative approach to persona creation, enabling practitioners to effectively align features with user requirements.

Theory of Change in Practice

Theory-driven evaluation emerged as a prominent approach with the publication of Chen's book in 1990, although its origins can be traced back to Tyler's concept in the 1930s (Coryn et al., 2011). These evaluations are referred to by various names such as program-theory evaluation, theory-of-action, theory-of-change, logical frameworks, realistic evaluation, etc.

(Coryn et al., 2011; Mark et al., 1998; Pawson & Tilley, 1997). Theory of Change (ToC) is widely used in various fields, including program evaluation, social innovation, and organizational development. A ToC can be succinctly defined as explaining how and why an initiative is expected to be effective. It prompts participants to clearly articulate the desired ultimate outcomes and impacts and the specific pathways they anticipate will lead to those outcomes (Weiss, 1995). During the design phase, integrating a Theory of Change (ToC) enhances the probability of stakeholders explicitly defining the intended outcomes of an initiative, the necessary activities to achieve those outcomes, and the contextual factors that may impact them (Connell & Kubisch, 1998).

James (2011) highlighted numerous benefits of using the theory of change approach. These include fostering a shared understanding, improving program clarity and effectiveness, providing a framework for monitoring and evaluation, enhancing partnerships and open conversations, organizational development, facilitating clear communication and reporting, and enabling individuals to participate actively in programs. '

The theory of change framework aligns with three critical aspects of evaluation practice: process-outcomes evaluation, responsive/interactive evaluation, and realistic evaluation. Process-outcomes evaluation focuses on understanding the program implementation and its impact on achieving objectives. Responsive/interactive evaluation promotes stakeholders' participation in the evaluation process and maximizes learning by ensuring their perspectives are included and recognizing the diverse value bases of different stakeholders. Additionally, ToC highlights the dynamic nature of the evaluation context, particularly concerning policy changes that may require program adaptations over time (Sullivan et al.,2002).

Milligan et al. (1998) conducted a study on a community-building initiative that prioritized community participation in developing the theory of change. The researchers engaged with three different stakeholder groups in distinct ways: a group interview with staff responsible for planning and implementing activities using open-ended questions based on the ToC framework, individual interviews with the Board of Trustees to understand their insights and perspectives on the initiative, and observations of village council meetings along with focus groups to gain further understanding and input. The researchers facilitated discussions and constructed theories of change based on the gathered input, which were then revised and developed in collaboration with the participants.

Gambone et al. (2001) highlight the significance and implementation of the Theory of Change (ToC) in shaping systemic changes in educational services. This report evaluates the ongoing First Things First (FTF) initiative, a comprehensive school reform program in Kansas City, Kansas. FTF adopts a theory of change framework, specifying steps for attaining desired outcomes and monitoring progress at different stages. The report examines the effectiveness of these efforts in establishing favorable conditions and enhancing the capacity for reform.

Hernandez and Hodges (2006) explore applying the theory of change approach in community-based service planning for children with serious emotional disturbance, specifically focusing on youth with juvenile probation. The theory of change process helps create a roadmap for implementing service plans that align with the community's goals. It consists of twelve stages and aims to assist stakeholders in articulating shared beliefs and establishing logical connections between the target population, desired outcomes, and strategies to achieve those outcomes.

Silva et al. (2014) suggest integrating ToC into the Medical Research Council (MRC) framework to enhance complex healthcare interventions' effectiveness, sustainability, and

scalability. ToC is applied and tested using two randomized controlled trials and one non-randomized evaluation of complex interventions. Findings indicate that incorporating ToC strengthens various MRC framework stages and facilitates stakeholder engagement, contextualizes intervention design, identifies knowledge gaps, and provides comprehensive evaluation indicators.

The ToC approach provides a comprehensive framework for identifying and understanding community needs, designing tailored interventions, and monitoring progress toward desired outcomes.

Program Evaluation

Program evaluation systematically uses analytical techniques to evaluate a program's design, implementation, enhancements, or outcomes (Rossi & Freeman, 1993; Short, Hennessy, & Campbell, 1996). Most program evaluators concur that program evaluation can have either a summative or a formative function which involves improving the program or making decisions on the continuation of a program (Worthen, 1990). Assessing the program structure, including its activities, the population it serves, its operation, and the characteristics of its participants, is the most basic type of program evaluation. Moreover, it also involves evaluating its allocated resources and whether it is carried out as intended (Posavac, 2015).

Kocaoglu (1983) proposed a comprehensive program evaluation methodology encompassing resource allocation, strategy implementation, and performance assessment. This approach involved measuring subjective values through constant-sum comparisons, developing a Hierarchical Decision Model (HDM), and establishing expert consensus through a hierarchical decision process. The program was viewed as a network of relationships across three critical levels of decision hierarchies: impact, target, and operational. The objective was to evaluate

program outcomes by comparing them to the possible results achievable with different resource allocations.

Recent advances in data analytics have led to the development of tools to understand and analyze student needs, trends, and behaviors and utilize them to enhance learning design, improve student retention rate, and create early warning systems customized for the specific needs of students (Freitas et al., 2015). Freitas et al. (2015) propose a fundamental learning analytics model (LAM) for higher education that emphasizes stakeholders' interaction with the data using visual analytics, promoting personalized learning and support services. For instance, this includes the use of self-organizing maps.

Sacre and Shuman (2013) created regression models that used quantified measures of student attitudes to predict attrition and performance in a freshman engineering program. They examined incoming students' attitudes toward engineering, their expectations of the educational experience ahead, and their self-assurance in achieving success in engineering. By administering a closed-form survey, they linked these attitudes to performance and retention in the freshman engineering program. The study revealed that student attitudes could effectively assess specific aspects of the freshman engineering program, especially attrition-related issues.

Consequently, implementing these models has enabled freshman advisors to better inform students about engineering opportunities, design more tailored study programs based on individual interests, and establish more realistic retention goals.

Fantz et al. (2011) examine the impact of pre-collegiate engineering experiences on student self-efficacy. The results show that pre-engineering classes and engineering hobbies significantly contribute to students' self-efficacy in engineering studies. The study suggests that engineering colleges should allocate resources to K-12 technology and pre-engineering teachers

to enhance students' self-efficacy. Thus, increasing self-efficacy during K-12 may lead to more students pursuing engineering, thereby addressing the potential shortage of trained engineers in the United States.

Wentz and Raebel (2015) examined the impact of Project Lead The Way (PLTW) on freshman Architectural Engineering students' performance at the Milwaukee School of Engineering, focusing on their freshman GPA. Students' high school transcripts were analyzed to determine whether they had taken PLTW courses. The study then assessed the cumulative GPA of each student at the end of their freshman year using the Independent Samples t-test to determine if there was a significant difference between them. The results indicated that students with PLTW experience had a higher GPA at the end of their first year than those without PLTW experience. The results showed that students with PLTW experience had a higher GPA, supporting the claim that PLTW helps prepare high school students for college.

The preliminary analysis of students' data can show enrollment and retention trends and student experiences. It is beneficial when emphasizing the importance of disaggregating all data by race, ethnicity, socio-economic status, and demographics. The Education Trust's director of higher education research and data analytics, Jinann Bitar, believes that reviewing and analyzing the disaggregated data is essential. In addition, emphasis should be given to the existing gaps and inequalities (Weissman, 2021). It might aid in understanding the impact of government policies based on aggregated data (Weissman, 2021).

Borrego et al. (2018) utilized multinomial logistic regression models to predict the intention to pursue a master's or Ph.D. degree. The study examined engineering undergraduate students' perceptions of graduate school and its effect on their enrollment decisions. The findings showed that self-efficacy most strongly influenced graduate school intention.

College access programs have been around for decades, intending to increase college preparedness and enrollment rates, particularly among underrepresented groups (Harvill et al., 2012). To accomplish the goal of enhancing college attainment and closing gaps between groups, we must ensure that all students can pay for college, the academic preparation required for college-level work, and the knowledge and support needed to navigate pathways into and through college (Perna, 2006; Perna & Jones, 2013; Perna, 2015).

The results from this research can guide universities to accomplish this goal and fill the knowledge gap by systematically gathering, reviewing, and analyzing the student data and the effectiveness of various programs designed to improve college readiness and enrollment for disadvantaged populations.

Chapter 3: Framework

The assessment of PENG programs in higher education has received limited research attention with regards to considering the students' perspective. Despite being a crucial stakeholder in the success of such programs, students' experiences, opinions, and needs have been overlooked in program evaluations. While school officials often assess program success based on enrollment and performance metrics, these evaluations may not provide a complete picture of the program's effectiveness. This research study addresses this knowledge gap by utilizing the Theory of Change (ToC) and Human-Centered Design (HCD) methods to investigate what constitutes an effective PENG program that considers student learning experiences, professors' perspectives, and academic advising department expectations. By centering on the students' voices and experiences, this study identifies factors contributing to program performance, bridging the gap between student perceptions, experiences, and program goals. Considering students' perspectives, this research achieves a more comprehensive understanding of PENG programs' effectiveness.

Theory of Change (ToC)

The theory of change (ToC) approach is used in this work to focus on understanding the problem, selecting ways to improve it, and addressing the rationale of how taking a particular approach will help accomplish the intended goals resulting in improved PENG program planning and development. It assists in accounting for the targeted research outcome and the long-term change it entails.

Theory of Change is a comprehensive and collaborative approach where participants (groups/individuals) in a planning process state their long-term goals, identify the interventions, and specify the conditions required. These goals are represented visually in a causal framework as desired outcomes. The ToC framework offers a functional model that describes different interventions (such as a single program or coordinated initiative), resulting in specific outcomes while keeping the implementation and evaluation process transparent (Taplin & Clark, 2012).

ToC analyzes if a specific method of operation will be efficient and demonstrates how change occurs over the short, medium, and long terms to have the desired result. ToC framework includes the following six steps: (1) Defining long-term objectives, (2) Backtracking and connecting the prerequisites/ requirements to achieve the desired objective, (3) Identifying fundamental context-related assumptions, (4) Determining the interventions that this initiative will implement to bring about the desired change, (5) Creating metrics to gauge the results to help evaluate how well the strategy is performing, (6) Developing a narrative to describe the reasoning behind the specific initiative. (Theory of change community, 2021)

Formulating these steps helps promote specifically defined outcomes and re-evaluate the viability of achieving goals during each project phase. Users must provide information on the target demographic, the degree of change necessary to indicate success, and the projected timeframe for the anticipated change. The classic model of Theory of Change is shown in Figure 1.

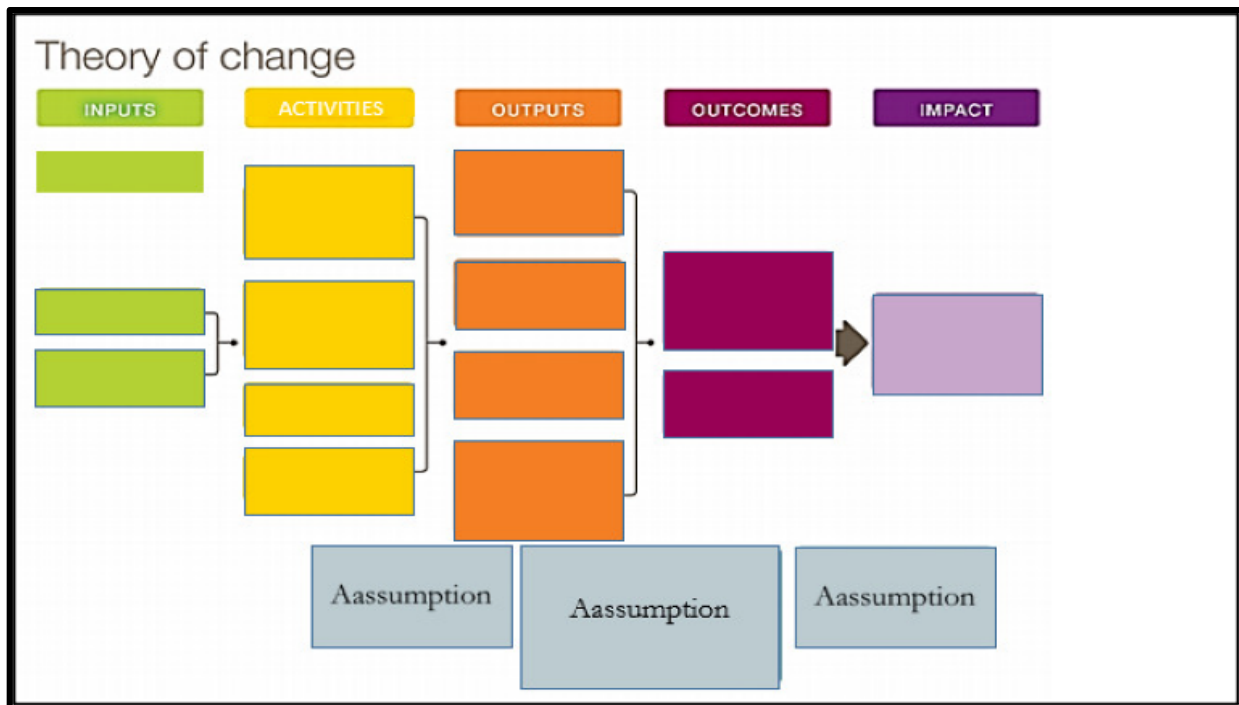


Figure 1: Classic model of Theory of Change (Ren & Guckin, 2022)

Educational programs/initiatives for both students and educators are typically designed and evaluated by teachers, principals, policymakers, curriculum coordinators, and other significant stakeholders in the field of education (Ren & Guckin, 2022). The ToC framework in this research focuses on the PENG program's ideation, development, and improvement at UM-Dearborn. It focuses on enhancements in the educational outcome, student experiences, and quality of teaching and learning. This work will assist the university in understanding the students' perspectives. Thus, improving the student experience and success rate, particularly for students from low SES communities and areas with low enrollment trends.

The ToC framework guides the project plan. It involves using a human-centered design process established by Stanford's Hasso Plattner Institute of Design to fulfill the research goals and understand the target audience. ToC prioritizes the voices/perspectives often left out of the discussion about change. This study invites several stakeholders and participants who are directly impacted by the success of the PENG program and adequately addresses their

perspectives. The participants include PENG students, faculty members, and academic advisors. Thus, collecting different insights can help identify diverse perspectives on how desired change is likely to occur, followed by the reasoning and assumptions behind it.

In this work, ToC helps document the impact participants seek to achieve and all the intermediate steps to ensure that respective activities and resources align well with said change. It includes utilizing a human-centered design process which starts with outlining the problem, including the identified root causes and stakeholders, defining the desired end goal, and articulating how activities are expected to lead to outputs, outcomes, and eventually impact. Table 3 describes the definitions and descriptions of each stage of the ToC framework. Thus, the HCD process will help collect information for each stage. The following section outlines the steps to gather and integrate participants' input using a human-centered design process.

ToC Steps	Description
INPUTS	Resources needed to meet the project goals. For instance, funds and equipment.
ACTIVITIES	Tasks/initiatives required to take place for each output to take place.
OUTPUTS	Immediate results of activities required to accomplish the outcomes
OUTCOMES	Intended and unintended changes that result from the project outputs
IMPACT	Systematic long-term changes derived from outcomes.

Table 3: ToC stages

Human-Centered Design Method

A human-centered design is a user-centered approach that emphasizes understanding the needs, preferences, and behaviors of the target users throughout the design process. It involves iterative stages of research, ideation, prototyping, and testing to create solutions that align with user needs and expectations. HCD methodology revolves around empathy mode, which is an effort to understand people and their emotional and physical requirements (Hasso Plattner Institute of Design). The contextual inquiry method helps us understand the behavioral needs and

issues of the user. It involves observing and interviewing the participants, including the students enrolled in PENG programs and people involved in PENG programs, including faculty members and academic advisors (CECS and START) in the field of education responsible for the significant policy changes and decisions in PENG programs. This step involves asking students to share their experiences and struggles with the support provided to them throughout their program. In addition, professors and academic advisors answer questions regarding classroom environment, program goals, academic support, mentoring techniques, etc., to help understand the issues, perspectives, challenges, and attitudes toward new changes needed. Open-ended questions help focus on the details of the participant's routines and thoughts on the entire procedure. If the participant agrees, the researcher records the audio from the sessions and transcribe it for analysis. The analysis includes taking notes on anything that piques the attention during the interview, such as specific actions or strong verbal signs.

This study incorporates the following user-centric strategies:

- Conducting user research: Participants involve students (currently/ alumni) enrolled in PENG programs, professors, and academic advisors in PENG programs, respectively.
- Determining the user needs/experiences: This involves a PENG program evaluation based on participants' experiences during the program. Surveys and interviews help understand the participants' experiences and perceptions regarding the PENG program.
- Generating multiple ideas: This involves co-design workshops facilitated for study participants (PENG students, professors, and advisors) to brainstorm new ideas and propose a research-informed solution to help improve student access, support, and success in the PENG program.

This study employs a mixed-method research design, including quantitative and qualitative research techniques. Qualitative description is a practical method frequently used to guide practice, policy decisions, and the creation or improvement of interventions (Neergaard, Olesen, Andersen, & Sondergaard, 2009). It aims to produce a detailed description of an experience or event that adheres to participants' perspectives. Furthermore, it combines a variety of sampling, data collection, evaluation, and representation methodologies reasonably (Sandelowski, 2000). Quantitative research techniques utilize measurements and numerical and statistical analysis to analyze behavior. It establishes an essential connection between quantitative relations expressed mathematically and actual observation. Thus, qualitative research delves deeply into specific experiences to describe and explore meaning through text, narrative, or visual-based data; by searching for patterns unique to a specific range of users, the quantitative analysis uses statistics to yield an unbiased result that can be generalized to some larger population (Given, 2008, Glesne, 2011).

Chapter 4: Identify Pain Points of PENG Students at UM-Dearborn

Participants

This work involves three major population categories from the PENG program at UM-Dearborn, including:

- College advisors (START and CECS) that play a significant role in program implementation,
- Students currently enrolled in the PENG program as well as students who graduated in recent years, and
- Faculty members who teach courses in the PENG program and have current information on the program's progress and outcomes.

The rationale for including student participants in this study is based on the understanding that their perceptions and experiences with the PENG program are critical factors in its successful implementation, maintenance, and sustainability. Including PENG faculty members and advisors in this study capture their experiences teaching and advising PENG students and any challenges they may have encountered in their roles. This comprehensive approach aims to provide a complete understanding of the PENG program and its effectiveness.

Table 4 displays the information for each participant involved in the study. The "PENG Participants" column lists each participant type, while the "Description" column lists the role of the participants in the PENG program. For instance, it describes the courses taught by faculty members, providing context for their involvement in the study. Overall, this table provides a clear and concise overview of the study's participants and their backgrounds

PENG Participants	Description
Students	PENG Current & Alumni students.
Faculty members	Faculty members who teach following subjects: MATH 090, MATH 105, MATH 115, CHEM 134, ENGR 100.
Advisors	CECS and START Advisors, Math Learning Center (MLC) Coordinator, Associate Dean for Undergraduate Education

Table 4: Study participants information

Participants for this study were recruited through convenience sampling. The PENG program faculty and staff were contacted via email and invited to participate in the study. Additionally, students were recruited through emails, flyers posted on campus, and announcements made in the PENG courses. Inclusion criteria for student participants include either being enrolled or having graduated from the PENG program at UM-Dearborn. Inclusion criteria for a faculty member and advisor participant include teaching or advising PENG students at UM-Dearborn.

To encourage student participation in this study, incentives have been provided. Upon completing the survey, student participants are automatically entered into a raffle with a chance to win one of five \$50 gift cards as a token of appreciation for their time and effort. This incentive is also offered for the follow-up survey. Additionally, students participating in the interview session were given a \$20 gift card as a thank-you gesture.

Using incentives in research studies is a common practice aimed at increasing response rates and minimizing non-response bias, potentially affecting the validity of study findings. These incentives have been designed to maximize participant engagement and representativeness and to improve response rates. Previous research studies have established the effectiveness of incentives in promoting participation and improving response rates (Smith et al., 2019; Singer &Ye, 2013).

Participants are informed of the study's purpose, procedures, potential risks, and benefits. They are assured of the confidentiality of their responses during all phases of this study,

including any experimental writings, published or not. For instance, procedures for maintaining confidentiality include using personas instead of real identities. Moreover, identifiers such as email, specific birth data, ZIP codes, etc., are not used/shared in the final findings/report. Participants are also informed of their right to withdraw from the study at any time without consequences.

Upon agreeing to participate, participants are asked to provide their availability for data collection activities (interview or co-design session), depending on the study phase. Overall, the convenience sampling method used for participant recruitment aimed to maximize the study's feasibility and minimize participant burden while ensuring a diverse range of participants across the PENG program. Table 5 summarizes the participant recruitment and engagement for the study.

Phases	PENG Participants	Data Collection Method	Reached out	Participated
Phase 1	Students	Survey	834	200
		Interviews	200	7
Phase 2	Faculty Members	Interviews	10	6
	Advisors	Interviews	3	3
	Math Learning Center Coordinator	Interviews	1	1

Table 5: Participant recruitment and engagement

Methodology

Instrument Design

The quality of data collection is a crucial factor in determining the research's reliability and strength. Data collection for this phase of the study uses two different instruments: an internet-based survey, and in-person and Zoom interviews. Each instrument is carefully designed and validated to collect accurate and reliable data.

Internet-Based Survey. The internet-based survey is developed using the Qualtrics platform (www.qualtrics.com/), a web-based software platform for creating surveys. The survey

is focused on collecting demographic information and data on students' perceptions, challenges, and experiences in the PENG program. Additionally, it utilizes a combination of Likert scale questions and open-ended questions to capture both quantitative and qualitative feedback from the participants. The Likert scale allows for the measurement of agreement or disagreement, while open-ended questions will provide an opportunity for participants to express their thoughts and provide additional insights. The survey's reliability and validity testing involve a pilot study where a small sample of participants provides feedback on the survey's clarity, ease of use, and relevance to the research topic. Based on this feedback, the survey is revised and finalized.

In-person and Zoom Interviews. In-person and Zoom interviews are used to collect more detailed and nuanced data from participants. The interview protocol is developed based on a review of the relevant literature and previous research studies. Moreover, the interview protocol refinement (IPR) framework is used for systematically developing and refining an interview protocol. Montoya (2016) described the IPR framework as a four-stage process that involves ensuring interview questions are relevant to the research questions, creating a conversational approach that encourages exploration and inquiry, obtaining feedback on the interview protocol, and testing the interview protocol through a pilot study. Thus, each stage of the IPR framework assists the researcher in progressing toward developing a research tool suitable for their participants and aligning with the research objectives. (Jones et al., 2014). The protocol includes open-ended questions and prompts to encourage participants to provide specific examples of their experiences and perspectives on the research topic. To validate the interview protocol, a small pilot study is conducted with a diverse group of participants who are asked to provide feedback on the clarity and relevance of the questions. Based on this feedback, the interview protocol is revised and finalized.

Data Collection and Analysis

This chapter of dissertation involves two phases focused on understanding the students' challenges/pain points in the PENG program at UM-Dearborn. Figure 2 represents the steps involved in data collection process for this study.

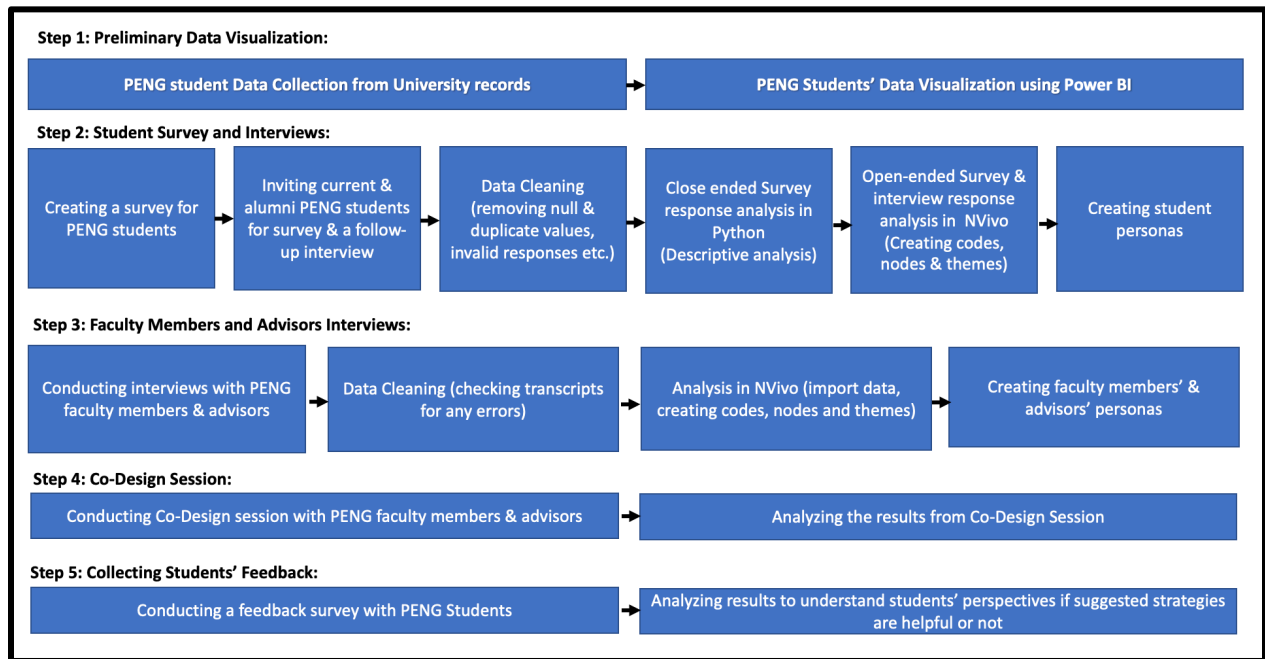


Figure 2: Representation of process for data collection and analysis.

Preliminary Data. Preliminary data collection involves obtaining PENG students' data from the College (UM-Dearborn) records. It includes students' demographic information such as gender, ethnicity, high school name, enrollment information, ZIP codes, etc. This data describes the PENG student population at the University. The Power BI dashboard assists in visualizing this preliminary data, providing an informative overview of the PENG student population.

In a world that relies heavily on data, dashboards have become essential tools that are widely used and valued. Businesses, non-profit organizations, and community groups all rely on them heavily to facilitate their daily operations (Sarıkaya et. al., 2018). Few & Edge (2007) describes dashboard as "A visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be

monitored at a glance." This study uses a dashboard to access PENG student data, encompassing comprehensive information on students' demographics, academic status, enrollment information, and more. The dashboard provides several advantages, including its ability to display data in a user-friendly format and identify patterns and trends quickly and easily. Overall, the Power BI dashboard is essential in informing subsequent research phases, identifying critical areas for further investigation, and providing a foundation for the subsequent data collection and analysis efforts.

The data presented in the dashboard is obtained from the university's student information system and covers the PENG student population from fall 2019 to winter 2022. The data is cleaned by removing duplicates or missing values, and transformations are performed to derive specific metrics, such as the percentage of students eligible for student aid. The dashboard is created using Power BI software, and statistical methods, such as pie charts and maps, are used to visualize and analyze the data.

The dashboard incorporates various visualizations, such as a slicer illustrating the distribution of students by gender, a pie chart displaying the number of students by race/ethnicity, etc. Thus, the dashboard in this research helps visualize the student's metrics, such as their demographics, academic status, enrollment rate, etc., allowing us to quickly identify areas of improvement and intervene with targeted support. The critical demographic data include race/ethnicity, gender, ZIP codes, etc., to identify any disparities or equity gaps within the student population. (As shown in Figure 3)

Preliminary research shows that ZIP Code level demographic attributes such as minority population, internet access, travel distance, educational level, total population, and college-eligible population contribute to students' enrollment decisions (Pawar, 2020). Therefore, this

work helps recognize the economic constraints faced by the students of particular ZIP codes, provides new insights into the community characteristics that admitted students represent, and aids university administrators and policymakers in developing strategies to recruit and enroll more students (Pawar, 2020).

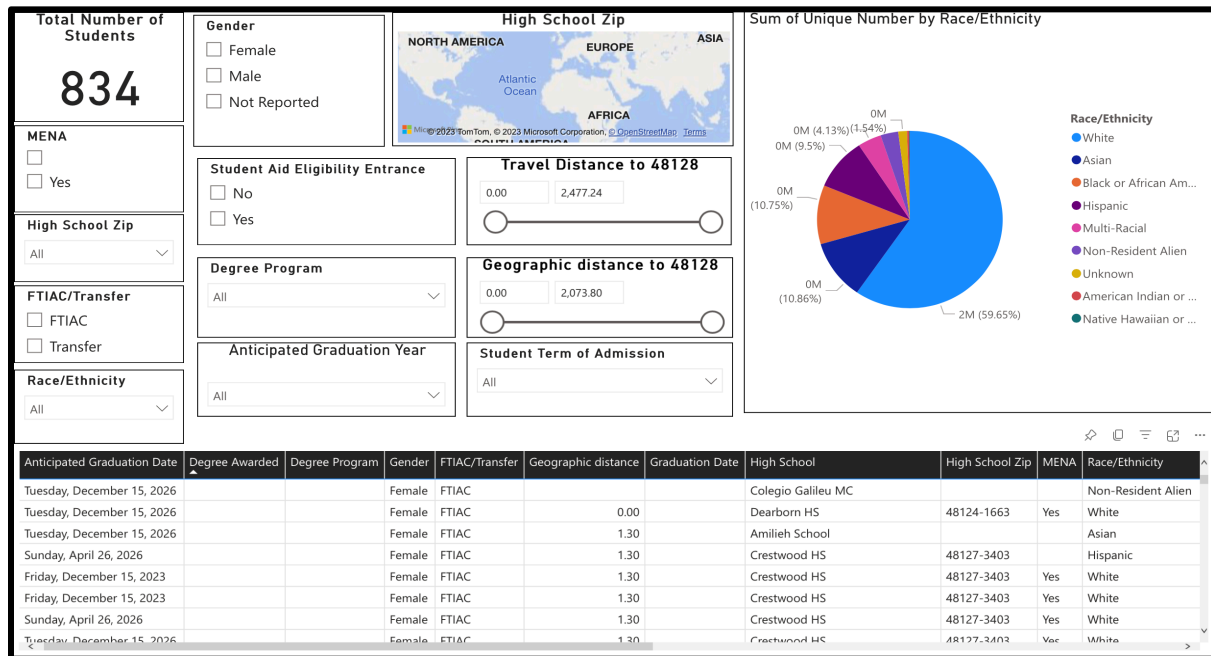


Figure 3: Data visualization using Power BI

Phase 1. In this phase, data is collected from current and previous PENG students through an Internet-based survey and subsequent interviews. The survey aimed to gather information on students' experiences with the PENG program, including their perceptions of its effectiveness, any challenges they faced, and suggestions for improvement. One of the reasons to utilize surveys is to collect more information, increasing the validity of the findings. Furthermore, interviews are conducted with a subset of survey participants to gather more in-depth information on their responses. Some sample survey and interview questions are as follows:

Phase 1 Sample Survey Question

- How were you first contact by UM-Dearborn?
 - High School Career Fair
 - Mailer
 - UM-Dearborn Campus Visit
 - Other _____

Phase 1 Sample Interview Question

- What factors, in your opinion, contribute to a successful PENG program at UM-Dearborn?

Refer to Appendix B and D for a complete list of survey and interview questions respectively. All interviews are done on the University campus, at the participants' convenience, or via Zoom following an interview protocol. This phase focuses on two key elements, i.e., students' perception and experience of the University admission process (e.g., the decision to pursue higher education, course expectations, etc.) and their experience with the current PENG program.

The survey data was collected using Qualtrics (<https://www.qualtrics.com>) and was sent out to 834 (currently and previously enrolled) students in the PENG program. A total of 200 responses were received, resulting in a response rate of 24%. The survey comprised of closed-ended and open-ended questions where closed-ended questions focused on PENG students' demographics, academic status, and experiences in the program. Moreover, open-ended questions aimed to explore the challenges faced by students during their time in the program. For instance, one such question is, "How could the student experience at this university be improved?"

The initial step in this analysis involves data preparation. This process entails removing all observations with null responses or missing values from the dataset. In addition, any inaccurate values were carefully examined and subsequently removed. These inaccuracies were primarily the outcome of incorrect data entry by the survey participants. These errors are fixed by eliminating such observations during analysis. Lastly, any columns that were not relevant to the research question were excluded from the dataset.

Data cleaning is an essential step in the data preparation process, which involves identifying and resolving errors, inconsistencies, and missing data in the dataset. This process is crucial in ensuring the data is clean, accurate, and appropriate for analysis. By removing errors, inconsistencies, and missing values, only complete and valid data was used for the analysis, thereby allowing for more robust conclusions to be drawn from the data. After the data-cleaning process, the final dataset includes 172 observations and 33 variables. Despite the lower response rate, the data still represents the PENG student population and provides valuable insights into their experiences in the program.

Close-Ended Survey Responses Analysis. Descriptive statistics in Python (version 3.9.1.) is used to explore the variables of interest. The survey includes student responses from across different years, from 2019 to 2022. Table 6 shows that out of the total 172 respondents, 50 responses (29.07%) were from students in the 2022 year, followed by 33 responses (19.19%) from students in the 2020 year, 29 responses (16.86%) from students in the 2021 year, and 19 responses (11.05%) from students in the 2019 year.

Enrollment Year	Count/Respondents	Percentage
2022.0	50	29.07%
2021.0	29	16.86%
2020.0	33	19.19%
2019.0	19	11.05%

Table 6: Students' enrollment data

Most students are 19 or younger ($n = 129$, 75%) at the time of admission to UM-Dearborn. The age range for the sample is 16-38 years old, with a mean age of 19.7 years old. The sample includes students from a diverse range of races/ethnicities. The most common response was White/Caucasian ($n = 102$, 59.3%), followed by Asian/Pacific Islander ($n = 26$, 15.1%). A smaller proportion of students identified as Other ($n = 17$, 9.9%), Hispanic American ($n = 15$, 8.7%), and Black or African American ($n = 12$, 7.0%). The frequency and percentage of participants in each age category and race/ethnicity category are presented in Figures 4 and 5, respectively.

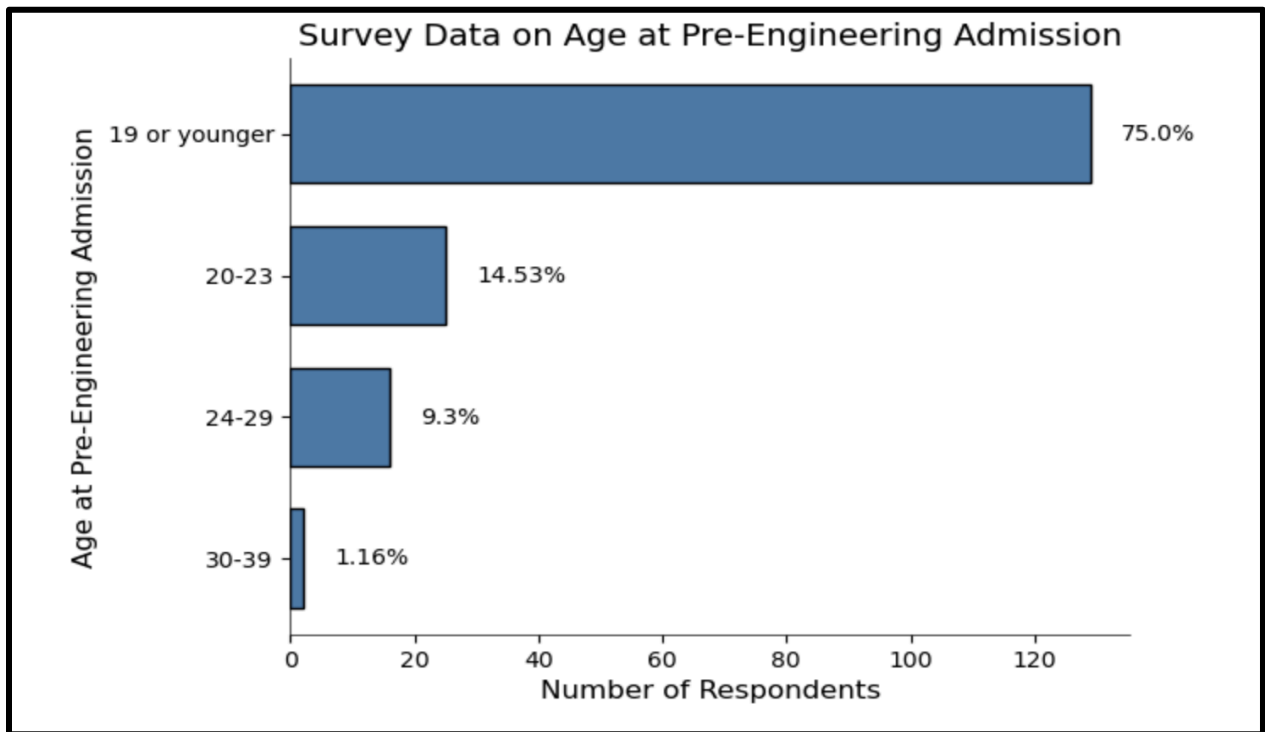


Figure 4: Frequency and percentage of participants in each age category

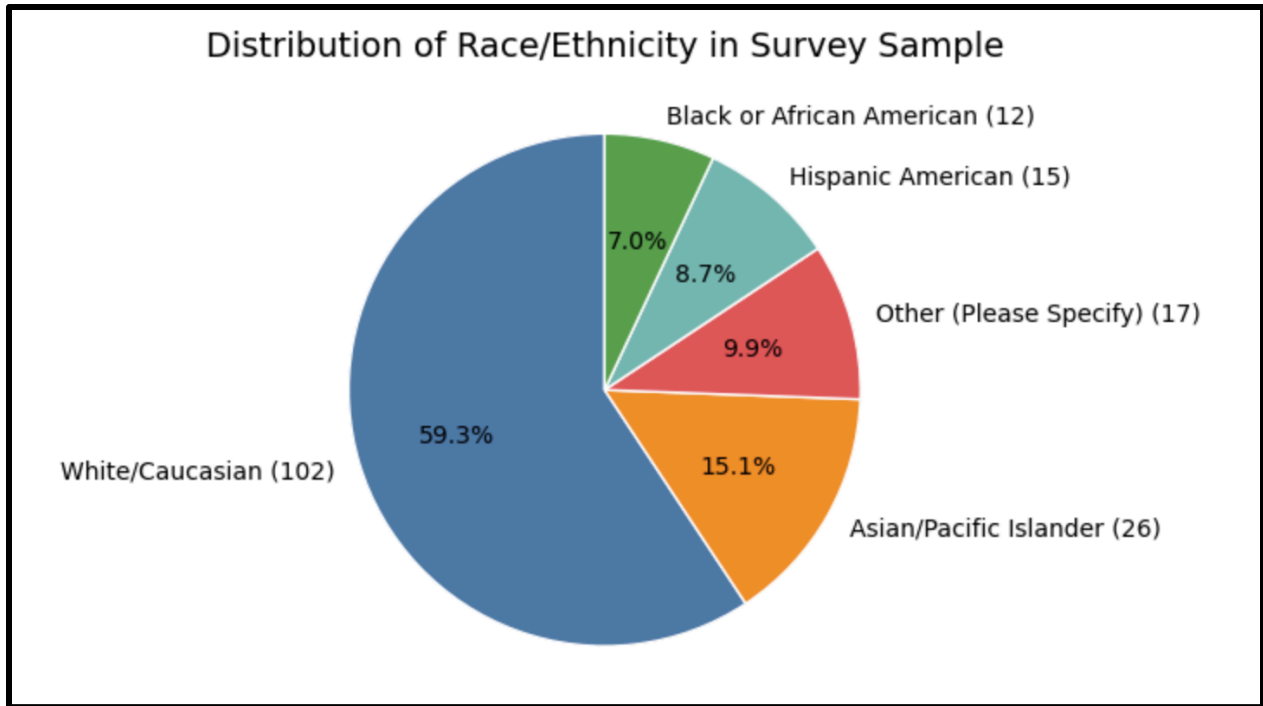


Figure 5: Count and percentage of participants in each race/ethnicity category

These survey analyses suggest that the PENG student population at UM-Dearborn is diverse in terms of age and race/ethnicity. However, it is important to note that the sample is limited to students who responded to the survey and may not be representative of the entire population of PENG students at UM-Dearborn.

Figure 6 shows the count of respondents by their current class standing, including first year students, juniors, sophomores, and seniors. The highest count was for first year students with 60 respondents, followed by juniors with 41, sophomores with 36, and seniors with 33. Regarding transfer student status, the majority of respondents (80.62%) reported being FTIAC students, while the remaining respondents (19.38%) reported transferring from another institution.

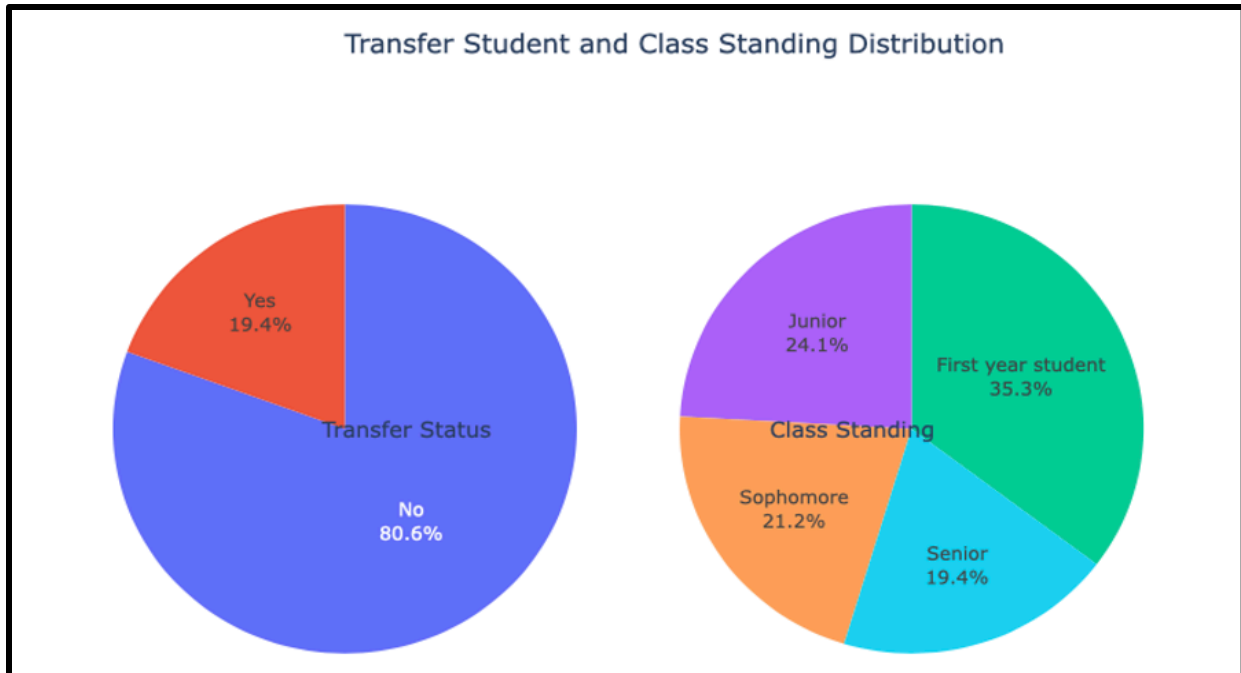


Figure 6: Information on students' Transfer/FTIAC status and class standing at the time of this study

The survey also collected data on the participants' academic major (or intended major), as shown in Table 7. Out of the 172 total respondents, most participants (87.2%) indicated that their intended major was in the College of Engineering and Computer Science (CECS). A small percentage of participants (3.5%) chose a major in College of Art, Sciences, and Letter (CASL), while 2.9% selected "Other." Only a few participants (1.7%) indicated they intended to major in the College of Business (COB).

Academic Major	Count	Percentage
College of Engineering and Computer Science (CECS)	150	87.21%
College of Art, Sciences and Letter (CASL) Major	6	3.49%
Other	5	2.91%
College of Business (COB) Major	3	1.74%

Table 7: Information on students' academic major (or intended major)

The survey data includes information on the ZIP code of the primary residence for each participant, which provides insights into the geographic distribution of the sample. Figure 7 shows the distribution of participants across ZIP codes. Data cleaning and processing are done to ensure the accuracy and completeness of the data.

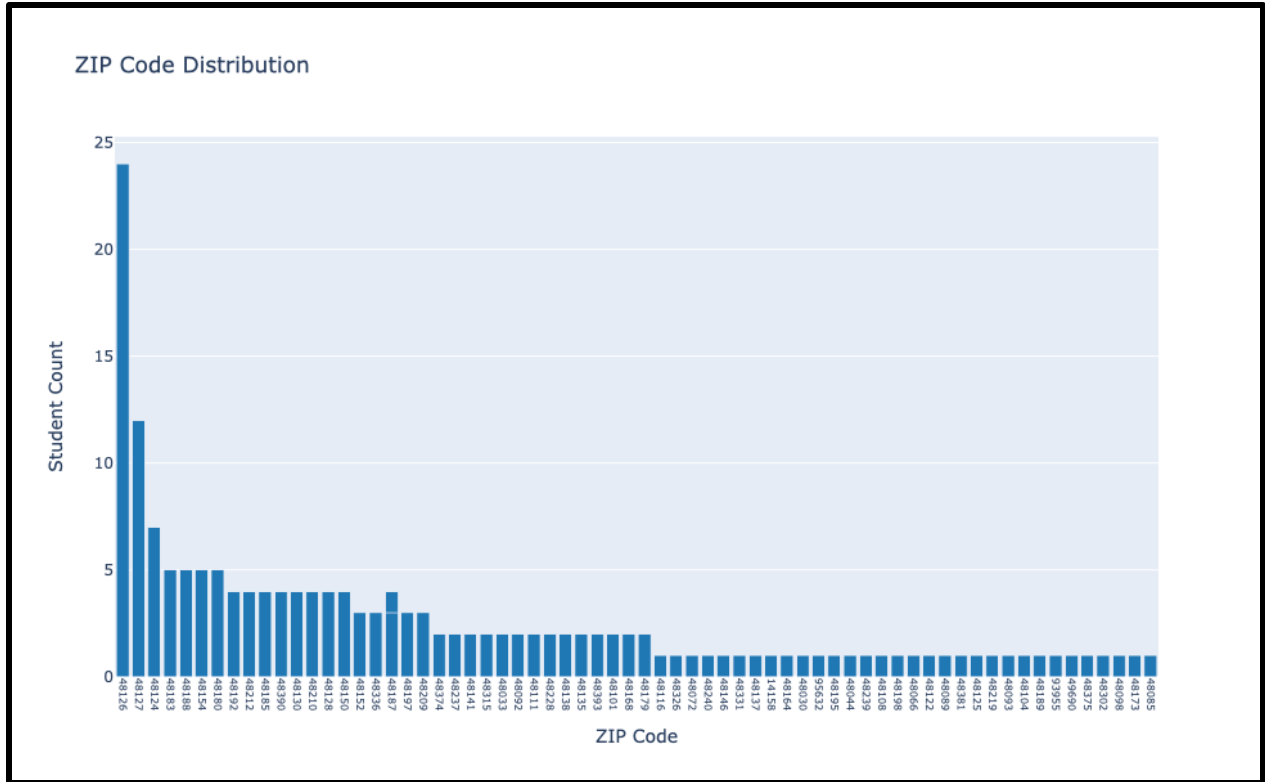


Figure 7: ZIP codes of PENG students' primary residence during the program

Figure 8 presents the distribution of education levels for the parents or guardians of the PENG students who participated in the survey, which provides insights into the educational background of the survey sample. As shown in the table below, the most significant percentage of students (26.16%) reported that their parent(s) or guardian(s) graduated from college, followed by those who graduated from high school or equivalent (GED) at 21.51%. Completing a master's degree or equivalent is the third most common response at 20.93%; the remaining categories accounted for less than 10% of responses individually.

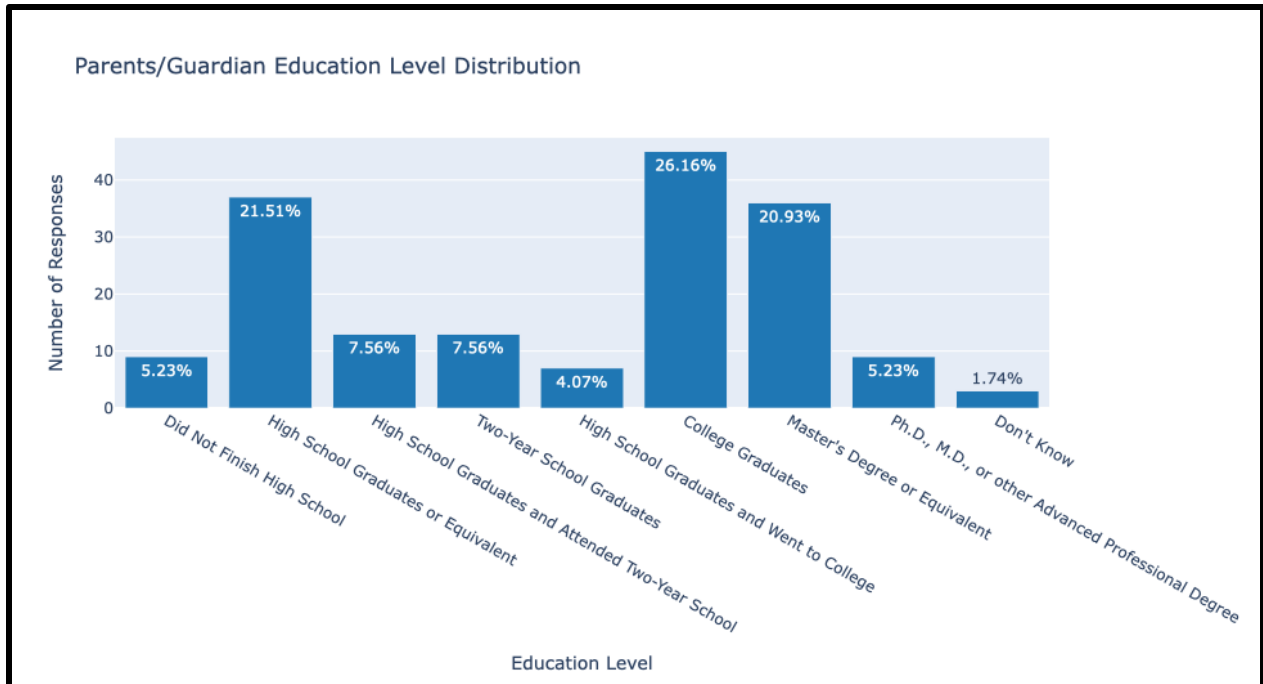


Figure 8: PENG students' parents/guardians' education levels

In the survey, participants (PENG students) were asked to report their high school or previous institution GPAs. Figure 9 shows that the 13.37% of participants reported a GPA of 4.0 or higher, majority of participants reported a GPA in the range of 3.76-4.0 (28.49%), followed by 3.51-3.75 (15.70%) and 3.26-3.5 (15.12%). Only a small number of participants reported a GPA lower than 2.0, with 1 participant reporting a GPA of 2.0 or lower and another reporting a GPA in the 2.0-2.25. It is also worth noting that eight responses were missing. Most participants reported a relatively high GPA, suggesting that the sample comprises high-achieving students.

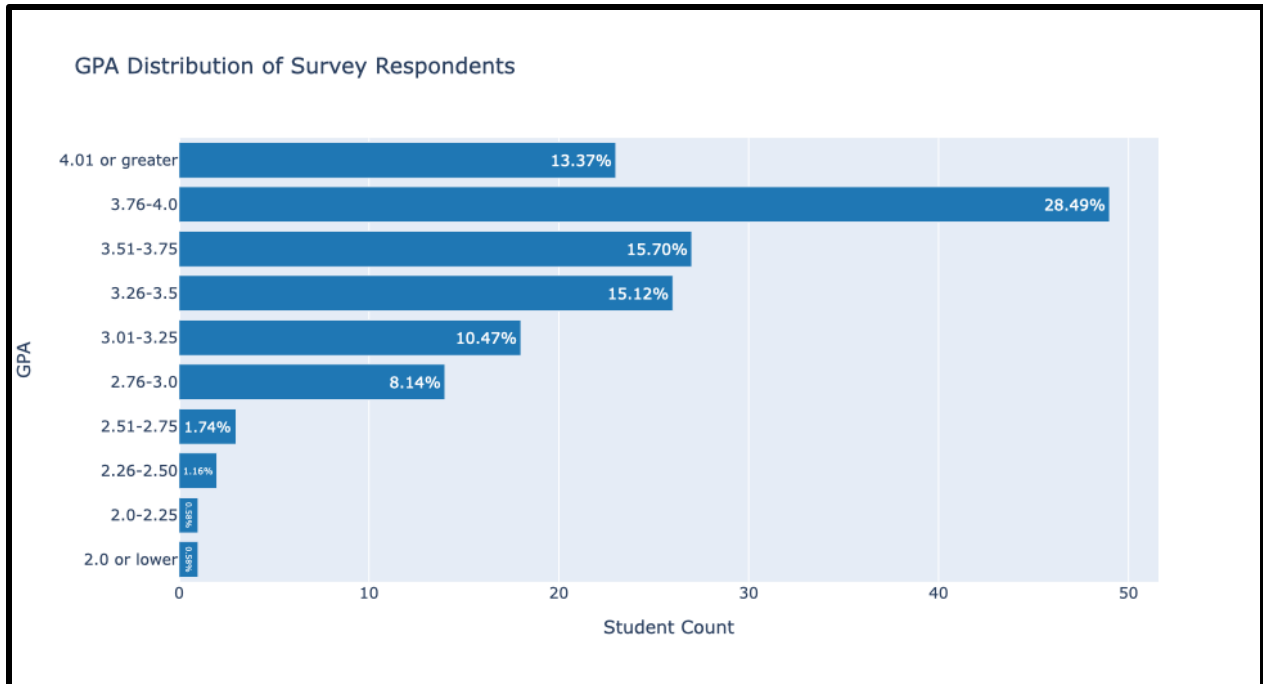


Figure 9: Survey participants' high school or previous institution GPAs

Survey responses conclude that among PENG students at UM-Dearborn, a majority students (50%) are employed part-time, followed by 35.47% who are unemployed. Only a small percentage (7.56%) are employed full-time, and an even smaller percentage (2.33%) are self-employed. (Refer to Table 8)

PENG Students Employment Status	Count	Percentage
Employed part-time	86	50.00%
Unemployed	61	35.47%
Employed full-time	13	7.56%
Self-employed	4	2.33%

Table 8: Employment status of survey participants

Survey participants were asked to rate their agreement with the statement 'The University did everything they could to make my admission process as easy as possible.' on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). This question asks respondents about their experience with the admission process at the University. Specifically, the question asks whether the University did everything possible to make the admission process easy for the respondent.

The responses to this question provide insights into the effectiveness of the University's efforts to make the admission process more accessible and less burdensome for prospective students. Figure 10 shows the students responses where, the mean response for this question was 3.63 on a scale of 1 to 5, where one denotes "strongly disagree" and five denotes "strongly agree" indicating a generally positive perception of the University's admission process.

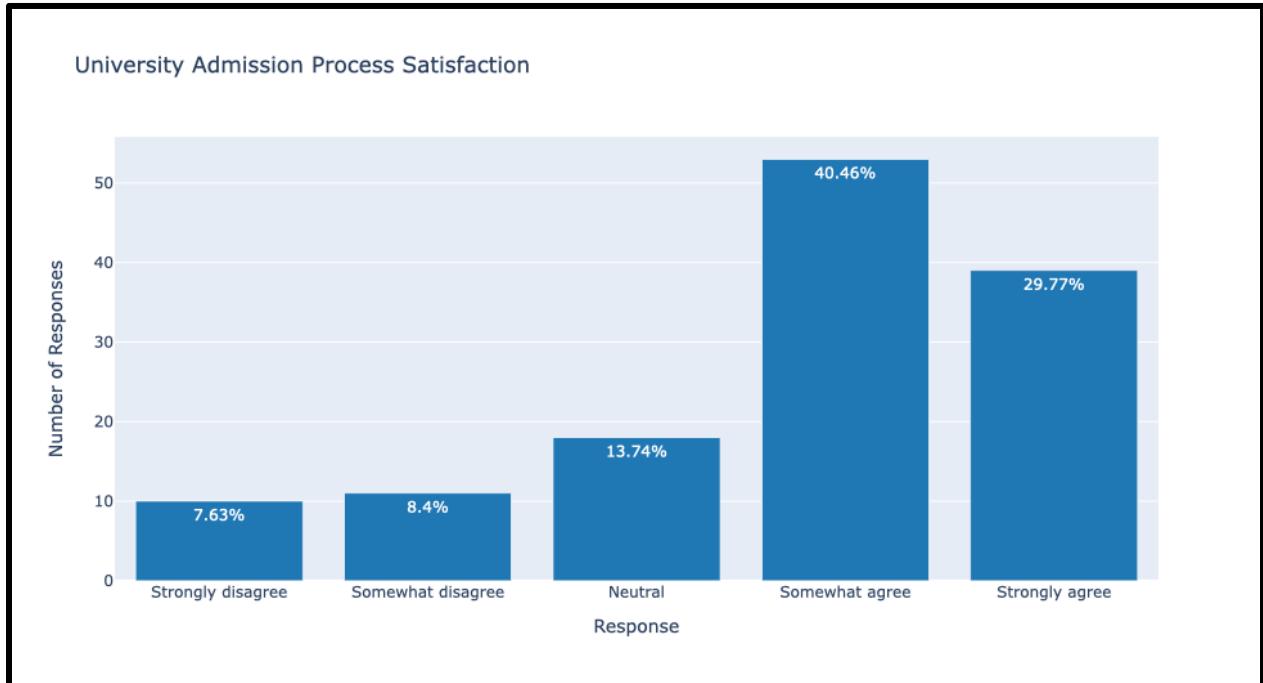


Figure 10: Distribution of responses to the survey question “University did everything they could to make my admission process as easy as possible”

The survey includes a question that asked participants to rate their satisfaction with the university's engagement during the admission process. This question aims to gain insights into students' perceptions of the university's engagement during this critical phase of their academic journey and how this impacts their overall satisfaction with the university. Participants were asked to rate their satisfaction on a scale of 1 to 5, with one being "very unsatisfied" and five being "very satisfied."

Figure 11 shows the distribution of responses to this question where most participants (66.41%) reported being satisfied with the university's engagement during the admission process.

However, a notable proportion of participants (14.50%) reported being either "extremely dissatisfied" or "somewhat dissatisfied" with the university's engagement during this time.

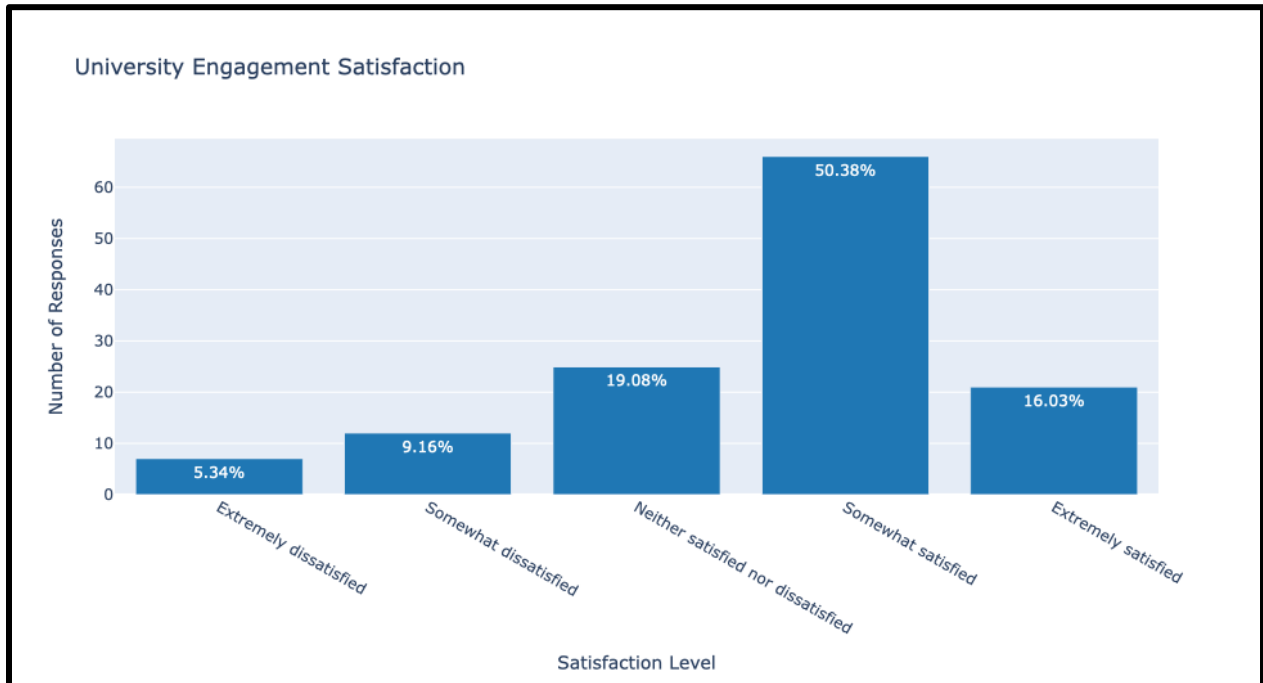


Figure 11: Distribution of responses to the survey question "How satisfied are you with the university engagement at the time of admission?"

Figure 12 shows the distribution of responses to the question, "How likely are you to recommend UM-Dearborn to family, friends, or colleagues based on PENG support and offerings?". The results show that 45.04% of the respondents chose the rating value "Somewhat likely," 25.19% of the respondents chose the rating value "Extremely likely," 14.50% of the respondents chose the rating value "Neither likely nor unlikely," and so on.

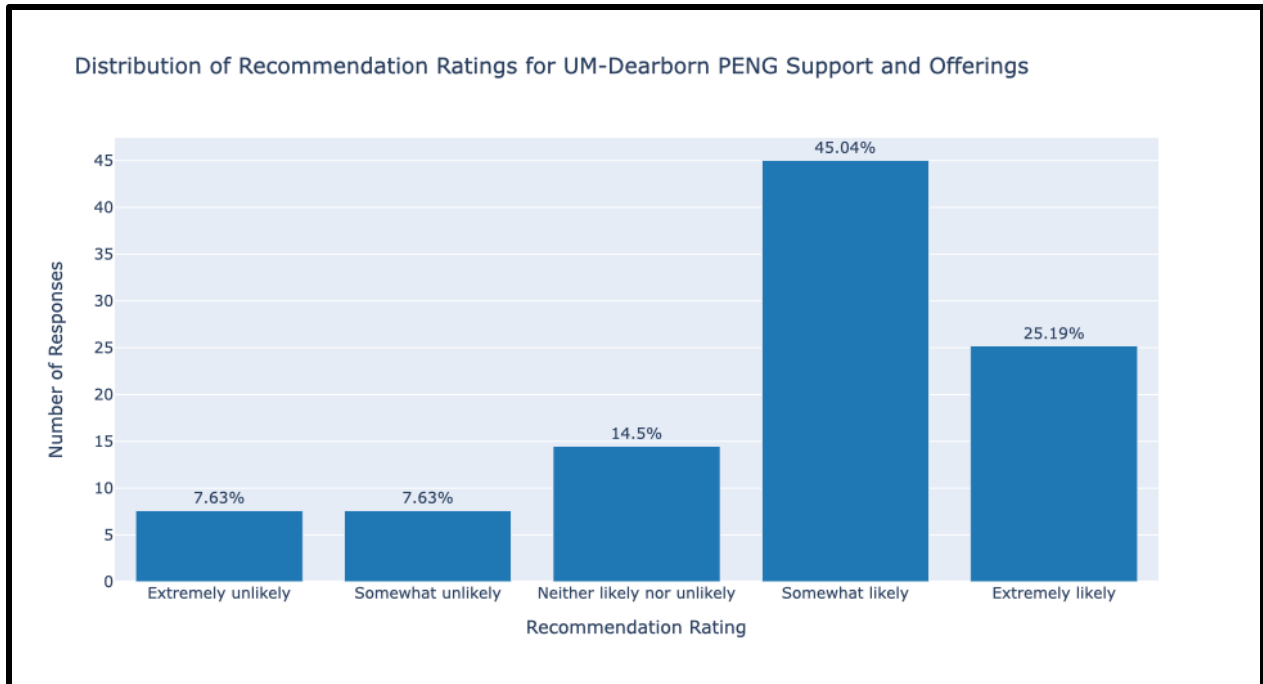


Figure 12: Distribution of responses to the survey question “How likely are you to recommend UM-Dearborn to family, friends, or colleagues based on Pre-Engineering (PENG) support and offerings”

The survey asked respondents about their satisfaction about their PENG program experience at UM-Dearborn (Figure 13). The responses were classified into three categories based on the Net Promoter Score (NPS) methodology: Detractors, Passives, and Promoters. The NPS methodology is a widely used metric that measures customer loyalty and satisfaction. In this methodology, respondents are classified into three categories: Detractors (score 0-6), Passives (score 7-8), and Promoters (score 9-10). The NPS score is calculated by subtracting the Detractors' percentage from the Promoters'. A higher NPS score indicates higher customer loyalty and satisfaction. Overall, the count shows how many respondents chose each satisfaction level.

Overall responses to the question "How satisfied were you with your Pre-Engineering program (PENG) experience at UM-Dearborn?" show that 15.3% of the respondents were promoters, indicating they were highly satisfied with their PENG experience. These individuals likely had a positive experience and would recommend the program to others, 48.1% of the

respondents were detractors, suggesting they were dissatisfied with their PENG experience. These individuals may have encountered issues or challenges during the program that affected their overall satisfaction. Lastly, 36.6% of the respondents were passive, indicating a neutral or indifferent stance towards their PENG experience. These individuals neither strongly recommended nor strongly criticized the program. It is important to note that the overall satisfaction level seems to be low, with a significant proportion of respondents expressing dissatisfaction (48.1% detractors). This suggests that there may be areas for improvement within the Pre-Engineering program at UM-Dearborn to address the concerns of dissatisfied students and enhance the overall experience.

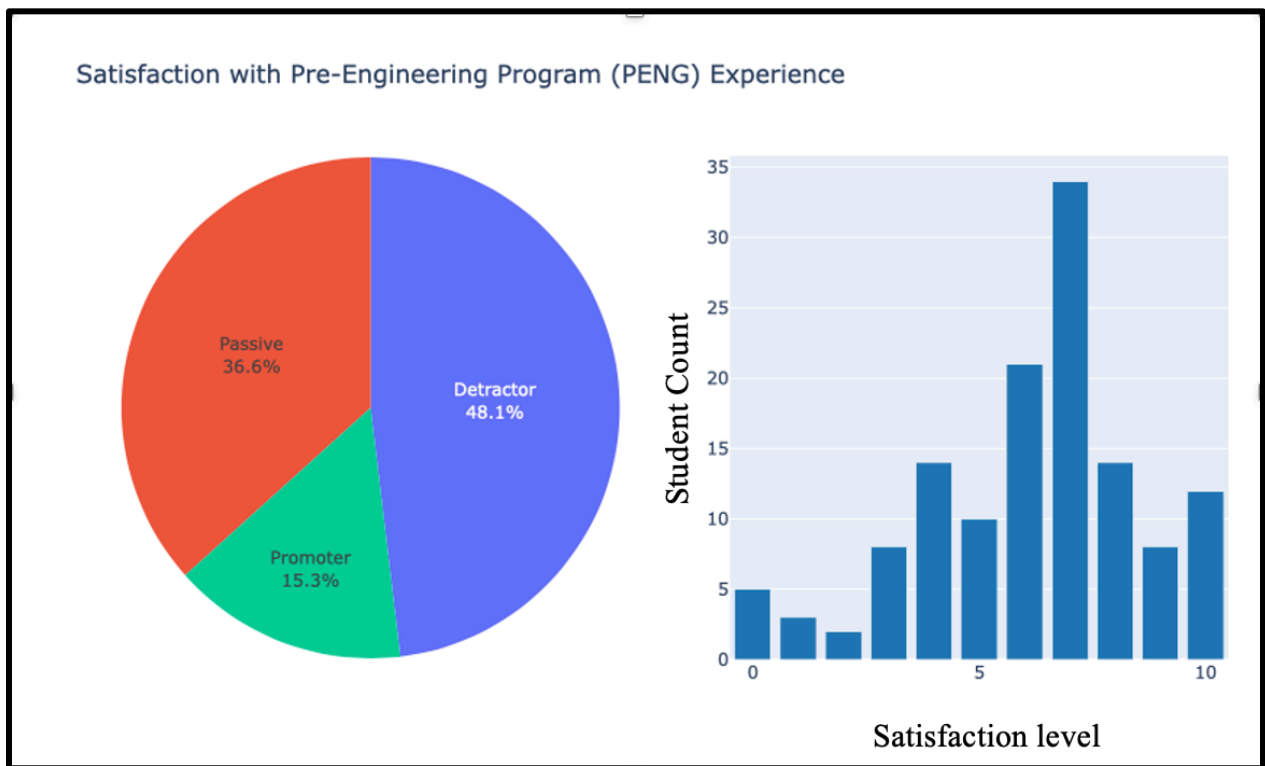


Figure 13: Responses to the survey question “How satisfied were you with your Pre-Engineering program (PENG) experience at UM-Dearborn?”

In addition, the ANOVA test examines any significant variations/associations in the responses among distinct categories, including age, race/ethnicity, parents' education, etc., to the survey question "How satisfied were you with your Pre-Engineering program (PENG)

experience at UM-Dearborn?" ANOVA helps identify specific groups or categories that exhibit significantly different satisfaction levels w.r.t PENG experience. This information can be valuable for program administrators and policymakers in understanding which factors may be influencing satisfaction. It can guide targeted interventions or improvements to address the concerns of dissatisfied groups and enhance the overall satisfaction with the Pre-Engineering program.

ANOVA is a method to determine the significance of an independent variable's effect on the observed variation in a set of measurements (Girden, 1992). ANOVA is often used when three or more groups or treatments are being compared. It helps to determine if there is a significant difference in the means of the groups and whether any observed differences are likely due to the treatment or factor being investigated rather than random chance (Scheffe 1999).

ANOVA holds great significance in exploratory and confirmatory data analysis, making it an essential method in statistical research and interpretation. It aims to comprehend the influence of various factors on an outcome variable by examining the portion of variance attributed to each factor (Gelman, 2005). In this case, ANOVA helps analyze if there are significant differences in the means of student PENG program satisfaction across different categories of the independent variables (race, age, parents' education, etc.) collected from the student survey. ANOVA analysis, conducted using frequentist statistics, relies on p-values for determining statistical significance. A p-value below .05 indicates the significance and rejects the null hypothesis, while a p-value above .05 suggests non-significance and retains the null hypothesis (Van et al., 2020). Table 9 provides information about the significance and effect of each variable on the outcome based on ANOVA.

Variable	df	sum_sq	mean_sq	F	PR(>F)
Age	3.0	7.477270	2.492423	0.3924	0.7587
Race	4.0	27.461675	6.865419	1.1027	0.3591
Parents/Guardian Education	6.0	50.800517	8.466753	1.3827	0.2283
ZIP Code of Residence	54.0	278.075074	5.149538	0.7081	0.899
Transfer Status	1.0	5.342943	5.342943	0.8539	0.3574
Major	3.0	5.162614	1.720871	0.2700	0.8469
Employment Status	3.0	2.602813	0.867604	0.1356	0.9386
Enrollment Year	3.0	11.191813	3.730604	0.5905	0.6225
Advisor Meeting frequency	3.0	3.674306	1.224769	0.1918	0.9018

Table 9: Analysis of variance in satisfaction with PENG experience at UM-Dearborn across different categories

The ANOVA results suggest that there is insufficient evidence to conclude that any of the variables (Age, Race, Parents/Guardian Education, ZIP Code of Residence, Transfer Status, Major, Employment Status, Enrollment year, and Advisor Meeting frequency) have a significant impact on the outcome or outcome differences within their respective categories or levels. Since all variables in the given ANOVA results have p-values (PR(>F)) greater than 0.05, it suggests that none of the variables show statistically significant differences between their respective categories or levels. However, it is essential to note that the small sample size and the self-reported nature of the data limited this study.

A Spearman correlation analysis is conducted to assess the relationship between different variables in the survey data and their correlation with the student satisfaction rating in the PENG program. The Spearman correlation coefficient is a non-parametric rank statistic introduced by Charles Spearman that quantifies the strength of an association between two variables (Hauke & Kossowski, 2011). It is appropriate for examining ordinal variables or relationships expected to be monotonic, regardless of linearity. Spearman correlation analysis evaluates how effectively an arbitrary monotonic function assesses the relationship between two variables without assuming anything about the frequency distribution of the variables (Bolboaca & Jantschi, 2006). Spearman correlation coefficients range from -1 to +1. A value of 0 signifies no linear or

monotonic association, while values closer to -1 or +1 indicate stronger relationships, approaching a consistently increasing or decreasing pattern (Schober et al., 2018).

Table 10 presents a comprehensive overview of students' individual-level characteristics, including GPA, Age, Race, Employment status, Parents' educational level, PENG course confidence rating, Orientation rating, Professor support, and Advisor support. These variables were analyzed for their correlation with the survey question, "How satisfied were you with your pre-engineering program (PENG) experience at UMD?".

Dependent Factor	Independent Factors	Correlation Coefficient
PENG Program Satisfaction	GPA	0.02
	AGE	-0.06
	RACE	0.00
	Parents/Guardian Education	-0.16
	Employment Status	-0.02
	PENG Course Confidence	0.62
	Orientation Rating	0.57
	Professor Support	0.16
	Advisor Support	0.11

Table 10: Spearman correlation analysis between students' individual-level characteristics and satisfaction with PENG experience at UM-Dearborn

The results indicate moderate correlations between the "PENG course confidence rating" and "Orientation rating" variables with the students' satisfaction rating of the PENG program. These findings suggest that the confidence level in PENG courses and the quality of the orientation experience play significant roles in shaping students' overall satisfaction with the PENG program at UM-Dearborn.

Following the Spearman correlation analysis, the subsequent step involves performing regression analysis. However, before regression, it is essential to employ a feature selection method to determine the most significant predictors to include in the model. It helps optimize the regression model's performance and facilitates a better understanding of the relationships between the selected features and the target variable. These correlated variables can be selected

as potential predictors in regression models to predict or understand the factors influencing students' satisfaction with the pre-engineering program.

The exponential growth of data poses challenges for machine learning, necessitating data preprocessing steps like Feature Selection (FS) and Feature Extraction (FE). Feature selection identifies relevant features, eliminates irrelevant or redundant data, and enhances predictive accuracy and comprehensibility. To obtain the optimal feature subset, it is essential to define the relevance of the features accurately based on their significance and importance (Kumar & Minz, 2014). Feature selection is an effective strategy for preparing high-dimensional data, improving model simplicity, enhancing data mining performance, and ensuring clean and understandable data (Li et al., 2017). In practical scenarios, data representation often includes numerous features, with only a subset relevant to the target variable. In such cases, feature selection becomes crucial to enhance learning speed and quality (Kira & Rendell, 1992). Ang et al. (2016) describe the first stage of the feature selection process as determining the search direction, which can be forward, backward, or random. Forward search adds features iteratively; backward search removes features; bi-directional search simultaneously adds and removes features and random search selects features randomly to form the subset.

Forward stepwise selection begins with an empty feature set and gradually incorporates one feature at a time based on a specified criterion like AIC or BIC (Zhang, 2016). Forward stepwise selection in a small dataset can lead to overfitting due to the increased likelihood of identifying false correlations that do not generalize well. It is essential to be cautious when adding more features to prioritize model simplicity and avoid overfitting. Additionally, it is worth noting that in the forward selection, including a new variable may render an existing variable non-significant, but it cannot be removed from the model once included (Chowdhury &

Turin, 2020; Babyak, 2004). On the contrary, backward stepwise selection initiates with a complete feature set. It progressively eliminates one feature at a time based on their test statistics or p-values, resulting in more efficient computational performance. The variable with the smallest test statistic or the highest p-value exceeding a predetermined threshold is initially eliminated. Subsequently, the model is reconfigured without that variable, and the test statistics or p-values are recalculated. This iterative process continues until all the remaining variables in the model are significant at the chosen cut-off value (Chowdhury & Turin, 2020; Ratner, 2010).

By employing a feature selection technique, such as forward selection, backward elimination, or regularization methods like Lasso or Ridge regression, we can assess the importance and contribution of each variable in predicting the target variable. In this work, a backward stepwise selection method is employed to perform feature selection, with the target variable being "student satisfaction in the PENG program". The aim is to identify and explore the quantitative relationship between the selected factors and student satisfaction. The selected features derived from the stepwise selection process include "Employment Status", "Coursework Confidence", "Professor Support", and "Orientation Rating". These features are identified as the most influential factors related to student satisfaction based on their statistical significance and contribution to the model. These selected features are the foundation for further quantitative analysis, enabling a more focused and comprehensive investigation of the factors that significantly influence student satisfaction. The selected features are then analyzed using regression analysis to gain deeper insights into their impact on student satisfaction.

Before proceeding with regression analysis, it is essential to conduct a multicollinearity analysis. Multicollinearity refers to high correlations (presence of linear relationships) among two or more predictor variables, which can cause instability and unreliable estimates of the

model parameters in the regression model (Alin, 2010). Collinearity can be detected through various methods, such as by examining correlations exceeding 0.8 or 0.9 between predictor variables, high R² values in regressions of individual predictors on all others, and a VIF value of ≥ 10 indicating the presence of potentially problematic collinearity. The variance inflation factor (VIF) is the inverse of unexplained variance $(1-R^2)^{-1}$ used to quantify collinearity, where a VIF value of ≥ 10 suggests the presence of potentially problematic collinearity (Franke, 2010). Understanding the VIF for each variable provides a tangible measure of how multicollinearity affects the variances of estimated coefficients (Mansfield & Helms, 1982).

Table 11 presents the VIF (Variance Inflation Factor) values for all the factors selected through the feature selection process. The VIF values indicate the presence and magnitude of multicollinearity for each of the listed features. In this case, all the features have VIF values close to 1, suggesting a low level of multicollinearity. A VIF value of 1 indicates no correlation or multicollinearity between the feature and the other predictors in the model. Therefore, based on these VIF values, there is no evidence of problematic multicollinearity among the listed features.

Sr No.	Features	VIF
1	Employment Status	1.066283
2	Coursework Confidence	1.460544
3	Orientation Rating	1.295179
4	Professor Support	1.254810

Table 11: Variance Inflation Factor (VIF) analysis for selected factors

Regression analysis is a statistical method employed to estimate the connection between variables that exhibit a cause-and-effect relationship. Multiple linear regression refers to regression models with single dependent and multiple independent variables (Uyanık & Guler, 2013). In this study, multiple linear regression is utilized to gain insights and understanding into the relationships between these variables and the survey question "How satisfied were you with your pre-engineering program (PENG) experience at UMD?" enabling the identification of

significant predictors and quantifying their effects. The application of multiple linear regression facilitates a comprehensive examination of the variables' associations and provides valuable insights into the fundamental dynamics of the studied phenomena.

Figure 14 shows the regression analysis result using the factors based on the Backward feature selection method. By quantitatively examining these factors, the aim is to enhance our understanding of the critical drivers of student satisfaction in the PENG program at UM-Dearborn.

OLS Regression Results						
Dep. Variable:	Program_satisfaction	R-squared:	0.636			
Model:	OLS	Adj. R-squared:	0.622			
Method:	Least Squares	F-statistic:	47.15			
Date:	Fri, 16 Jun 2023	Prob (F-statistic):	7.16e-23			
Time:	17:00:14	Log-Likelihood:	-206.29			
No. Observations:	113	AIC:	422.6			
Df Residuals:	108	BIC:	436.2			
Df Model:	4					
Covariance Type:	nonrobust					
	coef	std err	t	P> t	[0.025	0.975]
const	0.4322	0.555	0.779	0.438	-0.668	1.532
employment_status	-0.2656	0.148	-1.794	0.076	-0.559	0.028
Coursework_confidence	0.5039	0.066	7.608	0.000	0.373	0.635
Orientation_rating	0.3161	0.058	5.449	0.000	0.201	0.431
Professor_support	0.2859	0.141	2.027	0.045	0.006	0.566
Omnibus:	10.112	Durbin-Watson:	1.743			
Prob(Omnibus):	0.006	Jarque-Bera (JB):	10.590			
Skew:	-0.605	Prob(JB):	0.00502			
Kurtosis:	3.887	Cond. No.	39.3			
Notes:						
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.						

Figure 14: Regression analysis result

R-squared measures the proportion of variance in the dependent variable "Program Satisfaction", explained by the model's independent variables. In this case, the R-squared value is 0.636, indicating that the independent variables can explain approximately 63.6% of the variance in "Program Satisfaction". Adjusted R-squared adjusts for the number of predictors in the model and is often considered a more reliable measure. Additionally, the F-statistic tests the overall

significance of the regression model. In this case, the F-statistic is 47.15, and the associated p-value (Prob (F-statistic)) is 7.16e-23 (very small). This indicates strong evidence to reject the null hypothesis that all regression coefficients are zero, suggesting that the overall regression model is statistically significant.

The "coef" column provides each independent variable's estimated coefficients (regression slopes). These coefficients represent the expected change in the dependent variable "Program Satisfaction" associated with a one-unit change in the respective independent variable. For example, a one-unit increase in "Coursework Confidence" is associated with an estimated increase of 0.5039 in "Program Satisfaction".

The p-values associated with each coefficient test the null hypothesis that the corresponding regression coefficient is zero. If the p-value is less than the chosen significance level (often 0.05), it suggests that the coefficient is statistically significantly different from zero. For example, the p-value for "Coursework Confidence", "Orientation Rating", and "Professor Support" is very small (0.000), indicating a statistically significant relationship with "Program_satisfaction".

In another survey question, "Please rate the orientation for the Pre-Engineering (PENG) students on the following scale?" respondents were asked to rate their satisfaction level on a scale of 1 to 10, with 1 being the lowest level of satisfaction and ten being the highest. Figure 15 displays the categorization of respondents into Detractors, Passives, and Promoters on the left, while on the right, the figure exhibits the total number of responses for each satisfaction level.

The responses can be categorized as 57.3% detractors, indicating they rated the orientation experience low on a scale of 1-10. This suggests that there may be significant areas for improvement in the orientation process to address the concerns of dissatisfied students and

enhance their overall experience. It would be important for the program administrators to closely analyze the feedback and identify specific issues to make necessary changes in the orientation program to better meet the needs and expectations of the students; 16% of the respondents were promoters, suggesting they rated the orientation highly on a scale of 1-10. These individuals had a positive experience during the orientation and found it beneficial for their Pre-Engineering program; 26.7% of the respondents were passive, representing those who provided a neutral rating for the orientation. These individuals neither strongly endorsed nor criticized the orientation and may have had a mixed or indifferent experience.

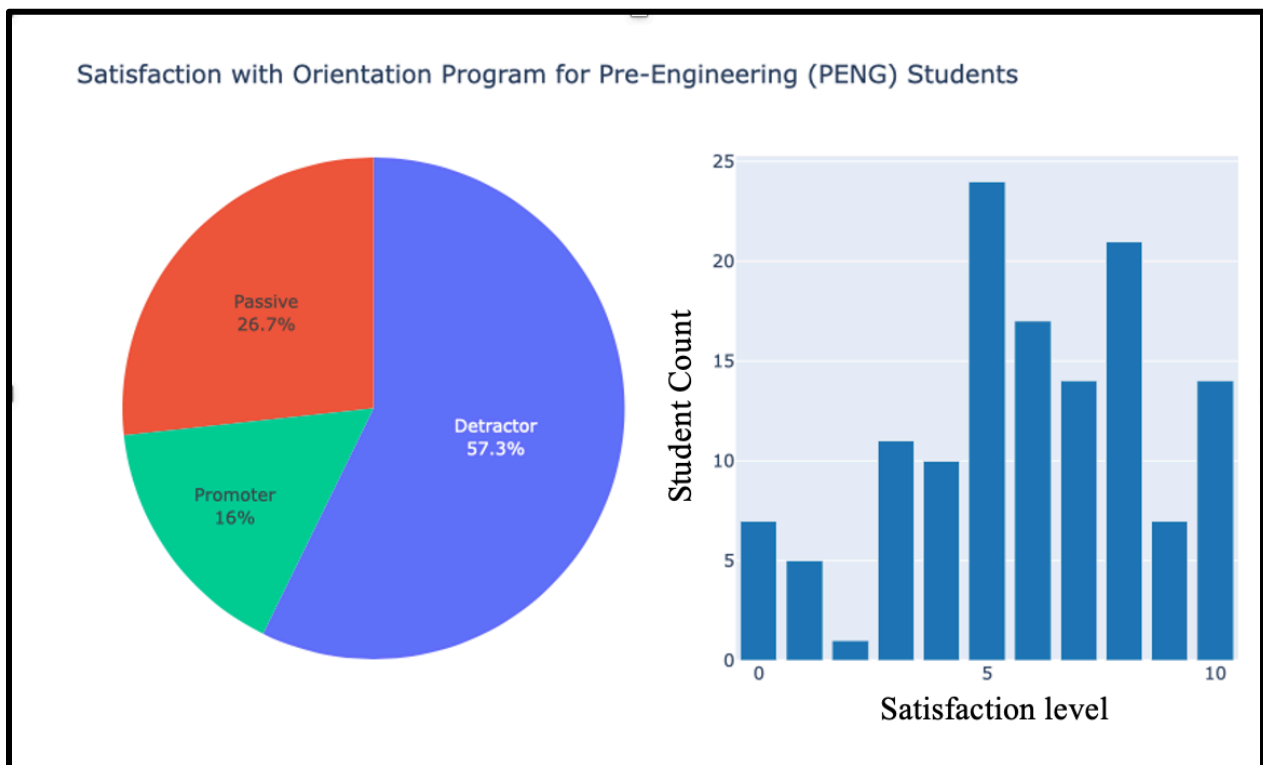


Figure 15: Responses to the survey question “Please rate the orientation for the Pre-Engineering (PENG) students on the scale of 1-10?”

This information highlights the need for improvement in the orientation program for PENG students at the university, as most respondents are not satisfied with the program. It also indicates that the survey may need to be refined in the future to encourage more respondents to respond to this question.

In a survey question, students were asked, "How easy is it to register for Pre-Engineering (PENG) classes at UM-Dearborn?". Figure 16 provides a quick overview of the distribution of satisfaction levels among the participants.

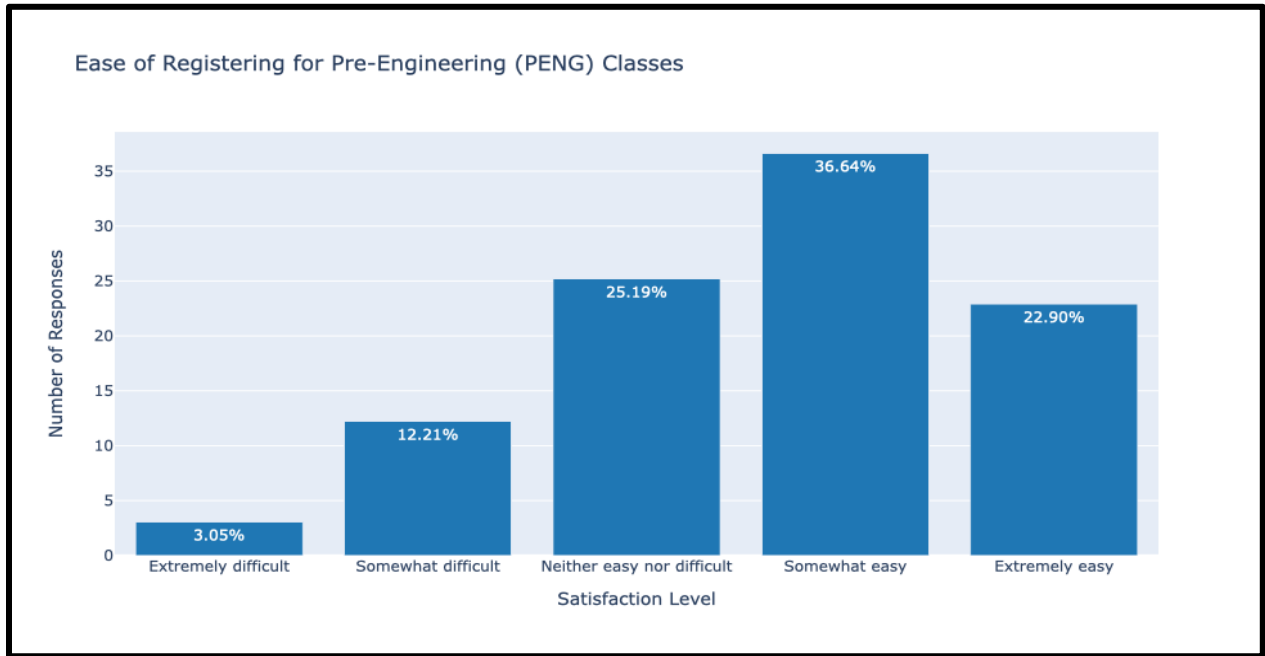


Figure 16: Responses to the survey question, "How easy is it to register for pre-engineering (PENG) classes at UM-Dearborn?"

In another survey question, students were asked, " On a scale of 1 to 10, how confident do you feel about the Pre-Engineering (PENG) coursework you have completed?". Figure 17 shows the distribution of confidence levels among the respondents.

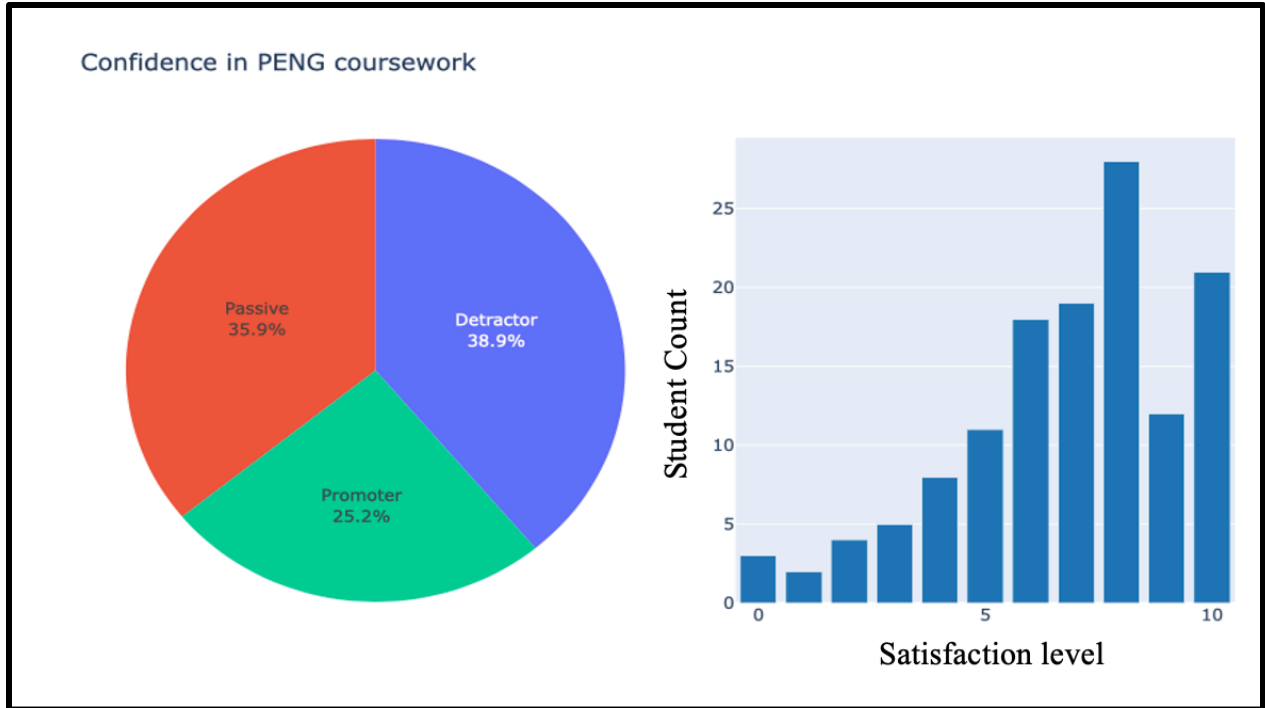


Figure 17: Responses to the survey question, "On a scale of 1 to 10 how confident do you feel about the Pre-Engineering (PENG) coursework you have completed?"

Figure 18 shows the percentage of responses to the question, "How much support did Pre-Engineering (PENG) professors provide while teaching the courses?". The respondents were asked to indicate how much support they received on a scale from 1 to 5, where one represents "as much as expected" and five represents "much more than expected."

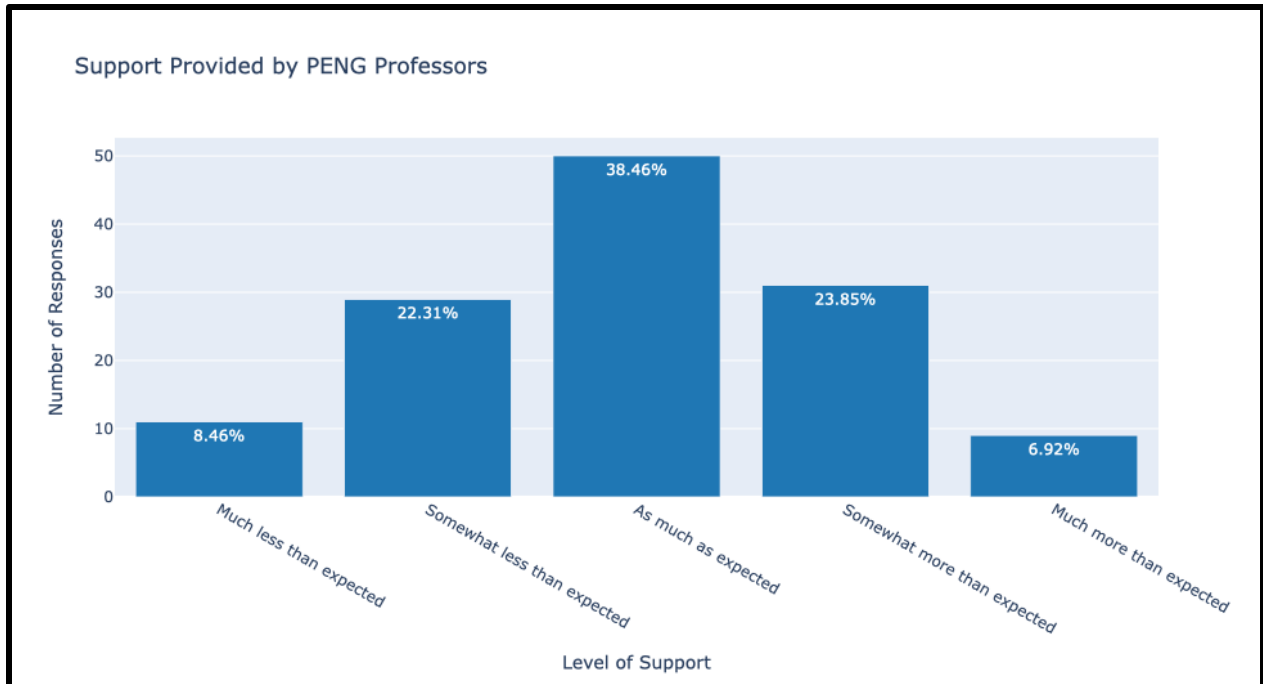


Figure 18: Responses to the survey question, “How much support did professors in the Pre-Engineering (PENG) provide while teaching the courses?”

These responses provide a summary of the distribution of support levels among the respondents, which is useful in understanding the extent to which PENG professors are meeting the expectations of the students and identifying areas where improvements can be made. For example, a significant proportion (30.77%) of the respondents reported receiving less support than expected. It may suggest a need for more personalized support or additional resources that can help bridge the gap between students' expectations and the support provided by the professors.

Figure 19 summarizes the distribution of rating levels for "How helpful is/was your academic advisor?". Responses show that most of students have a positive experience with their academic advisors. It is useful for understanding the participants' perception of the helpfulness of their advisors.

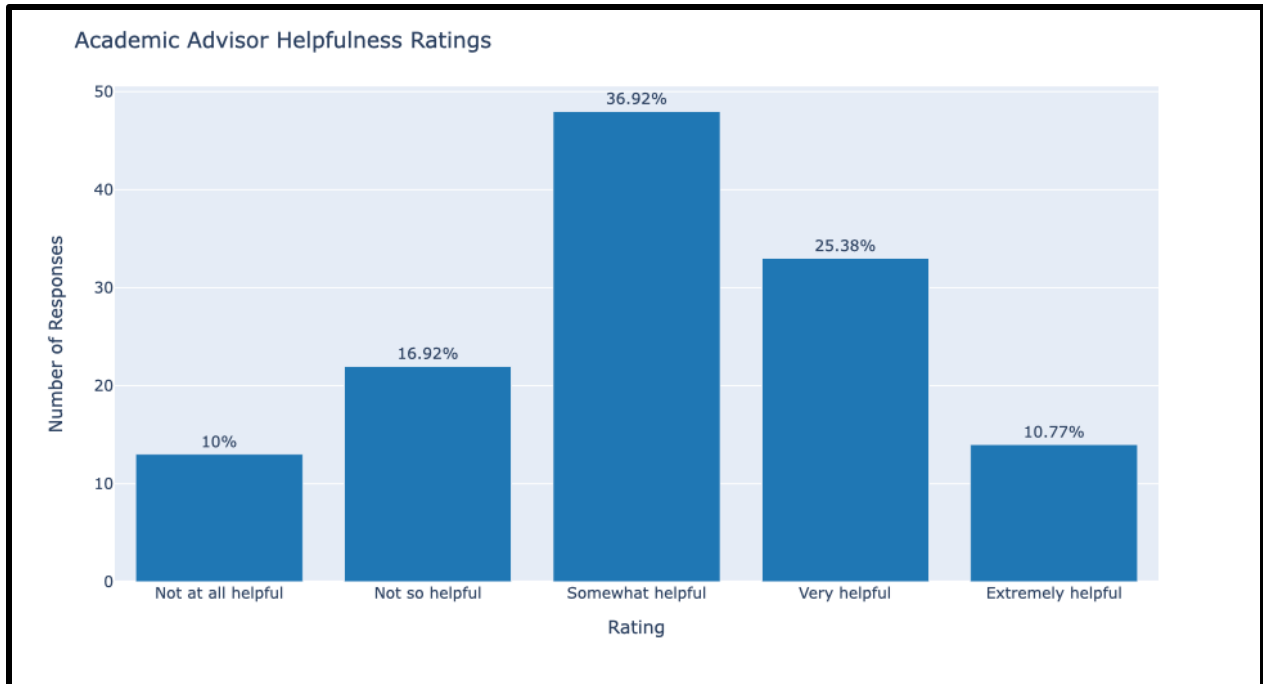


Figure 19: Responses to the survey question, "How helpful is/was your academic advisor?"

In a survey question, students were asked “How often do you meet/consult with your advisor?” The respondents were asked to indicate how often they interacted with PENG advisors, and they could choose from the following options: almost never, monthly, every few months, or once or twice per year. Figure 20 shows the percentage of students’ responses for each frequency of interaction with the Pre-Engineering (PENG) advisors.

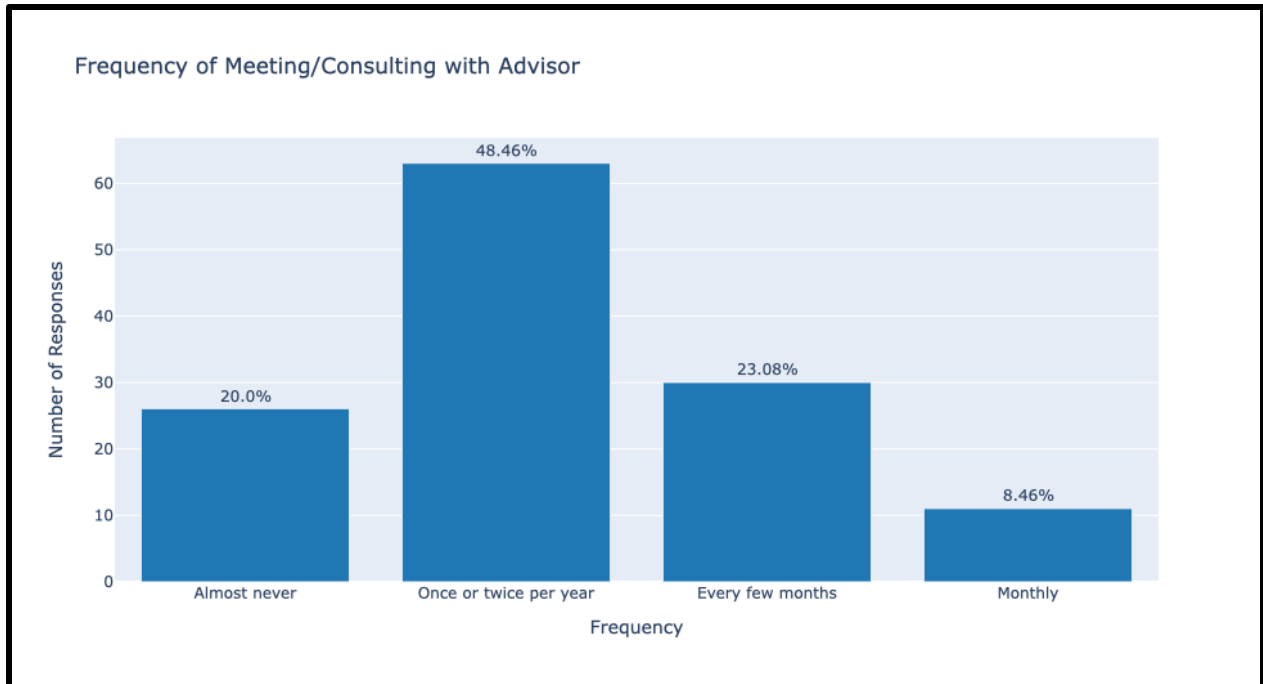


Figure 20: Responses to the survey question, "How often do you meet/consult with your advisor?"

In a survey question, students were asked, "How well maintained are the facilities (Labs/classrooms/resource availability) at this University?". Figure 21 shows that the majority of respondents, 54.62%, rated the facility maintenance level as "Very well maintained," followed by 24.62% of respondents rating it as "Extremely well maintained." 16.15% of respondents rated it as "Somewhat well maintained." In contrast, only a small percentage, 3.85% of respondents, rated it as "Not so well maintained." Additionally, only 0.77% of respondents rated the facility maintenance level as "Not at all well maintained."

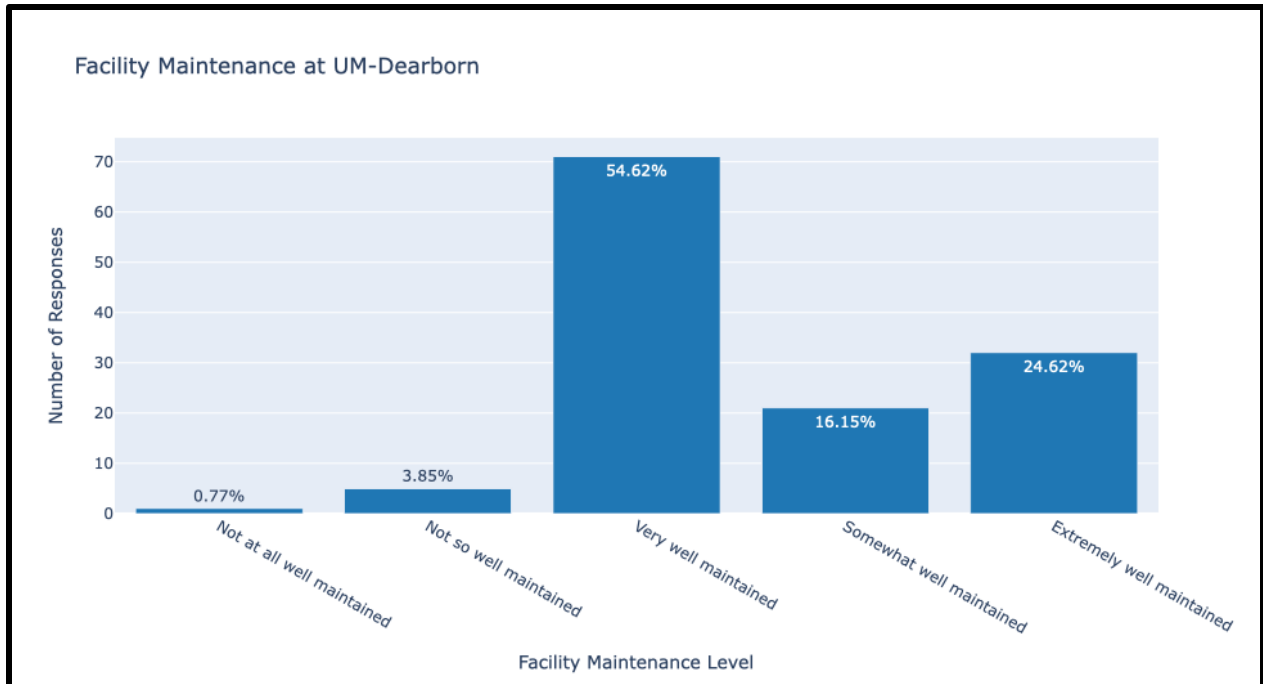


Figure 21: Responses to the survey question, “How well maintained are the facilities (labs/classrooms/resource availability) at this university?”

Open-Ended Survey and Follow-up Interview Analysis. In addition to the close-ended survey data questions, the survey administered to PENG students included five open-ended questions to gather students' opinions, suggestions, and concerns regarding their experience in the PENG program. Table 12 shows the list of these open-ended questions.

List of Open-ended questions in the survey	
1	What factors, in your opinion, contribute to a success in Pre-Engineering (PENG)?
2	If you could change one thing about how UM-Dearborn engaged with you at the time of admission, what would it be?
3	How did the Pre-Engineering (PENG) experience help you prepare for the engineering program?
4	Please share any other comments, questions, or concerns you may have about the Pre-Engineering (PENG) at UM-Dearborn?
5	Is there anything you would like to see for PENG students in the future. (For example: visits to CECS labs, hands-on activities to highlight Engineering and Computer Science, intros by CECS organizations, better connections to campus resources, etc.)

Table 12: List of open-ended questions in the survey

Table 13 shows the word frequency analysis for the student responses to the question, "What factors, in your opinion, contribute to success in Pre-Engineering (PENG)?" The word frequency analysis involved counting the occurrence of each word in the responses, allowing for

the identification of the most frequently mentioned words. This analysis provided insights into the key factors that students believed to be important for success in Pre-Engineering.

Words	Frequency
professors	29
studying	17
classes	9
support	7
students	6
coursework	6
work	5
learning	4

Table 13: Word frequency analysis of student responses on factors contributing to success in PENG

The word frequency analysis yields interesting insights into the responses provided by the participants. The term "professors" emerged as the most frequently mentioned word, appearing twenty-nine times in the analyzed text. It suggests that the participants emphasized the role of professors in their perceptions of success in the Pre-Engineering program. Similarly, "studying" and "classes" were mentioned seventeen and nine times, respectively, highlighting their perceived importance in the participants' journey toward success and the significance of dedicated study habits. The frequency of "support" was also relatively high, with seven occurrences. These findings are consistent with the outcomes obtained from regression analysis, indicating that the presence of adequate support systems is crucial for attaining success.

Furthermore, "students" and "coursework" appeared six times each, underscoring the importance of collaboration among peers and the role of academic assignments. "Work" and "learning" were mentioned five and four times, respectively, highlighting the participants' recognition of the need for effort and a focus on continuous knowledge acquisition. Overall, these results shed light on the factors the participants believe contribute to success in the Pre-Engineering program, providing valuable insights for further analysis and discussion.

Additionally, a word cloud is generated as part of the analysis process. Word clouds are a visually appealing way to summarize text by highlighting the most frequently used words,

qualitative data analysis software (CAQDAS) that helps researchers in various aspects of qualitative research, such as data collection, organization, analysis, visualization, and reporting (Dhakal, 2022).

Initial step is to import survey data into NVivo, codes are assigned to specific parts of the data, such as text passages/survey responses. The responses are coded into several categories related to challenges, needs, and suggestions mentioned by the students, including 'Orientation', 'Registration', 'Class Scheduling', 'Financial Aid', 'START Advising', 'Resources availability,' etc.

The coded data is then organized into a structure, grouping similar codes, and subdividing larger categories into more specific subcategories. For example, codes related to students' needs for "greater support from advising services," "more personalized early warning system," "improved coordination between counselors and faculty members," and "a better START advising" are grouped under the category of "student advising and support services." Using NVivo, the responses were examined and coded according to the relevant themes that emerged, resulting in a set of categories that captured the key issues and concerns raised by the students.

Although the survey data provides valuable insight into the student's needs and suggestions for improving the PENG program, there was a need for more in-depth discussion to understand the issues raised fully. To achieve this goal, more detailed interviews are conducted with PENG students to gain a deeper understanding of student pain points and enhance the validity of the research findings. Refer to Appendix D for a complete list of student interview questions.

The interview data is analyzed using a similar approach to the survey data, with the transcripts coded and categorized based on relevant themes and codes. Table 14 below briefly

overviews the codes used in the open-ended survey and the interview responses. This table includes a few examples of the codes identified in the study, but for a comprehensive list of all codes and coded excerpts, please refer to Appendix F.

CODES		DESCRIPTION
1	IMP-PERSONAL-WARNING	Implementing better personalized early warning system.
2	MANDATORY-RESOURCES	Making it mandatory for students to checkout available resources.
3	RESOURCE-ADVOCACY	Advocating for resource availability.
4	ADVISING-SUPPORT	Need more support from advising. This includes better advising in selecting courses and major, extra support for career exploration and showing available pathways in engineering.
5	DOCUMENTING-INFORMATION	Documenting program information: Students need more information on different programs, classes, major, and student organizations.

Table 14: Brief overview of the codes derived from students' survey and interview transcripts

The resulting survey and interview data are used for the final analysis, capturing the full range of student perspectives and experiences. Overall, NVivo enabled an efficient and effective analysis of the survey and interview data allowing for a comprehensive understanding of the needs and challenges faced by students in the PENG program. The analysis provides valuable insights into the factors affecting student success and suggests evidence-based recommendations for PENG program improvement. Furthermore, these codes and nodes identified in the analysis of the open-ended survey questions and the interviews are used to inform the development of student personas to address the needs and concerns of PENG students.

Alan Cooper (1999) pioneered the concept of personas in design and user experience to create a more effective way of generating user profiles. Personas are not actual individuals but hypothetical archetypes/ stand-ins of real users, defined with high rigor and precision to create empathy for real people. Thus, combining various characteristics of users/people into a single fictitious individual, particularly for the question, "Who do we optimize this product/service for?" For personas to be most effective, it is essential that the design team fully understands and

engages with them so that they become more than just abstract concepts. Personas represent tangible embodiments of the needs and objectives of the target users. They provide more accessible communication with a concrete and memorable point of reference than simply referring to an abstract concept of "the user" or a list of features. (Blomquist, 2002).

Thus, to analyze the data from the interviews and surveys, a thematic approach (personas) is used to identify patterns and themes across the responses. Two key student personas emerged from the analysis focusing on first-year PENG student challenges and pain points (Figure 21-22)

Phase 2. In this phase, data is collected from the faculty members and advisors (START advising team) in the PENG program through interviews to gain insight into their experiences with the PENG program, including their perceptions of its effectiveness, areas for improvement, and suggestions for enhancing the students' learning experience. Interviews are a crucial part of the human-centered design process for learning about the needs of the people/communities (target population) in their own words. It helps collect data and analyze current academic support and mentoring techniques in PENG programs to support students better. Refer to Appendix E for a complete list of interview questions.

Phase 2 Sample Interview Questions

- What factors, in your opinion, contribute to a successful implementation of a PENG program at UM-Dearborn?
- How can we improve PENG program to reduce the student drop-out rate and increase student success?

Both phases include semi-structured interviews, starting with a quick introduction describing the purpose of the interview: to understand the PENG students' challenges/ pain

points. Each interview lasts from 20 minutes to 1 hour. Interviews are conducted on-campus, at the participants' convenience, or via Zoom, governed by an interview protocol.

Analysis of Interview Responses from Faculty Members and Advisors. This phase of the study includes interviews with PENG faculty members and advisors to gain their perspectives on the challenges and needs of students in the program. The data analysis process for these interviews is similar to the student interviews. The interviews are transcribed and imported into NVivo to code and categorize the data. The responses are then analyzed to identify common themes and patterns compared with the themes from the student interviews. Thus, allowing for a comprehensive understanding of the students' challenges and needs in the program from students, faculty members, and advisors' perspectives. Table 15 below briefly overviews some of the codes derived from the interview transcripts analysis. This table includes a few examples of the codes identified in the study, but for a comprehensive list of all codes and coded excerpts, please refer to Appendix G.

CODES		DESCRIPTION
1	BUSY- OVERWORKED- CHALLENGE	Students express being very busy.
2	HIGH-EXPECT- CHALLENGE	University has high expectations for PENG students in academics, specifically math.
3	INATTENTIVE- CHALLENGE	Students show disinterest/disengagement in classroom activities and towards the course.
4	MATH-CHALLENGE	Description of math challenges faced by PENG students.
5	RESOURCES UNAVAILABILITY	Availability and utilization of resources for PENG students

Table 15: Brief overview of the codes derived from the faculty members' and advisors' interviews

After the primary researcher completed the NVivo coding and developed the themes in both phases, another researcher was asked to review them. The purpose of this review is to ensure the accuracy and validity of the coding and themes. The reviewing researcher carefully evaluated the codes and themes, offering feedback and suggestions for improvement. The

primary researcher then incorporated this feedback into the final coding and themes. This thorough review process helped ensure the research findings' rigor and reliability.

Analysis of these interview responses involves creation of personas for faculty members and advisors. These personas focus on PENG students' needs, challenges, and pain points but from faculty members' and advisors' perspectives. Thus, involving multiple perspectives helps develop a nuanced understanding of the factors contributing to student success and identify actionable recommendations for program improvement. This includes two personas representing PENG faculty member and advisor at UM-Dearborn, respectively.

Findings

This section provides a comprehensive overview of the results obtained from first two study phases. It summarizes the insights and conclusions drawn from the data analysis, including the trends and patterns that emerged from each phase. This section aims to provide a holistic understanding of the research topic and addresses the study's research questions.

Preliminary Findings

Preliminary data visualization using a dashboard is a supplemental viewpoint for understanding the student population in various ways. A dashboard provides a comprehensive overview of the student population by visualizing key data points and metrics clearly and intuitively. It helps identify trends and patterns that may be difficult to see otherwise. The dashboard (Figure 3) helps visualize comprehensive data on the PENG student population, covering Fall 2019 to Winter 2022.

The PENG student population at the university consists of 834 students, with 526 First Time-In-College (FTIAC) and 308 transfer students. Majority of PENG student population is male, with females comprising only 34%. Additionally, 85.70% of the students are eligible for

student aid at admission. The PENG student population is diverse, with 59.65% (497 students) identifying as White, 10.75% (89 students) identifying as Black or African American, 10.86% (91 students) identifying as Asian, 9.5% (79 students) identifying as Hispanic, and 4.13% (35 students) identifying as multi-racial. The dashboard further displays that 3.08% (26 students) identify as Non-Resident Alien, 1.54% (13 students) as Unknown, and 0.36% (3 students) as American Indian or Alaska Native.

Moreover, the dashboard presents information on the student's residential and high school ZIP codes, providing crucial contextual details about the student's environment. Specifically, the dashboard facilitates the visualization of a map showcasing the primary residence ZIP codes of students, revealing that 94.48% of students live within a 50-mile radius of the university. This finding aligns with prior research indicating that most public college students tend to enroll within 50 miles of their permanent residence. These results highlight the significant influence of location on student enrollment decisions. (Eagan et al., 2015; Wexler, 2016; Pawar, 2020).

The data presented in the dashboard provides valuable insights into the PENG student population, which can inform decision-making, policy development, and opportunities for intervention. For example, the predominance of males in the PENG student population could lead to initiatives to increase females' representation in engineering. The high percentage of students living within a 50-mile radius of the university could also inform marketing and recruitment strategies to attract more students outside the immediate area. Overall, the findings presented in the dashboard provide a comprehensive and detailed overview of the PENG student population, which can inform efforts to enhance student success and retention.

Phase 1 Findings

This section presents the findings derived from a comprehensive analysis of data collected through a student survey and interviews conducted as part of Phase 1 of the study. The purpose of this phase was to gain insights into the experiences, perspectives, and opinions of students regarding various aspects of the research topic. By utilizing a combination of PENG students' survey responses and in-depth interviews, a nuanced understanding of the subject matter from the student's viewpoint was sought. The following section provides a detailed examination and interpretation of the findings, shedding light on the key themes, patterns, and trends that emerged from the data obtained through these research instruments. Through an exploration of the survey and interview data, a comprehensive picture of the student experiences and perceptions in relation to the research topic is presented.

Findings from Close-Ended Survey Responses. The study uses descriptive analysis to analyze survey results obtained from PENG students. The survey consisted of close-ended questions to collect information about the students' demographic backgrounds, academic standing, and educational experiences.

Some of the questions included in the survey were: What was your age at the time of PENG admission (i.e., admission to UM-Dearborn)? Which race/ethnicity best describes you? What is your current class standing? Are you a transfer student? What is your (intended) academic major? For more detailed information on survey questions, refer to Appendix B. Descriptive analysis is used to gain insights into the distribution of the responses to these questions. For example, findings show that most of the respondents were 19 years old or younger ($n = 129$, 75%) at the time of admission to UM-Dearborn and that a relatively diverse mix of races and ethnicities is represented in the sample. Additionally, it is found that a significant

proportion of the respondents (80.62%) reported being FTIAC students, while the remaining respondents (19.38%) reported transferring from another institution and that the most common academic majors were in the College of Engineering and computer science. It is also observed that many respondents had high academic standing, with a large percentage reporting a high school or previous institution GPA of 3.0 or higher.

When asked about the highest level of education achieved by their parents/guardians, a significant proportion of students (26.16%) reported that their parent(s) or guardian(s) graduated from college, followed by high school or equivalent (GED) at 21.51% and completing a master's degree or equivalent at 20.93%. The distribution of education levels for the parents or guardians provides valuable information about the educational diversity of the survey sample, which can be used to identify potential gaps in the program's outreach efforts. Understanding the educational background of the survey participants can also inform program improvements and help to promote equal access to educational opportunities. The results also indicated that 50% of the respondents are employed part-time, with 7.56% employed full-time and 2.33% self-employed. Moreover, 35.47% of students reported being unemployed. This information can be helpful for the University in understanding their students' employment status and providing support or resources for those who may need it.

The analysis of the geographic distribution of the sample revealed that the majority of the participants had a primary residence in ZIP codes 48126, 48127, and 48124, where ZIP code 48126 had the highest count with 24 participants reporting it as their primary residence, followed by ZIP code 48127 with 12 participants and ZIP code 48124 with 7 participants. The remaining ZIP codes had lower counts, ranging from 1 to 5 participants each. The distribution of ZIP codes provides valuable information about the geographic diversity of the survey sample and can be

used to identify areas where the program may be underrepresented. This information can help guide outreach and recruitment efforts to increase the diversity of the program and promote equal access to educational opportunities. These findings suggest that the sample is geographically concentrated in certain areas, which may have implications for the generalizability of the results. For example, it is possible that the results may not accurately reflect the experiences of engineering students in other geographic areas. However, the findings may still be helpful in informing efforts to support engineering students in the local community by identifying areas where targeted support services may be needed.

The responses to the survey question "The University did everything they could to make my admission process as easy as possible" and "How satisfied are you with the University engagement at the time of admission?" indicates a generally positive perception of the University's admission process among the majority of survey respondents. The chi-squared test results indicated no significant association between the survey question "The University did everything they could to make my admission process as easy as possible" and demographic variables such as age, race/ethnicity, academic major, ZIP Code of primary residence, parents' education level, transfer/FTIAC status, employment status, class standing, enrollment year. However, this study was limited by the small sample size and the self-reported nature of the data. These findings have important implications for the University's admissions and student engagement strategies. Specifically, improving engagement with prospective students during the admissions process may increase overall satisfaction and retention rates. Further research is needed to explore the factors contributing to student engagement during the admissions process and how these can be leveraged to enhance the student experience.

The responses to the survey question "How likely are you to recommend UM-Dearborn to family, friends, or colleagues based on Pre-Engineering (PENG) support and offerings" suggest that a majority of the respondents (45.04% of the respondents chose the rating value "Somewhat likely," 25.19% of the respondents chose rating value "Extremely likely") are likely to recommend UM-Dearborn. This information helps to understand the overall sentiment of the respondents towards UM-Dearborn's PENG support and offerings. These findings can help inform efforts to enhance the University's PENG program and be useful for marketing and recruitment.

In the survey question "How satisfied were you with your Pre-Engineering program (PENG) experience at UM-Dearborn?" the survey responses were classified into three categories based on the Net Promoter Score (NPS) methodology. The NPS score is calculated by subtracting the Detractors' percentage from the Promoters'. In this survey, 63 out of 172 respondents (48.1%) fell into the Detractor category, 48 respondents (36.6%) fell into the Passive category, and 20 respondents (15.3%) fell into the Promoter category. The Detractor category, which indicates respondents unsatisfied with their PENG experience at UM-Dearborn, accounted for the largest percentage of respondents. The Passive category, which indicates respondents who were neither satisfied nor dissatisfied with their experience, accounted for the second-largest percentage of respondents. The Promoter category, which indicates respondents who were highly satisfied with their PENG experience at UM-Dearborn, accounted for the smallest percentage of respondents. The data shows that many respondents were unsatisfied with their PENG experience at UM-Dearborn. This could be an area for improvement for the University to address to increase student satisfaction and loyalty. The NPS methodology provides a useful metric for measuring customer loyalty and satisfaction, and the results of this survey can inform efforts to

enhance the PENG program at UM-Dearborn. Furthermore, the utilization of multiple linear regression to investigate the relationships between various variables and the survey question "How satisfied were you with your pre-engineering program (PENG) experience at UMD?" showed that that factors "Coursework confidence", "Orientation rating", and "Professor support" have a statistically significant relationship with Program_satisfaction.

The responses to the survey question " Please rate the orientation for the Pre-Engineering (PENG) students on a scale of 1-10?" suggest that 75 respondents (57.3%) were classified as Detractors, meaning they were not satisfied with the orientation program. Thirty-five respondents (26.7%) were classified as Passives, meaning they were neither satisfied nor dissatisfied, and only 21 respondents (16%) were classified as Promoters, meaning they were highly satisfied with the program. These findings indicate that most respondents were not satisfied with the orientation program for PENG students. The high percentage of Detractors suggests that there may be significant room for improvement in the orientation program. The low percentage of Promoters indicates that only a few respondents were highly satisfied with the orientation program, and further efforts may be necessary to increase satisfaction levels.

In the survey question "How easy is it to register for Pre-Engineering (PENG) classes at UM-Dearborn?" responses provided by the participants show 36.64% of participants reported that registering for PENG classes was "Somewhat easy." In comparison, 25.19% reported that it was "Neither easy nor difficult," 22.90% reported that it was "Extremely easy," 12.21% reported that it was "Somewhat difficult," and 3.05% reported that it was "Extremely difficult." This information could be useful for the institution to identify areas of improvement in the registration process and ensure a smoother experience for students.

Another survey question, "On a scale of 1 to 10, how confident do you feel about the Pre-Engineering (PENG) coursework you have completed?" shows that a significant proportion of respondents have low levels of confidence (38.9% detractors and 35.9% passives) in the PENG coursework they have completed. This suggests that there may be areas of improvement in the PENG curriculum, such as providing additional resources, offering more personalized support, or revising the coursework to better align with the needs of the students. On the other hand, 25.9% of respondents rated their confidence level as a promoter, indicating high confidence in the coursework. This suggests that aspects of the PENG curriculum are effective and well-received by the students. Overall, the distribution of confidence levels provides insight into the areas of strength and weakness in the PENG coursework and can be used to inform improvements to the PENG program better to meet the needs and expectations of the students.

Another survey question asked respondents about the helpfulness of their academic advisor, and the responses show that most of the respondents found the advisors helpful. Specifically, 36.92% reported it as "somewhat helpful," and 25.38% reported it as "very helpful." In addition, students were asked about the frequency of their interactions with PENG advisors. Most respondents (48.46%) reported interacting with PENG advisors once or twice per year, suggesting they had limited opportunities for direct interaction with their advisors. About 23.08% of the respondents reported interacting with PENG advisors every few months, indicating that they had more frequent but still limited interaction with their advisors. A smaller proportion of respondents (20.00%) reported rarely interacting with PENG advisors, indicating they had very limited or no opportunities for interaction. Finally, 8.46% of the respondents reported interacting with PENG advisors on a monthly basis, indicating that they had more regular interactions with their advisors. Overall, these findings provide valuable insights into the

helpfulness of academic advisors and the frequency of interactions with PENG advisors. Most respondents found their advisors helpful, suggesting that the advising program is generally effective. However, the limited opportunities for direct interaction with PENG advisors may be a concern, as it could impact the quality of education and support provided to PENG students. The findings can help inform efforts to enhance the advising and interaction programs for PENG students at the University. This is useful in understanding the level of support and guidance the PENG advisors provide and identifying areas where improvements can be made. For example, a significant proportion of the respondents reported limited opportunities for interaction with their professors; this suggests a need for increased availability of office hours, mentoring programs, or other forms of support that facilitate more frequent and meaningful interactions between students and advisors.

In a survey question, students were asked, "How well maintained are the facilities (Labs/classrooms/resource availability) at this University?". Thus, the majority of respondents had a positive perception of the facilities and resource availability at UM-Dearborn. More than three-quarters of respondents rated the facility maintenance level as "Very well maintained" or "Extremely well maintained," which indicates that the University is doing a good job of maintaining its facilities. However, it is also worth noting that some respondents still rated the facility maintenance level as "Not so well maintained" or "Not at all well maintained." This suggests that there may be some areas where improvements can be made. Therefore, it may be worthwhile for the University to gather additional feedback from students to identify improvement areas and continue working to maintain a high standard of facilities and resource availability.

Overall, the descriptive analysis of the survey results provides a detailed picture of the background and academic standing of the PENG students in the sample. These findings could inform efforts to improve the academic success and retention of PENG students, such as targeted support services or academic interventions tailored to the specific needs of the student population, etc.

In addition to the close-ended questions, the survey included open-ended questions (Table 11) where participants were asked to describe their experience with the PENG program. Additionally, interviews were conducted with PENG students to gain a more comprehensive understanding of their experiences with the program. The survey data provided valuable quantitative insights, while the interviews allowed for a more qualitative analysis of the students' perspectives. Thus, triangulation of these two data sources is used to identify a complete picture of the program's strengths and weaknesses and identify areas for improvement. Overall, this approach generated more robust findings and recommendations to enhance the PENG program's impact on student learning outcomes. The open-ended survey responses and the interview recordings are transcribed, and a coding scheme is developed in NVivo to analyze the data.

Findings from Open-Ended Survey and Interview Responses. The analysis of participant open-ended survey responses and the follow-up interviews revealed several themes related to their PENG program experience at UM-Dearborn (refer to Appendix B). One recurring theme identified in the data was the need for increased student advising and support services. Specifically, participants highlighted the importance of having a more personalized early warning system (Code 1), greater support from advising services (Code 4), improved coordination between counselors and faculty members (Code 12), and a better START advising experience (Code 27). For example, one participant stated,

"If anybody is struggling at that point, a better early warning system is needed. So, I will say that I had, at periods of time, gone through early warning. But it doesn't really do anything. No one really reaches out, and an email is very unprofessional. So, I would have loved; I probably would have benefited if an engineering advisor or faculty to have reached out and really talk to me to understand where, what's going on and to help advise me, mentor me at that point" (excerpt related to Code 1).

Another participant mentioned, "I had to figure out my second semester all on my own, and it set me up for failure. I needed that extra support for someone telling me like, okay, these are different routes that you could take" (excerpt related to Code 4). A participant suggested, "The counselor who runs the tutoring schedule should give the schedule to professors so that they can pass it on to students" (excerpt from Code 12). Additionally, a participant shared their negative experience with START advising, indicating that, "I didn't see START as extremely helpful for me" (excerpt related to Code 27).

The findings suggest that students need more comprehensive support services to help them navigate their PENG program experience effectively. These findings are consistent with previous research that emphasizes the importance of student support services in improving student retention, engagement, and success. (Weuffen et al., 2021; Hoyt et al., 2021). These findings can university to formulate effective strategies and interventions to enhance student support services and elevate the overall PENG students' program experience.

The findings from the participant responses suggest the need for mandatory resource checkout for students. Participants suggested that making it mandatory for students to use available resources, especially for the first few classes (Code 2), and advocating for resource availability (Code 3) could be helpful. For example, one participant stated,

"Getting students set up, explain to them that they have all these different resources. I would make it mandatory, especially for the first couple of classes that you do, to go to those resources as well. You know, you go to the Math Learning Center, you spend at least an hour" (excerpt related to Code 2).

Another mentioned, "Need better connection to resources to figure out what engineering field is right for them" (excerpt related to Code 3). Another theme that surfaced in the data pertains to the importance of documenting program information, including details about various programs, classes, majors, and student organizations (Code 5) and setting clear expectations for students (Code 11). To address these needs, one student suggests, "I would recommend creating an app that has all the info about clubs/organizations and general info about programs and how to participate" (excerpt from Code 5). Additionally, another student highlights the need for "More information on what we need and what is expected" (excerpt from Code 11).

In terms of improved student engagement, participants expressed a strong desire for more opportunities for engagement (Code 6), introducing weekly assignments with constructive feedback (Code 16), more hands-on activities (Code 18) and lab visits (Code 19), and a greater frequency of workshops and seminar (Code 20). For example, one participant suggested, "Offer more engagement opportunities prior to admission. Somehow make engaging through online methods better" (excerpt related to Code 6). Another student recommended, "giving homework without being too much homework and doing in such a way that the students can check their understanding, but also keep them on track" (excerpt related to Code 16). Furthermore, students expressed a desire for "More hands-on experiences or outside visits" (excerpt related to Code 18), "Visits to more CECS labs to get them more engaged and interested" (excerpt related to

Code 19), and "Interactive engineering meetings/seminars" (excerpt related to Code 20) to increase engagement.

Participants proposed enhancing the orientation process (Code 22) by incorporating more individualized support to ensure students are on the correct academic trajectory. For instance, a student expressed a need for "improving the orientation" process (excerpt related to Code 22). Another student indicated that the orientation experience was rushed and lacked individualized attention, stating,

"I feel like it was kind of rushed because it was a few people, a few students coming in sitting down registering and like, okay, you can step out. So, I think having that initial help for those students, like, okay, are you on the right track? Like what does that look like for you? And going like that" (excerpt related to Code 22).

Another prevalent theme relates to the necessity for consistent and transparent communication between faculty and students (Code 10) while also avoiding excessive weekly emails to students (Code 23). A student stated, "I would like communication to be a bit clearer and more obvious" (excerpt related to code 10). Moreover, another student said, "Weekly student emails seem unnecessary. It could easily be made a webpage for those interested. The important dates are helpful in emails, but weekly is not necessary" (excerpt related to code 10).

Another recurring theme that emerged is centered around enhancing program logistics. This theme encompasses a range of concerns, such as the need for better financial aid information sharing (Code 7), more transparent class registration instructions (Code 8), a streamlined fast-track application process (Code 9), updating lecture slides (Code 13), needed for changes in prerequisite and co-requisite requirements (Code 14), the need for short review lectures (Code 15), offering of multiple class times (Code 17), and enhanced support in the

MSEL (Code 21). These findings suggest that students value clear and concise course materials and expect quality instruction that aligns with their learning needs and goals.

Finally, participants discussed both positive and negative experiences with the PENG program at UM-Dearborn. Positive experiences included good faculty and advisors, fair programs, and supportive resources like the Engineering Learning Center, SI Leaders, and math support (Code 25). Negative experiences included unhelpful advising, higher math expectations, and a shortage of jobs on campus (Code 26). Participants also discussed their reasons for selecting UM-Dearborn, such as the fast response time, scholarships, clear communication, and connections to engineering companies nearby (Code 29). For additional excerpts, codes, and more detailed information, please refer to Appendix F.

These codes and themes are used to create student personas that capture the key insights and perspectives of the participants. These fictional representations of the different types of students within the Pre-Engineering (PENG) program serve as valuable tools in understanding the unique needs, challenges, and pain points experienced by students in the program. These personas are used in Phase 3 of the dissertation during the co-design sessions to effectively address specific concerns and tailor strategies that directly target the identified student pain points. These personas provide a human-centered approach to the design process, enabling a deeper understanding of students' experiences and facilitating the creation of more impactful and relevant solutions for enhancing the PENG program.

Persona creation involves identifying the data's most common themes and patterns and assigning them to different personas. The creation of student personas assists in gaining a deeper understanding of the experiences, needs, and motivations of different types of students. These personas inform the development of targeted interventions and support programs to address the

specific needs of different groups of students. Figures 23 and 24 show student personas created to represent PENG students [target user group] at UM-Dearborn. The personas help define the design challenge, i.e., "How might we understand students' learning experiences, attitudes, and struggles about the support provided in a PENG program?".

The persona, named Estelle Darcy, is a PENG student with a passion for innovation and problem-solving. From a young age, Estelle has been fascinated by science, technology, engineering, and mathematics (STEM) and has always sought to explore and understand the world through a scientific lens. She is a determined, hardworking student who desires to positively impact the world. The persona also includes a quote from her that reads, "As a PENG student I felt like I needed more guidance in exploring different academic routes I could take but did not receive that support".

This quote highlights a common theme among PENG students, who often struggle to navigate the complex academic landscape without adequate support and guidance. The persona includes another quote from Estelle, where she shared a concerning experience with a professor. As she recalled, "At one point a professor advised me to quit engineering over struggling in class due to work/school balance at the time."

This quote highlights a significant issue many PENG students face, who often have to balance demanding work schedules with their academic pursuits. Estelle's experience with her professor's lack of support and understanding underscores the need for better guidance and resources for PENG students to succeed academically.

Moreover, the persona shares common frustrations/needs of PENG students, such as the need for a better personalized early warning system, support for career exploration, more advising and clear direction, etc.



Figure 23: Student persona “Estelle Darcy”

In another student persona, Matthew Turner, a 19-year-old PENG student at UM-Dearborn. Matthew graduated from Canton High School and was part of the robotics and coding club. He has always been fascinated by machines and technology and loves to tinker with electronics in his free time. Matthew's persona shows the PENG students' frustrations/needs, such as more flexible class schedules, more program information, etc. This persona also includes quotes from him that read, “Despite being a commuter campus, schools limited class offerings for engineering and PENG classes make it difficult for students who work, as they often have to choose between taking early morning classes and working late at night or skipping class to make money for school”.

This quote highlights a critical issue facing PENG students, who often have to juggle demanding work schedules with limited academic resources and opportunities. Many PENG students also face significant challenges related to the limited class offerings available at their schools, particularly for those who work outside of their academic pursuits. The persona includes

another quote from Matthew where he shared the following perspective, “The orientation experience was not helpful for me, as it solely focused just on registering for classes and left me feeling confused.”

This quote highlights a fundamental issue with the orientation process for PENG students, who may feel overwhelmed and underprepared for the demands of their program without adequate support and guidance from the outset.

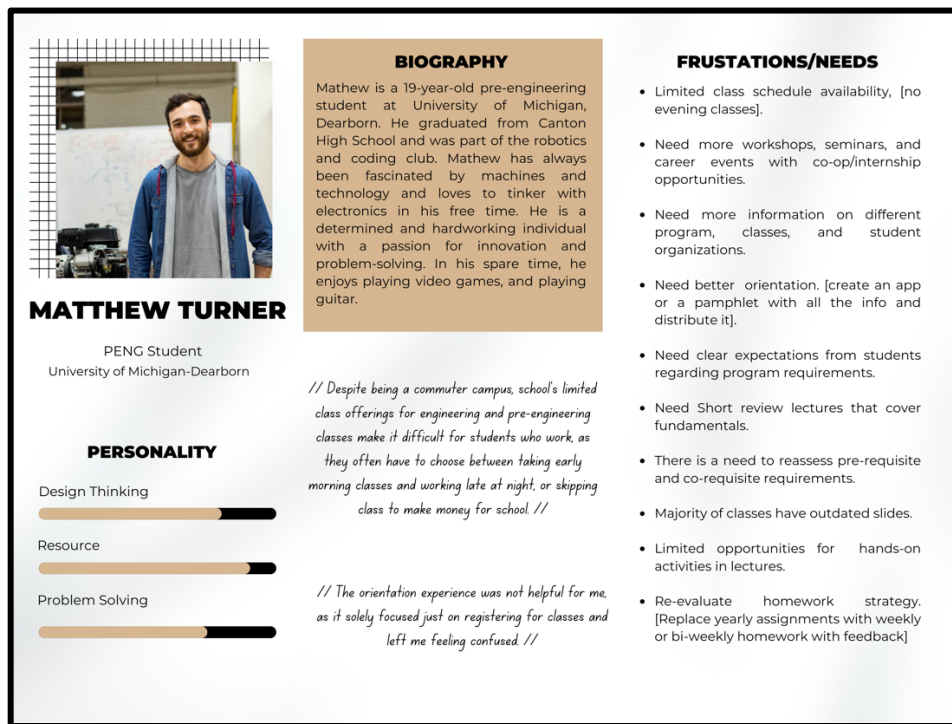


Figure 24: Student persona “Matthew Turner”

In this research, Estelle and Matthew are representative student personas to understand better the needs and preferences of PENG students like them. Thus, considering their goals, frustrations/ pain points assist in gaining valuable insights into designing and delivering adequate resources and services that support academic success and improve the PENG students' experiences at UM-Dearborn. These personas are designed to help advisors and faculty members better understand students' needs, challenges and suggest strategies to tailor support services and

activities to support PENG students better. The personas images visually represent the target user group and help better understand this group's needs, motivations, and pain points.

Phase 2 Findings

This section presents the findings from the interviews conducted with faculty members and advisors as part of Phase 2 of the study. The purpose of this phase was to gather valuable insights and perspectives from these key stakeholders in order to gain a deeper understanding of the research topic. The interviews provided an opportunity to explore their experiences, opinions, and recommendations, shedding light on important aspects related to our research objectives. By analyzing the interview data, we aim to uncover significant themes, patterns, and key findings that emerged from these engaging discussions with faculty members and advisors. These findings offer valuable contributions to the overall understanding of the research topic and inform the subsequent phases of the study.

Faculty Members and Advisors Interview Findings. The analysis of interview responses from PENG faculty members and advisors at UM-Dearborn uncovered various themes concerning students' experiences and challenges within the program (refer to Appendix G). Furthermore, this examination highlights strategies currently employed by PENG faculty and advisors to support students and recommendations for enhancing the support provided to these students in the future.

One recurring theme identified in the data was the challenges faced by PENG students (Codes 1-8). For instance, one of the most prevalent challenges is that students often feel busy and overworked (Code 1), with one participant stating that "students are overly busy" (excerpt related to Code 1). This may be exacerbated by the high expectations placed on PENG students, particularly in mathematics (Code 2), as the university expects a strong mathematical foundation

from these students. A participant shared that the "university has high expectations for the mathematical preparation of the students" (excerpt related to Code 2). Another challenge lies in the students' disinterest or disengagement during classroom activities and towards the course (Code 3). This is evidenced by comments such as "not paying attention to the structure or details of the course" (excerpt related to Code 3). Math-related challenges (Code 4) are a recurring theme, with faculty members describing difficulties in covering pre-calculus material as students have varying strengths and weaknesses. A faculty member remarked,

"Many of them learned math based on memorizing rules in the past. It is kind of hard to get past that and get comfortable with focusing on how things work and why they work the way they do" (excerpt related to Code 4).

Resource availability and utilization (Code 5) is another challenge faced by PENG students, with disparities in access to learning tools being a significant issue. One participant mentioned,

"Some of them don't even have a pen or a pencil, whereas some students have an iPad...and because of the tool, they can create colorful diagrams that can help them understand better" (excerpt related to Code 5).

Additionally, students often feel underprepared (Code 6), either academically or due to limited knowledge, leading to them feeling overwhelmed.

A lack of understanding of the importance of PENG courses (Code 7) contributes to the challenges faced by students. Many students were underprepared academically, and some did not understand the importance of PENG courses or their value. This lack of motivation was compounded by the fact that PENG credits do not count towards their degree, though they still appear on their transcripts. This is exemplified by comments such as "They don't have any real

motivation to learn the material because they don't see why they need it" and "Students feel like it's kind of a waste of time." Lastly, not receiving credit towards their degree for PENG courses (Code 8) is demotivating for students. A participant explained, "It doesn't count towards their degree, but it shows up on their transcripts" (excerpt related to Code 8).

As described by faculty members and advisors (Code 9), a successful PENG program should consist of several key characteristics. These aspects are crucial in enhancing the overall effectiveness of the program. Firstly, effective communication is essential, ensuring students feel included and fostering a sense of belonging within the program. One participant stated, "Making students feel that they are part of the program" (excerpt from Code 9) is crucial for their engagement and success.

Additionally, the program should prioritize enhancing students' mathematical proficiency through targeted instruction and practice, and addressing the broader aspects of academic success, such as study skills and subject-specific knowledge. Identifying the root causes of students' struggles and providing appropriate support is crucial to address individual needs. One participant shared their perspective regarding the key characteristics of a successful PENG program. Specifically, the participant stated that, "At least from the math perspective, I think a program which identifies reasons for students struggling" (excerpt from Code 9).

A successful PENG program should offer mentorship, valuable resources, and a robust academic support system. One participant emphasized the importance of a "robust academic support system" for student success (excerpt from Code 9). Moreover, promoting effective time management skills and integrating comprehensive math preparation into the curriculum are essential components of a well-rounded PENG program. Finally, the program should be designed to align with students' goals and expectations, ensuring a tailored and effective learning

experience for each participant. Additionally, it was noted that faculty members were not well-informed about the PENG program, which could hinder their ability to provide effective support.

As per the faculty member and advisor interviews, several strategies can be implemented to enhance the Pre-Engineering (PENG) students' experience. The participants suggest that improving advising and analyzing students' data to suggest program changes are crucial to addressing the barriers to successful program completion (Codes 11 & 12). For instance, a participant mentioned, "I think advising plays a major role, advising not only about the courses they take but how to manage everyday life-related things" (excerpt from Code 11). Another participant suggests,

"I think moving forward, we're going to really hone-in and look at that data on how many students successfully complete the program starting in a particular semester and, you know, what are the barriers that prevented them" (excerpt from Code 12).

Introducing a Blue Carpet program for all first-year students and providing opportunities for students to work together and collaborate are also important (Code 13 & 14). Participants also suggest designing an early alert system to identify struggling students and taking suggestions from successful PENG program graduates to improve the program (Codes 15 & 16).

Mentoring students and providing a seminar course to introduce them to CECS can also improve their experience (Code 17 & 18). For instance, a participant mentioned, "I think the mentorship is so important there to form a connection. So that they feel connected to engineering, to our college" (excerpt from Code 17).

Measuring the impact of the PENG program and providing necessary resources like access to student data, improving tutor availability in math learning centers, and introducing a website with practice math problems are also crucial to improving PENG students' experience

(Code 19 & 20). Participants suggest creating a requirement for students to explore different resources available to help improve the PENG experience (Code 21). For instance, a participant mentioned,

"A point system or a passport program where PENG students could be required to meet with the Math Learning Center or career services, student organization or attending a student-org meeting" (excerpt from Code 21).

Additionally, providing intrusive advising and physical support (Code 22), creating equality of resources, and re-introducing the summer bridge program (Codes 23 & 25) are important strategies. Furthermore, launching a supplemental instruction program for early-level courses (Code 26) can be beneficial. Overall, these findings suggest that implementing these suggestions can enhance the PENG students' experience, increase the likelihood of program completion, and ultimately contribute to their success in the field of engineering. For additional excerpts, codes, and more detailed information, please refer to Appendix G. Furthermore, Figures 25 and 26 represent two key personas that emerged from interviewing PENG faculty members and advisors at UM-Dearborn respectively.

The persona, David Lee, is an assistant professor at UM-Dearborn. He received his Ph.D. at the University of Pennsylvania. Dr. Lee is a dedicated and passionate teacher. He teaches undergraduate and graduate courses and has received high praise from his students for his engaging and innovative teaching style. This faculty member persona represents PENG faculty members who share common frustrations/needs such as lack of student motivation, need for an impact measurement model, unequal resource availability, etc. Moreover, another persona, Dr. Emily, is an Assistant Professor and a dedicated advisor with over a decade of experience helping students navigate the challenges of higher education. Her dedication to student success is

reflected in her innovative teaching methods. Emily is committed to promoting diversity in STEM and volunteering her time to mentor underrepresented groups. This persona represents PENG faculty members and advisors who share common concerns, such as students being overworked and underprepared, the need to expand the mentorship program, etc.

Figure 25: Faculty member persona “David Lee”

Figure 26: Faculty member and advisor persona “Emily Williams”

Thus, several factors contribute to student success in a PENG program. Both personas (Figure 23 and 24) emphasized the importance of building strong relationships with students and providing personalized support, such as one-on-one tutoring and mentoring.

Integrating qualitative and quantitative analysis in understanding Pre-Engineering students' program experiences at UM-Dearborn provides a comprehensive and well-rounded perspective. Qualitative methods, including surveys, interviews, coding, and persona generation, offer rich, contextual narratives, while quantitative methods like ANOVA, regression, and descriptive statistics provide statistical measures and relationships. The findings from both qualitative and quantitative methods are consistent.

Students in the PENG program at UM-Dearborn face challenges regarding busy schedules, high math expectations, disengagement, and limited understanding of course importance. Students suggest improvements such as a personalized early warning system, mandatory resource exploration, better-advising support, improved program documentation, and increased student engagement. They also request financial aid assistance, class registration, and student communication enhancements. Furthermore, they desire more hands-on activities, workshops, and seminars and better support for non-engineering CECS majors.

Moreover, recommendations from faculty and advisors include improving communication, enhancing math proficiency, providing resources, and aligning the program with students' goals. Other suggestions include early alerts, collaboration opportunities, mentoring, measuring program impact, introducing a summer bridge program, etc. Thus, the results indicate that a successful PENG program should take a multifaceted approach to address the challenges that students face in the PENG program.

Chapter 5: Redesign and Evaluation of PENG Program at UM-Dearborn

Participants

This phase involves the same individuals actively participating in Phase 1 and 2. Their ongoing involvement demonstrates their dedication and interest in the study, providing valuable insights into the research topic. These participants represent diverse individuals from various backgrounds, including students, faculty members, and administrators. They bring many perspectives and experiences to the study, contributing to a comprehensive understanding of the subject matter and ensuring a holistic approach to the research.

- The co-design session includes the active participation of faculty members, advisors, and the Dean of Undergraduate Studies. This diverse group brings their expertise and insights to the session, contributing to the collaborative design process.
- The evaluation survey, on the other hand, is exclusively conducted with PENG students. This targeted approach ensures that the survey captures this particular group's specific perspectives and experiences, allowing for a focused evaluation of the research outcomes.

The participants' knowledge and experience make them crucial contributors to the research process. Their active involvement will help us develop a comprehensive understanding of the research topic and guide the formulation of practical strategies and solutions. The rationale for including the Dean of Undergraduate Studies in the co-design session is to foster collaboration between research and administrative functions. This collaborative approach will bridge the gap between theoretical exploration and practical implementation, ensuring the relevance and applicability of the findings to real-world contexts.

In addition, the Dean's expertise and leadership within the academic community offer valuable guidance and insights in exploring and refining the research outcomes.

Table 16 provides an overview of the participant recruitment and engagement in Phase 3. The data collection methods employed for different participant groups are indicated, along with the number of individuals reached out to and the number who actively participated. The engagement of these diverse participant groups in Phase 3 ensures a comprehensive and multifaceted understanding of the research topic, incorporating the valuable input and perspectives of PENG faculty members, advisors, the Associate Dean, and students, respectively.

Phases	PENG Participants	Data Collection Method	Reached out	Participated
Phase 3	Faculty Members	Co-Design Session	6	4
	CECS and START Advisors	Co-Design Session	3	1
	Associate Dean for Undergraduate Education	Co-Design Session	1	1
	Students	Feedback Survey	200	42

Table 16: Participant recruitment and engagement

Methodology

Instrument Design

Data collection for Phase 3 of the dissertation study involves two primary instruments: an in-person co-design session and an internet-based feedback survey. These instruments are designed to facilitate active participation and gather valuable input for re-designing the PENG program and evaluating suggested strategies.

Co-Design Session. The co-design session is a collaborative platform for participants, including faculty members, advisors, and the Associate Dean for Undergraduate Education, to contribute their expertise and insights in re-designing the PENG program. The session is conducted in person to foster open discussions and enhance face-to-face interaction. The design of the session includes the following components:

- **Agenda:** A structured agenda is developed to guide the discussions and address critical topics related to the program re-design.
- **Facilitation Techniques:** Facilitation techniques, such as brainstorming exercises, group discussions, and interactive activities, encourage active participation and generate innovative ideas.
- **Materials and Resources:** Relevant materials, documents, and resources related to the PENG program are provided to participants to inform their discussions and decision-making processes.
- **Note-Taking and Documentation:** ToC Pamphlets are used to record the co-design session's key points, suggestions, and outcomes. This documentation serves as a reference for future analysis and implementation.

The in-person co-design session ensures that participants can engage in meaningful discussions, share their perspectives, and collectively contribute to the re-design process of the PENG program.

Internet-Based Feedback Survey. An internet-based feedback survey is conducted with PENG students to evaluate the suggested strategies generated during the co-design session. The survey is administered online to maximize accessibility and convenience for the participants. The design of the feedback survey includes the following elements:

- **Survey Questions:** The survey includes targeted questions related to the suggested strategies, focusing on their relevance, feasibility, and potential impact on the PENG program.

- **Likert Scale and Open-Ended Questions:** The survey includes Likert scale questions to capture quantitative feedback from the participants. The Likert scale allows for measuring agreement or disagreement from participants w.r.t suggested strategies.
- **User-Friendly Interface:** The online survey platform is designed with a user-friendly interface to ensure ease of navigation and comprehension for participants, promoting higher response rates and meaningful feedback.

By employing an internet-based feedback survey, the study gathers valuable feedback from PENG students, ensuring their perspectives and insights are considered in evaluating the suggested strategies for program re-design. The careful design of these instruments aims to foster active participation, collaboration, and valuable feedback from participants in Phase 3 of the dissertation study. By combining the in-person co-design session and the internet-based feedback survey, the study aims to generate robust data for re-designing the PENG program and evaluating suggested strategies.

Data Collection and Analysis

Phase 3. In this phase of the study, data collection and analysis encompass two key components: a co-design session focused on redesigning the PENG program and evaluating student feedback through a survey. These methods were chosen to gather comprehensive insights into the suggested strategies generated during the co-design session and assess their impact on the program. The co-design session is a collaborative platform, bringing together faculty members, advisors, and the Associate Dean for Undergraduate Education to contribute their expertise and insights. Participants collectively worked towards reimagining the PENG program through open discussions and interactive activities. Subsequently, an evaluation survey was administered to PENG students to capture their feedback on the suggested strategies. This

section delves into the data collection process during the co-design session and the subsequent analysis of student feedback, providing a comprehensive understanding of the outcomes and recommendations for the program's redesign.

Co-Design Session. The co-design session of this study played a pivotal role in the collaborative process of redesigning the PENG program. Bringing together faculty members, advisors, and the associate dean for undergraduate education, the co-design session is a dynamic and interactive platform for generating innovative ideas and strategies. With the shared objective of enhancing the program's effectiveness and relevance, participants engaged in open discussions, brainstorming exercises, and group activities. The co-design session fostered a rich exchange of expertise and perspectives, enabling the collective input of stakeholders with diverse backgrounds and roles. This includes using personas, card-sorting activity, and brainstorming sessions for data collection following a ToC documentation template (Figure 15). Participants find it beneficial to write down ideas as they progress through this phase so those artifacts may be analyzed and retained for future use. Thus, including a wide range of stakeholders in the theory of change fulfills the inclusion/engagement criterion so that everyone's perspective is visible and reflected along with the clearly defined assumptions. Table 5 and Table 16 summarizes the participant recruitment and data collection methods used in the respective phases of the study.

PENG faculty members and advisors are invited to work collaboratively to address student concerns/challenges in the PENG program at UM-Dearborn. During the session, participants shared their perspectives and insights regarding students' challenges to identify potential solutions and strategies to address these concerns. This session allows participants to work together to develop strategies considering each other's diverse perspectives and experiences

with PENG students and the program. Thus, creating a safe and inclusive environment where all voices could be heard and valued. This approach is designed to foster a sense of shared ownership and responsibility for addressing student concerns and to ensure that the resulting solutions are effective, feasible, and sustainable. Table 17 presents an overview of the activities that are included in the co-design session:

Activity	Description
Activity 1	Icebreakers and Introductions
Activity 2	Personas Introduction (Problem Identification)
Activity 3	Prioritization Card-sorting Activity
Activity 4	Group Prioritization Card-sorting Activity
Activity 5	Brainstorming and Idea generation using ToC Framework

Table 17: Co-design session activities

At the start of the co-design session, participants are provided with all the necessary materials to facilitate the activities. This includes a folder containing activity sheets, sorting cards, personas, and other relevant materials. Additionally, participants were provided with a whiteboard, markers, and post-it notes to aid in the brainstorming sessions. Access to these materials ensured that participants had everything they needed to actively participate in the co-design process and contribute to developing effective and practical solutions. The whiteboard, markers, and post-it notes were handy during the brainstorming and ideation stages, as they allowed participants to share their ideas and insights visually and interactively.

Overall, providing these materials is an essential aspect of the co-design session. It helps facilitate collaboration and active participation among participants and ensures that the solutions are comprehensive, practical, and tailored to the target audience's needs.

The co-design session starts with activity 1, which involves icebreakers and introductions. This activity is designed to help participants get to know each other better and establish an inclusive environment. Participants are instructed to introduce themselves by sharing their names and affiliation with PENG. They are also asked to share their favorite book or movie

and one thing they hope to learn or accomplish during the co-design session. The icebreaker activity allowed participants to share a little bit about themselves and their interests while also allowing them to express their goals and expectations for the co-design session. This helped to create a sense of connection among participants, which is essential for the success of the co-design process. Thus, setting a positive tone for the co-design session.

During Activity 2 of the co-design session, participants (PENG faculty members and advisors) are instructed to review the personas provided in the folder. This activity aims to help participants understand PENG students' needs, frustrations, and pain points based on different personas. Furthermore, they are asked to use these personas as a reference point throughout the design process and are given 10 minutes to familiarize themselves with each persona's characteristics as well as identify their unique needs and challenges. They are encouraged to take notes and ask questions if they need clarification on any personas.

By reviewing the personas, participants gain a deeper understanding of the target audience for the co-design session and identify specific areas where improvements and solutions are needed. This information is used to inform the brainstorming and ideation process as participants work together to generate ideas and proposals that address the needs and concerns of the different personas. Overall, this activity is an essential step in the co-design process, as it helps participants to align their thinking with the needs of the target audience (PENG students) and to ensure that the resulting solutions are practical and tailored to the specific needs of the different personas.

Activity 3 (Individual Prioritization Card-sorting Activity) involves priority-based sorting of 19 cards, each containing PENG students' needs/frustrations. This activity is to be completed in a time duration of 10 minutes. Participants are instructed to prioritize the identified needs and

challenges based on their importance, urgency, feasibility, and potential impact on PENG students. The cards are provided in an envelope labeled "Activity 2" in their files and represent different needs or pain points of PENG students at UM-Dearborn.

Participants are instructed to sort and label the cards in order of priority, with the highest priority labeled as "1" and the lowest priority labeled as "19". Participants are explained that there are no right or wrong answers and are encouraged to use their best judgment and think about what is most important for PENG students from their perspective.

To begin the activity, participants are asked to review the cards and consider how to prioritize them. They are then instructed to sort the cards into different piles or columns based on their priority level, with the flexibility to move cards between piles or columns or change the order of the cards as needed. Once the activity is completed, participants are instructed to place the cards in the same envelope. The Prioritization Card-sorting Activity is an essential step in the co-design process. It helps participants identify PENG students' most pressing needs and challenges and prioritize them according to their perspectives. Table 18 shows the top five PENG students' needs based on individual participants' perspectives. Refer to Appendix H to review the list of all 19 cards.

Participants	Ranks	Cards
Participant 1 (Engineering Faculty)	1	- Fastrack admission and financial aid process - More student engagement opportunities
	2	- Web page for weekly student emails/ announcements, - better connection to campus resource availability, - better information sharing on different program, classes, and student organizations, - improving orientation experience.
	3	- More clear registration instructions & Course selection help, - better advising support and clear direction to stay on track.
	4	- Additional support for career exploration, more workshops, seminars, and career events
	5	- More introductory coding classes, - short review lectures that cover fundamentals, - update lecture slides, - more hands-on activities in lectures.
Participant 2 (Advisor)	1	- Better connection to campus resource availability
	2	- More student engagement opportunities - Additional support for career exploration, - Better information sharing on different program, classes, and student organizations.
	3	- More hands-on activities in lectures.
	4	- Improving orientation experience
	5	- More introductory coding classes, - more workshops, seminars, and career events
Participant 3 (MATH Faculty)	1	- Better advising support and clear direction to stay on track.
	2	- Better information sharing on different program, classes, and student organizations.
	3	- Fastrack admission and financial aid process
	4	- Better personalized early warning system
	5	- More clear registration instructions & Course selection help
Participant 4 (CHEM Faculty)	1	- More hands-on activities in lectures
	2	- Fastrack admission and financial aid process
	3	- Improving orientation experience
	4	- Better connection to campus resource availability
	5	- More workshops, seminars, and career events
Participant 5 (MATH Faculty)	1	- Better advising support and clear direction to stay on track
	2	- More clear registration instructions & Course selection help
	3	- Clear expectations from students regarding requirements
	4	- Fastrack admission and financial aid process
	5	- Class schedule time flexibility
Participant 6 (Advisor)	1	- Improving orientation experience
	2	- More hands-on activities in lectures
	3	- Better advising support and clear direction to stay on track, - more clear registration instructions & Course selection help
	4	- Clear expectations from students regarding requirements
	5	- Additional support for career exploration, - Better connection to campus resource availability, more workshops, seminars, and career events, - Better information sharing on different program, classes, and student organizations

Table 18: Top 5 cards based on individual card sorting activity

In the study, individual card sorting is initially conducted to gain insight into the individual perspectives of PENG faculty members and advisors regarding their preferences and

priorities on “What is most important for PENG students?” After collecting the individual results, the process moved on to group card prioritization.

In activity 4 (Group Card Prioritization Activity), the participants identified the top five pain points as a group observed through the personas and card sorting exercise. The group is again encouraged to prioritize these pain points based on their importance, urgency, feasibility, and potential impact on PENG students. By identifying and prioritizing these pain points, the group can focus on developing a solution that addresses the most critical issues. This card-sorting activity effectively ensures that the group is aligned on the most significant pain points and is working towards a solution that meets the needs of the target audience and community.

This step allowed for the consolidation of individual preferences and helped identify the top priority-based cards. The group card prioritization process enabled the researchers to focus on the most critical aspects, as agreed upon by most participants, for further analysis and potential strategies, recommendations, and implementation. The activity is expected to take 10 minutes. The top five needs identified through the group card sorting activity are shown in Table 19, where rank 1 indicates the most crucial need identified through the activity, and rank five indicates the least crucial need identified.

Ranks	Top 5 Cards (Most critical student needs)
1	<ul style="list-style-type: none"> - Improving orientation experience [create an app or a pamphlet with all the info and distribute it] - More student engagement opportunities
2	<ul style="list-style-type: none"> - Fastrack admission and financial aid process
3	<ul style="list-style-type: none"> - Clear expectations from students regarding requirements. - More hands-on activities in lectures.
4	<ul style="list-style-type: none"> - Better advising support and clear direction to stay on track. - Class schedule time flexibility. - More clear registration instructions and course selection help.
5	<ul style="list-style-type: none"> - Better connection to campus resource availability - Additional support for career exploration - Better information sharing on different program, classes, and student organizations

Table 19: Top 5 group of cards based on group card sorting activity

Lastly, activity 5 focuses on generating ideas and strategies for addressing the most critical pain points and needs of PENG students (shown in Table 15). The activity lasts 30 minutes and utilizes the Theory of Change (ToC) framework to guide the idea-generation process. Figure 27 displays the sample template for ToC documentation.

Program:	[Name of program or initiative]
Goal:	[Overall goal of the program or initiative]
Inputs:	[List the resources, funding, staff, and materials required to implement the program or initiative]
Activities:	[List the specific actions or interventions that will be taken to achieve the desired outcomes]
Outputs	[List the immediate results or products of the program or initiative]
Outcomes	<ul style="list-style-type: none"> • Short-Term Outcomes: [List the immediate changes or results that are expected to occur as a result of the program or initiative] • Intermediate Outcomes: [List the mid-term changes or results that are expected to occur as a result of the program or initiative] • Long-Term Outcomes: [List the ultimate goals or results that are expected to be achieved as a result of the program or initiative]
Assumptions: (If any)	[List the beliefs, values, and expectations that underlie the program or initiative and may affect its success]
Risks: (If any)	[List the potential obstacles, challenges, or external factors that may affect the success of the program or initiative]
Monitoring and Evaluation:	[List the methods and tools that will be used to track progress, measure outcomes, and make any necessary adjustments to the program or initiative]

Figure 27: ToC documentation sample template (Weiss, 1995)

In this activity, the group builds upon the outcomes of the previous activity (Activity 4), where PENG students' most critical pain points and needs were prioritized. The group is asked to brainstorm different strategies for addressing these needs, considering feasibility, effectiveness, and impact on PENG students. The personas developed earlier are used to provide a better understanding of the needs and pain points.

Using the ToC framework, the group develops five pamphlets, each addressing one need (or a similar group of needs) at a time, identified in the group card prioritization activity. The ToC framework involves defining the intended outcomes or goals of the initiative, identifying the resources required to achieve the outcomes, determining the activities or interventions that will be implemented, and identifying the short-term, intermediate, and long-term outcomes expected from the activities or interventions.

The group utilizes personas, post-it notes, whiteboards, and markers to generate strategies and solutions. This approach aims to develop evidence-based strategies tailored to the specific needs of the PENG students. The ToC pamphlet also requires participants to develop a monitoring and evaluation plan to track progress and outcomes. The ToC Pamphlets completed by the PENG faculty members and advisors are included in the findings section (Figure 27-31). These resulting ideas and proposals generated during the co-design session, documented as ToC templates, are assessed using the PENG student feedback survey.

Student Evaluation Feedback Survey. The evaluation feedback survey plays a crucial role in Phase 3 of the study, allowing for a comprehensive analysis of the strategies suggested during the co-design session. Specifically, the focus of this survey is to capture the perspectives and insights of PENG students, who are the primary beneficiaries of the program. Conducted through an internet-based platform, the survey is designed to gather a diverse range of feedback

from students, ensuring their voices and experiences are considered during the evaluation process. This section introduces the evaluation feedback survey, outlining its design and implementation, as well as the subsequent analysis of the collected data. Through this analysis, valuable insights are gained into the effectiveness and feasibility of the suggested strategies, enabling informed decisions to be made regarding the future direction of the program.

This survey helps understand the students' perspectives on how implementing the suggested changes and improvements would address the student concerns (identified in the Phase One survey and interviews). The survey consists of five close-ended questions based on a Likert scale focusing on different strategies suggested by faculty members and advisors in the co-design session. Additionally, an open-ended question is asked to students asking them to provide any additional comments or concerns they may have. More detailed feedback survey information is included in findings section (Figure 32-36).

This mixed methodology approach provides a valuable opportunity for faculty members, advisors, and PENG students to collaborate and work together meaningfully, with the ultimate goal of improving the educational experience for PENG students.

Findings

Phase 3 Findings

The findings section of this study presents the results of the co-design sessions and the evaluation feedback from the student feedback evaluation survey. These findings provide valuable insights into the effectiveness of the strategies proposed during the co-design sessions for redesigning the Pre-Engineering program. The survey data was analyzed based on effectiveness criteria to assess the impact of these strategies on addressing student needs and enhancing the overall program experience. By examining the co-design session findings and

student feedback evaluation survey results, this section offers a comprehensive understanding of the proposed strategies and their potential effectiveness in meeting the identified objectives of the program redesign.

Co-Design Session Findings. Co-design session involved using personas developed from previous phase to inform the brainstorming and ideation process, with participants working collaboratively to generate ideas and proposals that addressed the needs and concerns of the different personas. By aligning their thinking with the needs of the target audience, participants were able to create practical and tailored solutions that met the unique needs of each persona. Overall, the development and use of personas were crucial steps in the co-design process, helping to ensure that the resulting solutions were practical, feasible, and tailored to the specific needs of PENG students. The personas proved to be a valuable framework for understanding the PENG students' needs, while also promoting empathy and understanding among participants. Through the review of the personas, participants identified specific areas where improvements and solutions were needed, such as improvement in orientation, registration and financial aid assistance, and academic support.

Participants utilized the personas as a point of reference during co-design session activities, beginning with individual card sorting activity, followed by group card sorting activity. This allowed participants to gain a deeper understanding of the unique needs and concerns of PENG students, and to generate ideas and proposals that were tailored to these specific needs. During the individual card sorting activity, participants (faculty members and advisors) sorted the cards according to their priorities and perspectives. This allowed for a more personalized approach to identifying the needs and challenges facing PENG students, as each participant was able to consider their unique perspective and experiences. As a result, the top

five needs identified by each participant differed, depending on their personal experiences and priorities (as shown in Table 14). However, analyzing these individual rankings provides valuable insights into their diverse perspectives w.r.t the needs and challenges faced by PENG students. These insights were further consolidated and refined during the group card-sorting activity.

In the group card sorting activity, participants collaborated to identify the top five pain points based on importance, urgency, feasibility, and potential impact on PENG students. The group card prioritization process enabled the researchers to focus on the most critical aspects agreed upon by most participants. This approach allowed for a more holistic view of the needs and challenges facing PENG students, as it incorporated the perspectives and insights of multiple participants. While there were differences in the specific needs identified through the individual and group card sorting activities, both approaches provided valuable insights into participants' perspectives w.r.t to the needs and challenges facing PENG students.

Group 1	Group 2	Group 3	Group 4	Group 5
More student engagement opportunities specially during pre-admission.	Fastrack admission and financial aid process.	Clear expectations from students regarding requirements.	Better advising support and clear direction to stay on track.	Better connection to campus resource availability.
Improving orientation experience. [create an app or a pamphlet with all the info and distribute it].		More hands-on activities in lectures.	Class schedule time flexibility.	Additional support for career exploration [Information on available pathways in engineering].
			More clear registration instructions & Course selection help.	Better information sharing on different program, classes, and student organizations.

Figure 28: Top five groups of critical student needs identified through the group card sorting activity

Figure 28 shows the top five groups of critical student needs identified through the group card sorting activity. These needs are addressed by the participants (PENG faculty members and advisors) in the brainstorming session using the ToC (Theory of Change) pamphlets. The

brainstorming session includes creating and discussing different ideas that might eventually fulfill the needs of the PENG students—formulation of questions such as "How Might We" serve as the foundation for this session. The ToC approach is used to develop potential strategies and solutions that address the identified needs and challenges, focusing on creating measurable outcomes that lead to positive changes in the PENG student experience.

The ToC pamphlets served as a valuable tool for mapping out the steps and resources needed to achieve the desired changes, ensuring that the strategies developed are grounded in the needs and perspectives of the target audience and community. Overall, the findings from the prioritization card-sorting activity served as an essential starting point for the co-design process. The solutions developed helped improve the PENG student experience by addressing the most critical student needs. Each ToC (Theory of Change) pamphlet from the co-design session focuses on specific students' needs. Each pamphlet outlines the goals, inputs, activities, outputs, outcomes, assumptions, risks, and monitoring and evaluation strategies for a plan to address the specific need.

ToC pamphlet-1 focuses on improving the orientation experience and providing more student engagement opportunities for PENG (Pre-Engineering) students during their transition from high school to university. The plan includes integrating PENG students into the general orientation program, creating a dedicated track for PENG students, developing resources to assist PENG students in selecting courses, managing their schedules, and hiring tutor mentors to provide academic guidance and support. This requires funding and resources to hire tutor mentors, access to student data and analytics, and adequate staff resources to manage the tutoring program, develop orientation materials, etc. The short-term outcomes include increased awareness and understanding of course expectations, increased participation and engagement in

orientation programs and events, and increased tutoring and mentorship resources utilization. The medium-term outcomes include improved academic performance, higher satisfaction, and confidence. Also, the long-term outcome includes enhanced career readiness for PENG students. The plan also identifies assumptions and risks, such as inadequate training or support for tutor mentors. It outlines monitoring and evaluation strategies to assess the plan's effectiveness and make necessary adjustments. For more detailed information on the goals, inputs, activities, outputs, outcomes, assumptions, risks, and monitoring and evaluation strategies for this plan, please refer to Figure 29.

Goal:	<ul style="list-style-type: none"> - Improve orientation experience. - Provide more student engagement opportunities.
Inputs:	<ul style="list-style-type: none"> - Funding and resources to hire tutor mentors to guide PENG students through their transition from high school to university during their first term. - Access to student data and analytics to identify trends and patterns in PENG student academic performance and inform the development of targeted interventions. - Adequate staff resources to support and manage the tutoring program for PENG students, including recruitment, training, and supervision of tutor mentors. - Resources to develop and disseminate orientation materials, such as brochures or website/app creation.
Activities:	<ul style="list-style-type: none"> - Integrate PENG students into the general orientation program, rather than completely separating them from the rest of the student body. - Create a dedicated track or day within the orientation program specifically for PENG students. - Focus on PENG students during Blue Carpet Day, a campus visit day for admitted students. - Clearly communicate course expectations and scheduling options to PENG students. - Develop a resource (in the form of a website/Pamphlet/Application/Canvas page) to assist PENG students in selecting courses and managing their schedules. - Hire tutor mentors to provide academic guidance and support to PENG students during their first term of study [i.e., during their transition from high school to engineering]
Outputs	<ul style="list-style-type: none"> - Availability of Orientation planning worksheet [Website/Pamphlet/Application] - Improved/Customized orientation experience for PENG students. - Availability of mentorship resources for PENG students throughout their academic journey.
Outcomes	<p>Short-Term Outcomes:</p> <ul style="list-style-type: none"> - Increased awareness and understanding of course expectations and scheduling options among PENG students. - Increased participation and engagement in orientation programs and events among PENG students. - Increased participation and engagement in Blue Carpet Day among PENG students. - Increased utilization of tutoring and mentorship resources by PENG students. <p>Medium-Term Outcomes:</p> <ul style="list-style-type: none"> - Improved academic performance among PENG students, as evidenced by higher GPAs and completion rates. - Higher satisfaction and confidence levels among PENG students in their ability to navigate the university's academic requirements. <p>Long-Term Outcomes:</p> <ul style="list-style-type: none"> - Enhanced career readiness for PENG students.
Assumptions: (If any)	Disseminating orientation materials, such as brochures, websites, or mobile apps, will facilitate the clear and comprehensive communication of PENG program requirements to incoming students, thus increasing their awareness and understanding of the program's expectations and guidelines.
Risks: (If any)	<ul style="list-style-type: none"> - Lack of interest or engagement among PENG students in the orientation and mentorship programs, leading to low participation rates and reduced effectiveness. - Inadequate training or support for tutor mentors, leading to ineffective guidance and support for PENG students. - Limited availability of mentorship or tutoring resources, leading to long wait times or inability to access support when needed. - Lack of follow-up or evaluation of the orientation and mentorship programs, leading to an inability to assess their effectiveness and make necessary adjustments.
Monitoring and Evaluation:	<ul style="list-style-type: none"> - Surveys or feedback forms to gather feedback from PENG students on their orientation and mentorship experiences, as well as their academic performance and satisfaction. - Tracking attendance and participation rates in orientation and mentorship programs to assess their effectiveness and identify areas for improvement. - Conducting focus groups or interviews with PENG students to gather more in-depth feedback and insights into their experiences and needs. - Regular evaluation of tutor mentor performance and training to ensure that they are providing effective guidance and support to PENG students.

Figure 29: ToC pamphlet 1

ToC pamphlet-2 provides a comprehensive overview of a plan to Fastrack the admission and financial aid process for PENG students. The pamphlet outlines the specific inputs required for the plan, including knowledge of the specific needs and challenges faced by PENG students and access to relevant data and research on the financial barriers faced by PENG. The activities required to implement the plan are also detailed, including advocating for specific support from financial aid for PENG, analyzing existing financial aid policies, and developing a set of policy recommendations to address identified gaps and support the financial needs of PENG students. Thus, leading to a more streamlined admission and financial aid process. The table also details the expected outputs, outcomes, assumptions, risks, and monitoring and evaluation strategies associated with the plan. For example, the plan's expected short-term outcomes include reduced paperwork and administrative tasks, faster processing times for financial aid applications, and increased student satisfaction and confidence in the financial aid process. The long-term outcomes include increased enrollment in higher education among traditionally underrepresented groups and greater equity and access to higher education for low-income, first-generation, and minority students.

Overall, ToC pamphlet-2 provides a comprehensive overview of the plan, the steps required to implement it, and the expected outcomes and strategies for monitoring and evaluating progress. For instance, one evaluation plan mentioned is developing a clear set of indicators and metrics to measure progress toward the desired outcomes. For more detailed information, refer to Figure 30.

Goal:	Fastrack admission and financial aid process.
Inputs:	<ul style="list-style-type: none"> - Knowledge of the specific needs and challenges faced by PENG (Persons with Disabilities, non-citizen, and low-income individuals, and/or Single Parents). - Access to relevant data and research on the financial barriers faced by PENG
Activities:	<ul style="list-style-type: none"> - Advocate for specific support from financial aid for PENG. - Conduct research and gather data on the financial challenges faced by PENG in accessing higher education. - Analyze the existing financial aid policies and identify gaps and areas for improvement to better support PENG. - Develop a set of policy recommendations to address the identified gaps and support the financial needs of PENG. - Engage with relevant stakeholders, including financial aid administrators, policymakers, and community organizations, to advocate for the policy recommendations. - Analyze the existing admission and financial aid processes and identify areas that can be fast-tracked or streamlined without compromising quality. - Pilot the fast-tracked admission and financial aid processes at a small scale to test their effectiveness. - Scale up the fast-tracked admission and financial aid processes to larger groups of students once their effectiveness has been demonstrated.
Outputs	<ul style="list-style-type: none"> - Policy changes or reforms that incorporate specific support for PENG in the financial aid system. - Streamlined admission and financial aid processes that reduce the time and effort required for students to apply for and receive financial aid
Outcomes	<p>Short-Term Outcomes:</p> <ul style="list-style-type: none"> - Reduction in paperwork and administrative tasks for students applying for financial aid. - Faster processing times for financial aid applications. - Increased student satisfaction and confidence in the financial aid process. - Increased number of students who are able to enroll in college due to more accessible financial aid and streamlined admission processes. <p>Medium-Term Outcomes:</p> <ul style="list-style-type: none"> - Improved retention rates for students who receive financial aid. - Greater awareness among college administrators and policymakers of the benefits of fast-tracked admission and financial aid processes. - Increased adoption of streamlined admission and financial aid processes by colleges and universities - Decreased financial stress for students and their families. <p>Long-Term Outcomes:</p> <ul style="list-style-type: none"> - Increased enrollment in higher education among traditionally underrepresented groups - Greater equity and access to higher education for low-income, first-generation, and minority students
Assumptions: (If any)	NA
Risks: (If any)	<ul style="list-style-type: none"> - Bias and inequity: If not designed carefully, fast-tracked admission and financial aid processes could exacerbate existing biases and inequities, particularly if they disadvantage certain groups or favor those with more resources or connections. - Incomplete or inaccurate data: Streamlining processes may require data integration from multiple sources, and if data is incomplete or inaccurate, this could result in errors or delays.
Monitoring and Evaluation:	<ul style="list-style-type: none"> - Developing a clear set of indicators and metrics that can measure progress toward the desired outcomes. For example, these might include measures such as the number of financial aid applications processed within a certain timeframe, the percentage of students who receive financial aid within a certain timeframe, and the retention and graduation rates of students who receive financial aid. - Establishing a system for data collection and analysis to track progress toward the desired outcomes. This might involve setting up databases or dashboards to collect and analyze data on financial aid applications and enrollment, as well as conducting surveys or focus groups to gather feedback from students and other stakeholders. - Regularly reviewing and analyzing the data to identify any trends or patterns that suggest progress or areas for improvement. This might involve conducting regular meetings or check-ins with stakeholders to review the data and discuss any necessary adjustments or modifications to the plan. - Adjusting or modifications to the plan as necessary based on the data and feedback collected. For example, if the data suggests that the fast-tracked admission process is not achieving the desired outcomes, the plan might be adjusted to focus more on streamlining the financial aid process instead. - Communicating the results of the monitoring and evaluation process to stakeholders to maintain transparency and accountability. This might involve providing regular progress reports or presentations to college administrators, policymakers, and other stakeholders to keep them informed of the progress toward achieving the desired outcomes.

Figure 30: ToC pamphlet 2

ToC pamphlet-3 outlines a plan to set clear expectations for PENG students regarding program requirements and incorporate more hands-on activities in lectures to improve academic achievement and engagement. The plan includes requiring students to attend face-to-face classes until they pass their PENG coursework, setting clear expectations for courses and scheduling options, grouping students into cohorts for improved academic achievement and engagement, and implementing various activities to encourage the exploration of campus resources. The plan also prioritizes inclusivity, reasoning, and group discussions in the learning environment, with group worksheets and partner quizzes assigned to promote collaborative learning and a weekly recitation activity where a group of students will solve assigned problems on the board. The expected short-term outcomes include increased collaboration and teamwork skills among students, clarity and understanding among students regarding course expectations and scheduling options, and increased motivation and engagement among low-performing students. The medium-term outcomes include improved course planning and scheduling efficiency, improved students' critical thinking and problem-solving skills, and improved academic achievement through peer-to-peer learning and support. The long-term outcome is increased student satisfaction with course offerings and scheduling options. The plan identifies assumptions, such as the assumption that alternative forms of assessment are more effective than traditional exams for all students, and risks, such as the risk of students dropping out or becoming disengaged if they cannot attend face-to-face classes for any reason. The plan also outlines monitoring and evaluation strategies, such as conducting student surveys or focus groups for assessment and monitoring student attendance and participation rates in face-to-face classes and academic achievement. For more detailed information, refer to Figure 31.

Goal:	<ul style="list-style-type: none"> - Setting clear expectations from students regarding program requirements. - More hands-on activities in lectures.
Inputs:	<ul style="list-style-type: none"> - Adequate staffing and support for monitoring and facilitating the activities
Activities:	<ul style="list-style-type: none"> - Requiring that students attend face-to-face classes until they pass their PENG coursework. [setting clear expectation] - Clear expectations will be set for students regarding the courses they are taking, as well as their scheduling options. - Students will be grouped into cohorts for improving academic achievement and engagement. - Various activities, such as a scavenger hunt, will be implemented to encourage students to explore the campus and its resources. - Prioritize inclusivity, reasoning, and group discussions in a learning environment. - Group worksheets and partner quizzes will be assigned to promote collaborative learning. - Students will be paired based on their first test scores, with high and low performing students working together on test corrections for extra credit. - A weekly recitation activity will be introduced where a group of students will solve assigned problems on the board. - Shift away from traditional exams to alternative forms of assessment such as concept maps and portfolios.
Outputs	<ul style="list-style-type: none"> - Leading to more clear expectations and requirements. - Increased attendance and participation in face-to-face classes.
Outcomes	<p>Short-term:</p> <ul style="list-style-type: none"> - Increased collaboration and teamwork skills among students. - Increased clarity and understanding among students regarding course expectations and scheduling options. - Increased motivation and engagement among low-performing students. <p>Medium-term:</p> <ul style="list-style-type: none"> - Improved course planning and scheduling efficiency. - Improved critical thinking and problem-solving skills among students. - Improved academic achievement through peer-to-peer learning and support. <p>Long-term:</p> <ul style="list-style-type: none"> - Increased student satisfaction with course offerings and scheduling options.
Assumptions: (If any)	<ul style="list-style-type: none"> - Assumption that alternative forms of assessment are more effective than traditional exams for all students.
Risks: (If any)	<ul style="list-style-type: none"> - Risk of students dropping out or becoming disengaged if they are unable to attend face-to-face classes for any reason. - Risk of decreased validity or reliability of alternative forms of assessment compared to traditional exams.
Monitoring and Evaluation:	<ul style="list-style-type: none"> - Conduct student surveys or focus groups for assessment. - Monitor student attendance and participation rates in face-to-face classes. - Monitor student academic achievement [GPA].

Figure 31: ToC pamphlet 3

ToC pamphlet-4 is focused on providing better advising support, clear direction to stay on track, class schedule time flexibility, more straightforward registration instructions, and course selection help for Pre-Engineering (PENG) students. The plan includes a structured peer mentoring program, bringing in successful PENG alumni to share their experiences and insights, a "Spotlight on" activity to showcase successful PENG alumni in lectures, gathering information about PENG students' backgrounds, monitoring their progress throughout the term, and

approaching each PENG student's case individually. The outputs include implementing a peer mentoring program, networking, and communication resources to bring in successful PENG alumni and create a sense of accountability among students. The outcomes include increased awareness and utilization of peer mentoring and support resources among PENG students, the establishment of a solid and supportive PENG community at the university, enhanced academic success and career readiness of PENG students, and continual improvement and refinement of the PENG program based on ongoing evaluation and feedback. Monitoring and evaluation will be done through surveys, progress reports, retention rates, feedback sessions, assessments, benchmarking, monitoring peer mentor matching, and establishing performance metrics. for peer mentors to refine the program. For more detailed information refer to Figure 32.

Goal:	<ul style="list-style-type: none"> - Better advising support and clear direction to stay on track. - Class schedule time flexibility. - More clear registration instructions and course selection help.
Inputs:	<ul style="list-style-type: none"> - Funding to hire and pay peer mentors to provide weekly check-ins and guidance to PENG students. - Networking and communication resources to bring in successful pre-engineering alumni to share their experiences and insights.
Activities:	<ul style="list-style-type: none"> - Implement a Structured peer mentoring program by hiring upper-level class students to provide weekly check-ins and guidance to a group of PENG students, ensuring that they receive individualized attention and support. - Peer mentors to offer recommendations for classes that are necessary for PENG students' academic progress, while also considering their strengths and interests to ensure a challenging yet manageable workload and considering their personal goals and needs. - Bring in former pre-engineering students [alumni] who have achieved success to share their experiences and insights, inspiring and motivating current students to succeed. - Incorporate a "Spotlight on" activity into lectures, featuring brief stories [using PPT slides] of successful pre-engineering alumni to showcase the potential outcomes of the program and inspire current students. - Gather information about PENG students' backgrounds, including their high school experience and prior coursework, through a survey on the first day of class, in order to tailor the teaching approach to their individual needs. - Monitor PENG students' progress throughout the term and provide guidance and support as needed to ensure their academic success. - Approach each PENG student's case individually, recognizing their unique needs and providing tailored support and guidance to facilitate their success.
Outputs	<ul style="list-style-type: none"> - Implementation of a peer mentoring program for PENG students, providing individualized attention and support. - Establish networking and communication resources to bring in successful pre-engineering alumni to share their experiences and insights. - Development of the "Spotlight on" activity to showcase successful pre-engineering alumni in lectures. - Creates a sense of accountability among students, as they know their peer mentors will be checking in with them every week. This fosters a culture of academic responsibility.
Outcomes	<p>Short-term outcomes:</p> <ul style="list-style-type: none"> - Increased awareness and utilization of peer mentoring and support resources among PENG students. - Improvement in PENG students' ability to make informed decisions about their class schedules and academic progress. - Higher levels of satisfaction and engagement among PENG students with the pre-engineering program. <p>Medium-term outcomes:</p> <ul style="list-style-type: none"> - Establishment of a strong and supportive pre-engineering community at the university. - Continual improvement and refinement of the pre-engineering program based on ongoing evaluation and feedback. <p>Long-term outcomes:</p> <ul style="list-style-type: none"> - Enhanced academic success and career readiness of PENG students, leading to a more competitive workforce and better outcomes for the community as a whole.
Assumptions: (If any)	NA
Risks: (If any)	NA
Monitoring and Evaluation:	<ul style="list-style-type: none"> - Surveys: Administering surveys to PENG students and peer mentors to assess their satisfaction with the program, their engagement, and their perception of its impact on their academic success. - Progress reports: Monitoring PENG students' academic progress and providing regular progress reports to both students and peer mentors to identify areas of improvement and provide tailored support as needed. - Retention rates: Tracking PENG students' retention rates to assess the effectiveness of the program in retaining and supporting students in the pre-engineering program. - Feedback sessions: Conducting regular feedback sessions with PENG students and peer mentors to gather feedback on the program and identify areas for improvement. - Assessments: Administering pre- and post-program assessments to assess the impact of the program on PENG students' academic progress, confidence, and motivation. - Benchmarking: Comparing the program's outcomes and effectiveness to similar programs at other universities to identify areas of improvement and best practices. - Monitoring peer mentor matching: Keeping track of the number of PENG students who were matched with peer mentors and monitoring their progress. - Peer mentor performance metrics: Establishing performance metrics for peer mentors and monitoring their performance against these metrics to identify areas for improvement and refine the program.

Figure 32: ToC pamphlet 4

ToC pamphlet-5 focuses on providing a better connection to campus resources, additional support for career exploration, and better information sharing on different programs, classes, and student organizations. Some inputs required for this initiative include video recording equipment, online storage and sharing platform, advertising resources, staffing, funding for senior students, etc. The activities to be undertaken include encouraging senior students to document their challenges and successes via recorded testimonials or stories, creating a comprehensive database of these recordings, inviting senior students to share their personal stories during orientation, providing prospective students with access to these videos prior to admission, and displaying these videos on multiple screens around the campus. A "coffee hours" program will also be introduced to allow students to engage with faculty members in a relaxed and informal setting. The short-term outcomes will be increased awareness and interest in PENG from senior students' stories, increased engagement and motivation among incoming students, increased engagement and support from senior students and faculty members, etc. The medium-term outcomes will be improved recruitment and retention rates, enhanced diversity and inclusivity within the student body, enhanced faculty-student relationships and teaching practices, and increased engagement and support from alumni. The long-term outcomes will be increased graduation rates, improved student success, enhanced career development opportunities, etc. The pamphlet also outlines the assumptions, such as faculty members and staff having the necessary resources, time, and capacity to support the initiative effectively, the initiative will not negatively impact faculty members' or staff's workload or productivity, etc. The risks may include privacy concerns among senior students. It also mentions the monitoring and evaluation strategies, including tracking the number of video views, conducting regular surveys or feedback mechanisms, monitoring

recruitment and retention rates, evaluating coffee hour attendance and feedback, monitoring the accessibility and availability of the videos, etc. For more detailed information, refer to Figure 33.

Goal:	<ul style="list-style-type: none"> - Provide better connection to campus resource availability, - Provide additional support for career exploration [info on available pathways in engineering], - Provide better information sharing on different program, classes, and student organizations
Inputs:	<ul style="list-style-type: none"> - Video recording equipment: Senior students will need access to reliable video recording equipment to record their testimonials or stories. - Video editing software: The recorded videos will need to be edited, compiled, and stored in a suitable format for easy access by faculty members. - Online storage and sharing platform: The compiled videos need to be stored in a reliable online platform that allows easy sharing and access by faculty members. - Advertising resources: Advertisements and promotional materials may be necessary to promote the availability and accessibility of the video repository to students. - Staffing: Staff may be needed to manage and coordinate the various activities and resources required to fulfill the above needs. - Funding for senior students: Incentives or funding may be required to encourage senior students to participate in creating these videos. - Coordination among faculty members and admissions office: Coordination among the faculty members and the admission's office is necessary to ensure that the videos are accessible to prospective students, and to integrate them into the overall admission process. - Space for playing the videos on campus: The availability of suitable spaces to play these videos on campus may be required to ensure that they are widely accessible to students. - Technical support: Technical support may be needed to ensure that the video repository and sharing platform are fully functional and easy to use for all stakeholders.
Activities:	<ul style="list-style-type: none"> - Encourage senior students to document their challenges and successes during their pre-engineering studies via recorded testimonials or stories. - Create a comprehensive database of these recordings that can be accessed by faculty members at any time. - Invite senior students to share their personal stories and experiences during the orientation program. - Provide prospective students with access to these videos prior to admission, to offer them a glimpse into the UMD community. - Display these videos on multiple screens around the campus to promote awareness and engagement among students. - Introduce "coffee hours" as an opportunity for students to engage with faculty members in a relaxed and informal setting over coffee and snacks, held outside the faculty office on campus.
Outputs	<ul style="list-style-type: none"> - Accessibility of the videos to students at any point, even before they decide to attend UMD, acting as a powerful testimony. - Coffee hours program will encourage students to engage with faculty members in a relaxed and informal setting allowing for more information sharing, providing better support.
Outcomes	<p>Short-term outcomes:</p> <ul style="list-style-type: none"> - Increased awareness and interest in PENG from the stories of senior students. - Improved engagement and motivation among incoming students. - Increased engagement and support from senior students and faculty members. - Improved visibility and reputation of the institution. <p>Medium-term outcomes:</p> <ul style="list-style-type: none"> - Improved recruitment and retention rates. - Enhanced diversity and inclusivity within the student body. - Enhanced faculty-student relationships and teaching practices. - Increased engagement and support from alumni. <p>Long-term outcomes:</p> <ul style="list-style-type: none"> - Increased graduation rates and improved student success. - Enhanced career development opportunities for students. - Improved institution's brand reputation by showcasing its commitment to providing a supportive and engaging environment for students. - Enhanced research opportunities and partnerships for the institution. - Increased community engagement and support.
Assumptions: (If any)	<ul style="list-style-type: none"> - Faculty members and staff have the necessary resources, time, and capacity to support the initiative effectively. - The initiative will not negatively impact the workload or productivity of faculty members or staff. - The initiative will not create any significant additional financial burdens for the institution. - The coffee hours program will be well-attended and effectively promote engagement between students and faculty members. - Senior students are willing and able to create and share their stories and testimonials. - Prospective students are interested in and motivated by the experiences of senior students.
Risks: (If any)	<ul style="list-style-type: none"> - Privacy concerns: The availability of videos may raise privacy concerns among senior students, especially if they share sensitive information about themselves or their experiences.
Monitoring and Evaluation:	<ul style="list-style-type: none"> - Number of video views: The number of views of each video in the repository can be tracked to evaluate the level of engagement and interest among students and faculty members. - Survey or Feedback from students, faculty members, and alumni: Regular surveys or feedback mechanisms can be used to gather feedback on the usefulness and relevance of the videos, as well as areas for improvement. - Recruitment and retention rates: The impact of the initiative on recruitment and retention rates can be monitored to evaluate its effectiveness in attracting and retaining a diverse student body. - Coffee hour attendance: The attendance and feedback from coffee hours can be used to evaluate the effectiveness of the program in promoting engagement between students and faculty members. - Availability and accessibility: The accessibility and availability of the videos can be monitored to ensure that they are accessible to a broad range of students. - Website embedded in Canvas course page: The number of courses that have embedded the video repository in their Canvas course page can be tracked to evaluate the effectiveness of the strategy in promoting student engagement with the initiative.

Figure 33: ToC pamphlet 5

Thus, the results from this design workshop (Co-Creation Session) involving PENG advisors and faculty members help develop new ideas to improve the current PENG program. The effectiveness of these ideas is further analyzed using a feedback survey distributed to PENG students.

Student Evaluation Feedback Survey Findings. The ideas and proposals generated by the participants in the co-design session, documented in the form of ToC (Theory of Change) templates, are shared with PENG students through a feedback survey. To assess these proposals' viability and potential impact, a PENG student feedback survey is conducted to gather their perspectives on how implementing the suggested changes and improvements would address their concerns. This feedback survey comprises five close-ended questions (Figure 34-38) based on a Likert scale focusing on the different strategies suggested by faculty members and advisors during the co-design session.

A numerical value is assigned to each rating category to determine the mean effectiveness rating for each activity. The ratings range from "Not effective at all" with a value of 1, to "Slightly effective" with a value of 2, "Moderately effective" with a value of 3, "Very effective" with a value of 4, and "Extremely effective" with a value of 5. These numerical values are utilized to calculate the average rating for each activity, providing a quantitative measure of its perceived effectiveness. This approach allows for a more objective assessment of the survey responses and facilitates a clearer understanding of the overall effectiveness of each activity based on the mean rating. The responses to these questions help gauge students' agreement or disagreement regarding the proposed changes. In addition to the close-ended questions, the PENG student feedback survey also includes an open-ended question that asks students to share any additional feedback or needs that they feel were not addressed in the study. This question is

designed to gather other insights students may have regarding the PENG program at UM-Dearborn.

Figure 34 shows that activities proposed to address student needs related to providing a better connection to campus resources, additional support for career exploration, and better information sharing on programs, classes, and student organizations are rated at least slightly effective. Activity #4, which provides prospective students access to the recorded testimonials or stories before admission, received the highest ratings of very effective and extremely effective from most respondents. Activities #1, #2, #3, and #5 all received mixed ratings, with some respondents rating them as ineffective or slightly effective. In contrast, others rated them moderately, very effective, or extremely effective. Calculating the mean effectiveness ratings for each area allows us to understand the average perception among the respondents. These results indicate varying levels of perceived effectiveness across the different activities.

Activity #1 and Activity #2 received moderate ratings on average (mean=3.2), suggesting that encouraging senior students to document their challenges and success stories and displaying these videos on campus is considered moderately effective. Activity #3, inviting senior students to share their personal stories, has a slightly higher average perception of effectiveness (mean=3.6), leaning towards moderate to very effective. In Activity #4, the average perception of effectiveness increases further (mean=4), indicating that providing prospective students access to these videos before admission is quite effective. Finally, Activity 5 demonstrates the highest average perception of effectiveness among all the areas (mean=4.2), suggesting that introducing coffee hours is highly effective according to the students.

Overall, the survey data suggests that providing prospective and current students with access to recorded testimonials or stories from senior students and introducing coffee hours may

be the most effective way to address the identified student needs. However, the other proposed activities may also help meet these needs, and a combination of these activities may be the most effective approach. It is worth noting that the sample size and representativeness of the survey data are unknown, and further analysis and interpretation may be necessary to draw more robust conclusions.



Figure 34: Survey responses on strategies suggested in ToC pamphlet-1

Figure 35 shows that all six proposed activities related to improving the orientation experience and providing more student engagement opportunities for Pre-Engineering (PENG) students received varying effectiveness ratings. The mean effectiveness ratings shows that Activity #1 and Activity #3, which proposes integrating PENG student in general orientation and focusing on PENG students during blue carpet day and campus visits, are perceived as less effective (mean =2.8 and 2.19). This suggests that this activity is perceived to be moderately effective on average. In contrast, Activity #2 and Activity #4, which proposes to create a dedicated track for PENG students within the orientation program and clear communication on course expectations and scheduling options, respectively, indicate a slightly more positive

perception of effectiveness than the previous strategies (mean =3.1). Lastly, Activity #5 and Activity #6 also have similar ratings (mean =3.3), indicating that developing a resource (website/pamphlets) for course selection and program information and hiring mentors to provide academic guidance may be the most effective approach. These strategies demonstrate a slightly higher average perception of effectiveness than previous strategies.

Overall, the survey data suggests providing resources and support for PENG students during orientation and throughout their first term of study is essential. However, the other proposed activities may help meet the identified student needs. However, it is crucial to note that these findings are solely based on the mean ratings and do not capture the full range of opinions or provide context for the evaluation criteria. Additional analysis and consideration of specific factors and qualitative feedback would be necessary to gain a more comprehensive understanding of the respective strategies' effectiveness.

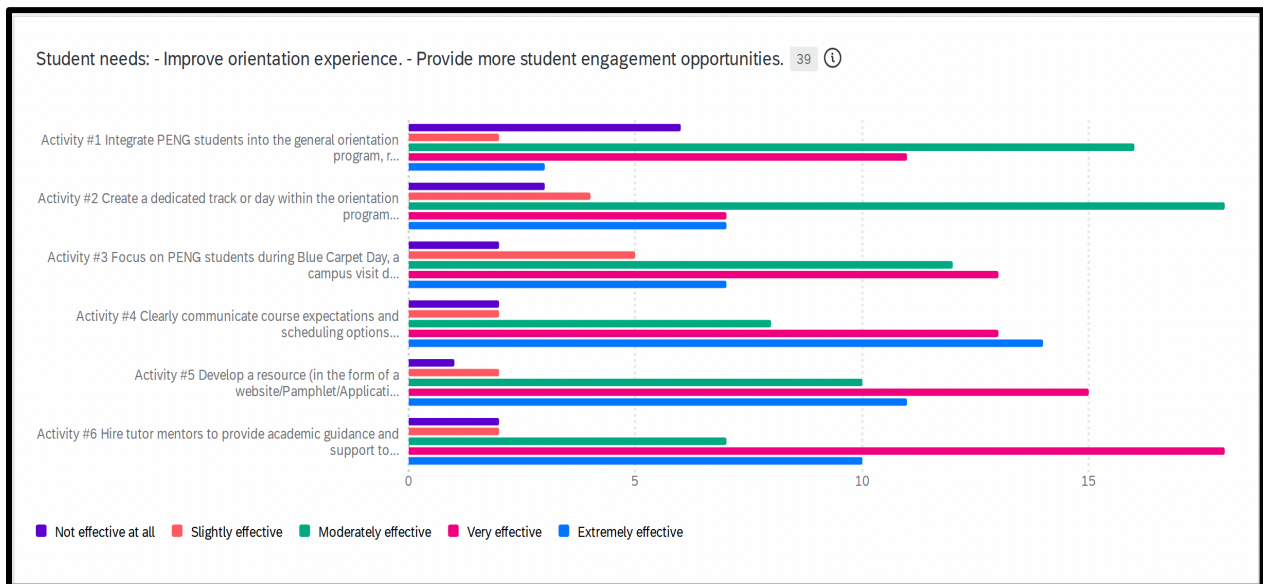


Figure 35: Survey responses on strategies suggested in ToC pamphlet-2

ToC pamphlet 3 focuses on better advising support, clear direction to stay on track, class schedule time flexibility, and more straightforward registration instructions and course selection help. The findings from the analysis of the mean effectiveness ratings offer insights into the

perceived effectiveness of respective activities. Figure 36 shows the student feedback on suggested activities in ToC pamphlet 3. Results show that, on average, students perceive Activity #1 as moderately effective (mean=3.75). Activity #2 has a slightly higher average perception of effectiveness (mean =4.0), generally considered moderately to somewhat effective. It involves implementing a structured peer mentoring program and having peer mentors offer class recommendations. While they may not be as effective as the alumni-focused activities, they still have the potential to provide valuable support and guidance to PENG students.

In Activity #3, (mean = 4.833) indicates a higher average perception of effectiveness than the previous activities, leaning more towards being very effective. It involves bringing in former PENG students to share their experiences and insights, which the respondents rated highly effective. It suggests that including alumni can be a powerful motivator for current PENG students.

Activity #4 and Activity #5 (mean = 4.5) suggest a consistent perception of effectiveness, leaning more towards very effective. These activities are generally considered quite effective by the respondents. Activity #4 incorporates a "Spotlight on" activity into lectures featuring brief stories of successful PENG alumni. Activity #5 involves approaching each PENG student's case individually and providing tailored support. While individualized support is essential, it may not be as effective as other activities. Thus, including alumni and peer mentorship programs may be an effective way to address these needs.



Figure 36: Survey responses on strategies suggested in ToC pamphlet-3

Figure 37 shows the PENG students' feedback on the strategies suggested w.r.t to setting clear expectations from students regarding program requirements and more hands-on activities in lectures (as mentioned in ToC pamphlet 4). mean effectiveness ratings for each activity show a varied student response. Activity #1, which focuses on mandating face-to-face classes, indicates moderate effectiveness (mean= 3.14). Activity #2 mentioned grouping students into cohorts for improving academic achievement and engagement received mixed reviews with a slightly higher average rating (mean= 3.42), suggesting a somewhat stronger perception of effectiveness. Activity #3 offers various activities to encourage students to explore the campus and its resources. It had an average rating of approximately (mean=3.06), indicating a moderate effectiveness level.

Similarly, Activity #4 and Activity #5 show moderate perceived effectiveness (mean =3.19). Activity #6 proposed a weekly recitation activity where students solve assigned problems on the board. This activity received primarily positive with a moderate effectiveness level (mean= 3.17). Lastly, Activity #7 had a relatively more robust perception of effectiveness than

the other activities (mean= 3.47), suggesting that shifting away from traditional exams to alternative assessment forms such as concept maps and portfolios is an effective strategy.

These findings demonstrate that the respondents' perceptions of effectiveness varied across activities. While some areas were perceived as moderately effective, others were rated slightly higher, suggesting a relatively more robust significance level. These insights can provide valuable information for further analysis and decision-making on improving and addressing specific areas to enhance effectiveness in different domains. Overall, it seems that the proposed activities can potentially address some of the identified student needs. However, further exploring and refining these activities may be beneficial based on the survey data and feedback from students and faculty.

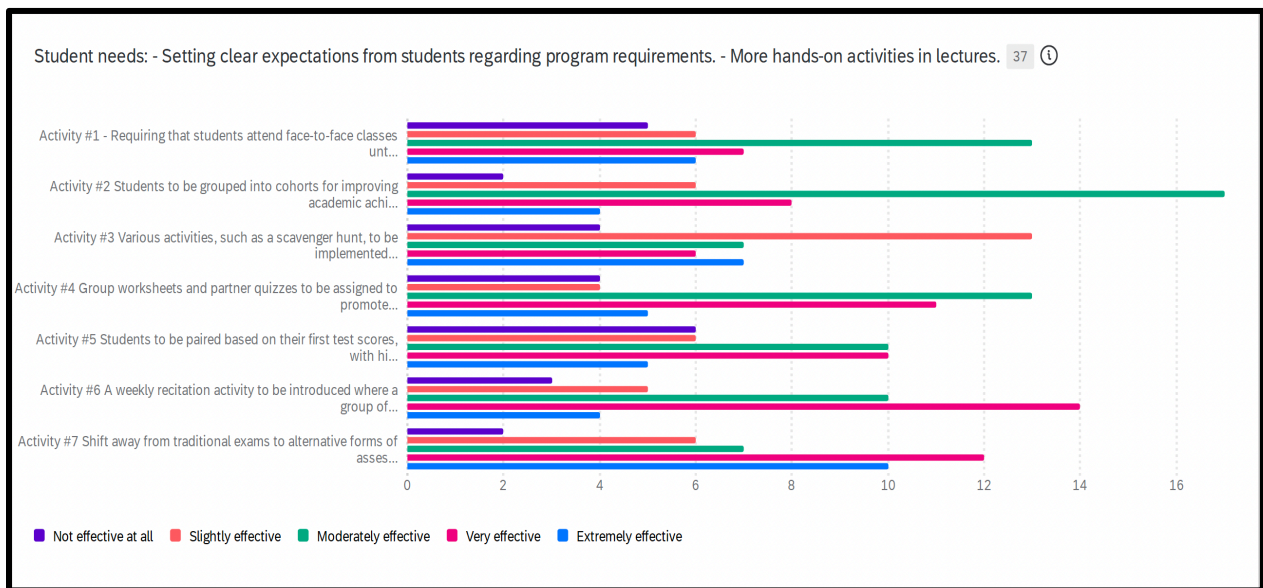


Figure 37: Survey responses on strategies suggested in ToC pamphlet-4

Feedback survey responses for ToC pamphlet 5 (Figure 38) show that the student needs for fast-track admission and financial aid processes are seen as a priority. Activity #1, which involves conducting research and gathering data on the financial challenges faced by PENG in accessing higher education, is rated slightly to moderately effective by many students (mean 3.6). It suggests that, on average, the respondents perceive the subject or aspect in this area to be

moderately effective. The ratings provided by the participants varied, with "Slightly effective" and "Very effective" being the most common ratings. Overall, it appears that students feel that improvements in the admission and financial aid processes would benefit their success in the program.

Activity #2, which involves analyzing the existing financial aid policies and identifying areas for improvement, is rated very effective by many students (mean =4.2). It indicates that, on average, the participants perceive the subject or aspect in this area to be highly effective. The ratings provided predominantly fell in the categories of "Moderately effective," "Very effective," and "Extremely effective."

Activity #3, which involves analyzing the existing admission and financial aid processes and identifying areas that can be fast-tracked or streamlined without compromising quality, is also rated moderately to highly effective by many students (mean=4.0). The participants' ratings primarily ranged from "Moderately effective" to "Extremely effective," suggesting a positive perception of the subject or aspect being evaluated.

It is important to note that without additional context or specific criteria for effectiveness, these mean ratings provide a general overview of the participants' perceptions. They serve as a starting point for understanding the average effectiveness ratings in each respective activity, reflecting the participants' overall sentiment toward the strategies or aspects under evaluation. Again, it is worth noting that the sample size and representativeness of the survey data are unknown, and further analysis and interpretation may be necessary to draw more robust conclusions.

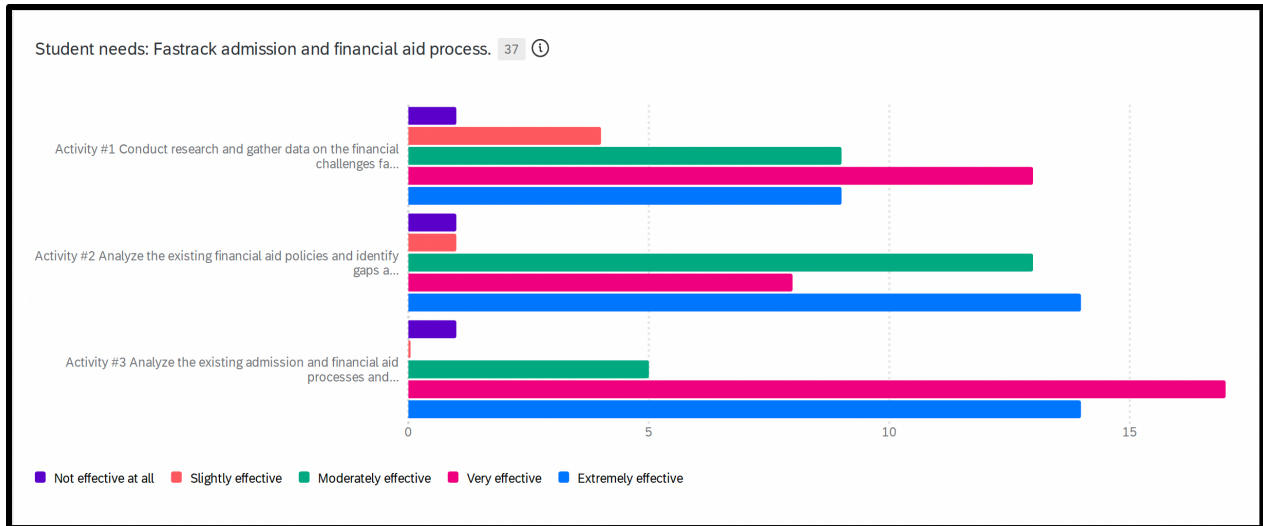


Figure 38: Survey responses on strategies suggested in ToC pamphlet-5

The open-ended question in the evaluation survey provided valuable insights into the additional feedback and needs of students within the Pre-Engineering program at UM-Dearborn. The findings highlight several key areas that require attention and improvement to enhance the student experience.

Firstly, students expressed the need for more programming practice, indicating a desire for increased hands-on experiences and exercises to develop their programming skills. This finding emphasizes the importance of providing practical opportunities for students to apply and reinforce their knowledge in programming. Secondly, students emphasized the importance of enhanced support and resources. They specifically requested more contact with former graduates, additional tutoring sessions, and access to resources and support networks. Students identified the value of peer mentors, tutors, and alumni connections in providing personalized guidance and bridging the gap between theoretical knowledge and practical application.

Additionally, the findings highlighted the need for considerations to accommodate working-class students. Specifically, students suggested including evening classes, particularly for ENGR 100 LAB. This finding highlights the importance of flexible scheduling options to

ensure equal access for all students. Moreover, students expressed the need for support in integrating and adapting to the UM-Dearborn environment, particularly for existing and transfer students. They requested initiatives and resources to help these students feel connected and involved within the program. This finding emphasizes the significance of providing targeted support and orientation programs tailored to existing and transfer students' unique needs. Clear communication and program organization were also identified as areas for improvement. Students emphasized the importance of transparent communication regarding the program's structure and expectations. This finding underscores the need for clear and effective communication strategies to enhance student engagement and success.

Furthermore, fostering collaborative learning emerged as a valuable aspect highlighted by students. They emphasized the importance of teamwork and collaborative problem-solving opportunities. This finding suggests the significance of creating a supportive and collaborative learning environment that encourages student interaction and knowledge sharing. Lastly, students appreciated receiving pre-information about campus life and culture. They recognized the importance of understanding the involvement and opportunities within the Pre-Engineering program and the broader university community. This finding emphasizes the need for providing comprehensive information and resources to help students integrate into the university's social and cultural environment.

The findings from the open-ended question shed light on various areas of improvement within the Pre-Engineering program. Addressing these needs and feedback will contribute to a more comprehensive and supportive learning environment, better student engagement, and overall program enhancement at UM-Dearborn. Overall, the feedback survey conducted for the PENG program plays a pivotal role in redesigning and improving PENG Program, as it allows

for aligning proposed changes with the needs and expectations of the students. The insights gained from the survey results can be used to refine and enhance the proposed changes, ensuring their feasibility and effectiveness in addressing the concerns of the student community.

In conclusion, the findings section highlights the challenges faced by PENG students and explores various strategies suggested by faculty members and advisors to improve student's experience in the program. These strategies encompass a wide range of areas, such as bolstering resources and support systems and fostering increased engagement and collaboration opportunities. By considering and implementing these strategies, the PENG program can strive to provide an enriched and fulfilling educational journey for its students.

Chapter 6: Discussion

This study aims to utilize the Human-Centered Design (HCD) approach and Theory of Change (ToC) Framework to analyze student needs and challenges within the PENG program at UM-Dearborn. Gall et al. (2021) define HCD as an inclusive approach that places individuals at the core, involving them in co-creation and considering the impacts on present and future societies. The current study emphasizes placing students at the core of the program redesign process. It advocates for users' active involvement and participation, including PENG students, faculty members, and advisors, throughout every stage of decision-making and design processes.

IDEO's HCD process for problem-solving encompasses three key phases: inspiration, ideation, and implementation (IDEO.org, 2015). The current study adopts a similar approach to enhance student access and achievement within the PENG program. The initial phase involved examining students' needs, expectations, and pain points in the PENG program. Maguire (2001) outlines various techniques employed during this stage, such as conducting a survey of existing users, conducting user requirements interviews, organizing focus groups, creating user scenarios, developing personas, and analyzing the existing system. This study employed a comprehensive methodology, using surveys, interviews, and personas, to gather extensive data to gain a profound understanding of the challenges encountered by PENG students at the University of Michigan Dearborn. Notably, the scope of the study extended beyond PENG students, as faculty members and advisors were actively engaged through interviews and co-design sessions, allowing for a comprehensive exploration of their perspectives on the experiences and challenges

faced by PENG students. This data is utilized to formulate effective strategies to enhance the (students') user experience in the PENG program. Maguire (2001) also discusses several methods that can be employed for effective design, including brainstorming, storyboarding, parallel design, affinity diagrams, and card sorting. In this study, a co-design session was conducted, which involved activities such as card sorting and brainstorming using the ToC framework. Evaluations also play a crucial role in the user-centered design process, representing the final phase, where a select group of representative users provides feedback on the final version of the design (Abrams et al., 2004). According to Kahraman (2010), this phase involves designers using opinion questionnaires or interviews to gather qualitative data on user satisfaction. In this study, a student evaluation feedback survey was conducted to determine whether the proposed strategies met the needs and expectations of students in the PENG program. The study findings indicated that involving students at every stage of the redesign process led to the development of practical strategies and solutions to address student pain points and challenges.

First-year students in the professional realm often need support during their transition to higher education (Morosanu et al., 2010). This transition brings academic and socio-cultural challenges, requiring adaptation to new environments where institutional support plays a vital role by providing academic advice and guidance (Clark, 2005; Inkelas et al., 2007). In educational research, student learning and support have been examined from different perspectives. This dissertation explores the students' pain points/challenges in the Pre-Engineering program, specifically focusing on enhancing their overall experience.

The first research question, "How do Pre-Engineering students describe their program experiences at the University of Michigan Dearborn?" was formulated to delve into the first-hand experiences and perceptions of Pre-Engineering (PENG) students at UM-Dearborn. By

addressing this question, the study aimed to gain comprehensive insights into the various aspects of the PENG program experienced and articulated by the students. Furthermore, the second research question, "How can we redesign the Pre-Engineering program to support students better?" sought to explore potential strategies, challenges, and outcomes related to redesigning the Pre-Engineering program. By examining this question, the study aimed to identify opportunities for enhancing the program's support mechanisms and overall effectiveness in meeting the needs of PENG students.

Despite the multifaceted challenges faced by students in the PENG program at UM-Dearborn, a comprehensive analysis has revealed the emergence of 19 distinct needs that encapsulate the significant goals and requirements of PENG students as identified in this study. From these 19 needs, particular emphasis was placed on addressing the top five priority-based needs during this investigation. The following represents the top five emerging challenges/needs that were specifically targeted and addressed in this study: (a) enhancing the orientation experience and providing more student engagement opportunities, (b) fast-tracking admission and financial aid processes, (c) incorporating hands-on activities in lectures, (d) improving advising support and clarity in program requirements, offering class schedule time flexibility, enhancing registration instructions and course selection assistance, (e) improving connection to campus resources, supporting career exploration, and facilitating information sharing on different programs, classes, and student organizations.

The first need, enhancing the orientation experience and providing increased opportunities for student engagement, aligns with existing literature highlighting its significance in facilitating positive transitions for students entering college and university environments. Previous research has established that effective orientation programs contribute to various

positive outcomes, such as reducing attrition rates, improving academic performance, aiding personal adjustment, enhancing emotional and social development, fostering positive attitudes toward the institution, and increasing students' awareness during the transition. (Hollins, 2009; Gass et al., 2003; Evans et al., 1998; Galloway, 2000; Tinto, 1993; Upcraft & Gardiner, 1993). According to Mullendore and Banahan (2005), orientation programs provide students with crucial information about academic requirements, available courses, and registration procedures. Failing to achieve these outcomes can have financial and personal consequences, particularly in attrition and retention.

Prior studies have examined orientation programs for first-year students. Collins and Dodsworth (2011) investigated the University of Waterloo's efforts to expand outreach during orientation week with the campus-wide "Jumpstart Friday" program, while Soria et al. (2012) found that extended orientations at a public research university improve academic performance and retention into the second year by promoting institutional social identity and a sense of belonging. Despite the prevalence of orientation programs in colleges, empirical studies on their impact are limited (Mayhew et al., 2011). Deggs and Associates (2011) highlight the need to avoid a generic approach (one-size-fits-all approach) when developing orientation programs. Orientation programs have significant potential to bring about both short-term and long-term changes, as college students generally exhibit high receptivity during this transitional period (Gass & Sugerman, 2003).

The current study addresses the gap by focusing on first-year students' narratives and participation to improve the program, aiming to enhance awareness, engagement, and utilization of resources. Participants suggested incorporating more individualized support during orientation to ensure students are on the correct academic trajectory, i.e., creating a dedicated track or day

within the orientation program for PENG students acknowledges their unique needs and provides targeted information and support. By providing personalized attention and guidance, the university can help students make informed decisions about their academic goals, leading to a smoother transition into the program and increased student satisfaction. Additionally, the findings highlighted the importance of consistent and transparent communication between faculty and students. For instance, enhancing student-faculty interaction and introducing "coffee hours" held outside faculty offices on campus creates an informal setting for students to engage with faculty members. This initiative encourages open communication, fosters relationships, and allows students to seek guidance and support outside formal academic settings. Participants expressed the need for more transparent communication channels to convey information to students effectively. It emphasizes the importance of establishing effective communication strategies to keep students informed and engaged in their academic journey.

The second need is to Fastrack and improve the admission and financial aid process, which confirms past research. Perna (2015) emphasizes the importance of addressing systemic inequalities in the pathways to higher education to achieve equitable college access and completion. It entails recognizing the financial barriers that disproportionately impact low-income students, including visible and hidden costs such as admission test fees and application expenses. Advisory Committee on Student Financial Assistance (2008) has consistently indicated that the complexity of the Free Application for Federal Student Aid (FAFSA) and insufficient information are the main factors deterring students from initiating the financial aid process. Davidson (2013) suggests that financial aid administrators can educate and engage staff and faculty members to improve communication and the FAFSA completion rates. Efforts should be made to simplify, communicate, and raise awareness about financial aid opportunities

by integrating existing structures and procedures. States and institutions can improve communication by informing students of their eligibility and potential awards without requiring an application (Davidson, 2014). Financial aid administrators should employ various communication channels and prioritize personal assistance to support community college and low-income students throughout the financial aid process (Bettinger et al., 2011). Kentucky Educational Excellence Scholarship (KEES) determines awards based on high school performance (AP/IB scores, ACT, SAT) and notifies students of accrued aid each year (Kentucky Higher Education Assistance Authority, 2013; Davidson, 2014).

The current study highlights the importance of streamlining the admission and financial aid process, particularly for PENG students. Findings suggest that by analyzing the financial aid challenges faced by PENG students, evaluating current policies, and formulating policy recommendations, it is feasible to minimize the time and effort involved in applying for and obtaining financial aid.

The third need focuses on "setting clear expectations for PENG students regarding program requirements and incorporating more hands-on activities in lectures to improve academic achievement and engagement." Numerous students discontinue their studies in a particular field because their career expectations do not align with the actual reality of those career paths (Thistlethwaite, 1960; Pervin, 1966). Students' expectations play a crucial role in shaping their ability to adapt during the initial stages of their university education, which subsequently impacts their overall progress. Hirst et al. (2004) suggest that it is essential for lecturers to recognize these factors and incorporate them into the design of the learning experience for students. Moreover, the presence of a more diverse student body, a rise in student fees, and a decrease in the amount of personal interaction between academic staff and students

have resulted in students rating the feedback they receive as subpar compared to other aspects of their education (Holmes & Papageorgiou, 2009). Students' expectations upon entering university and a lack of preparedness contribute to higher dropout rates and prolonged completion times. Money et al. (2016) suggest that understanding students' perceptions, expectations, and experiences is crucial in developing supportive academic programs that aid their transition and university journey. Phillip (2002) discusses an example of creating and sharing rubrics with students or involving them in the process to set clear expectations for them. It allows students to actively participate in their learning and assessment by creating, sharing, and fulfilling the set criteria.

Moreover, the results of this study suggest the importance of integrating hands-on activities into the PENG program. Hands-on learning activities enhance students' readiness for technology-focused jobs and equip engineering graduates to excel in a competitive market (Pusca et al., 2017). Malik and Zhu (2023) describe the development and refinement of the Introduction to Computer Networks course at Midwest University, integrating theory and hands-on activities. It used the Internet to teach theoretical and practical aspects of computer networking, meeting ABET and industry requirements. Catena and Carbonneau (2019) examined the impact of hands-on activities in lectures and suggested that hands-on activities facilitate better student performance while incorporating cognitive learning and enhancement.

The current study provides qualitative insights into students' expectations from college, their first-year experiences, and their need for more hands-on learning activities in the PENG program. The findings also emphasize enhancing student engagement within the PENG program. Participants expressed a strong desire for more opportunities for engagement, including hands-on activities, lab visits, and workshops/seminars. It indicates the importance of providing various

interactive and practical experiences to foster student learning, motivation, and interest in the field. By incorporating these engagement opportunities, the university can improve the learning experience and promote student success and satisfaction. Other in-class activities include grouping students into cohorts, promoting academic achievement and engagement, fostering collaboration and a sense of belonging, implementing scavenger hunts, encouraging students to explore the campus and its resources, and promoting engagement and familiarity with available support services. Thus, promoting inclusivity, reasoning, and group discussions in the learning environment enhances critical thinking and problem-solving skills. It includes assigning group worksheets, partner quizzes, and weekly recitation activities that foster collaborative learning, encourage interaction, and strengthen understanding of engineering concepts. Lastly, participants suggested shifting away from traditional exams to alternative forms of assessment, such as concept maps and portfolios, which allows for a more comprehensive evaluation of students' knowledge and skills. For example, Erstad (2008) emphasizes the significance of IT in enhancing standardized testing through adaptable approaches that cater to various requirements and encourage the development of intricate cognitive abilities. It facilitates the implementation of innovative assessment techniques, including multimodal representations, digital portfolios, and simulations.

The fourth need discussed in this work is focused on providing better advising support, including course selection help, clear direction to stay on track, clear registration instructions, and class schedule time flexibility for Pre-Engineering (PENG) students. To enhance student success, colleges and universities have enhanced academic support services. Habley (2004) addresses that the academic advising process presents a formal opportunity for institutions to facilitate meaningful exchanges between students and the academic environment, promoting

quality interactions. For instance, establishing dedicated teams of expert advisors who cater to distinct student population needs (Kot, 2014). Tinto's model was one of the first to link institutional features to student attrition and highlight the significance of the institution-student relationship for academic achievement. The model outlined five critical conditions: expectation, advice, support, involvement, and learning in an educational setting (Tinto, 1975; Tinto, 2007).

The recurring theme of the need for increased student advising and support services highlights the importance of providing comprehensive assistance to students throughout their academic journey. In the current study, participants (PENG students) desired a more personalized early warning system, more significant support from advising services, improved coordination between counselors and faculty members, and an enhanced START advising experience. These findings emphasize the crucial role of effective advising in helping students navigate challenges, make informed decisions, and receive the necessary support to succeed in their program. By addressing these concerns, the University can enhance student satisfaction and retention.

Furthermore, the findings of this dissertation align with a study conducted by Jones et al. (2013), which also examined the issue of academic advising in a similar educational context. Jones et al. evaluated academic advising based on student needs, expectations, and success rather than relying on satisfaction alone. Six factors related to student success include advisor accountability, advisor empowerment, student responsibility, self-efficacy, study skills, and perceived support. These findings resonate with the current research, further underscoring the significance of improving academic advising within the PENG college context. By incorporating the insights from both studies, it becomes evident that students consistently demand enhanced advising practices that cater to their unique requirements. Kuh (2001) highlights that the

development of students is shaped by various institutional initiatives beyond their academic interactions with faculty. Hence, this study adopts a human-centered design approach, with students at the core, to explore additional educational components. The aim is to establish a strong connection between students' overall academic experience and inform institutional strategies that foster supportive environments conducive to student development.

One of the strategies suggested in this work is implementing a structured peer mentoring program by bringing in successful PENG alumni to share their experiences and insights. Furthermore, encouraging senior students to document their challenges and successes through recorded testimonials or stories and offering valuable insights to incoming PENG students creates a sense of community. This endeavor will catalyze inspiring and motivating current PENG students to succeed. These findings comport with work by Magolda (2001), who explained that peer influence had been recognized as a potent factor shaping students' behavior. Understanding the importance of peer networks in aiding incoming students during their college transition is crucial, as they offer support and lay the foundation for lifelong friendships (Gass et al., 2003).

This need also emphasizes the importance of accommodating class schedule flexibility for PENG students, particularly considering their work schedules. Students expressed the need for greater flexibility, including the availability of evening classes. Jacoby and Garland (2004) also emphasize the significance of commuting for college students and the need for extended campus office hours and evening classes to support commuter students' success. Students require flexible class participation options to manage their busy lives effectively (Beatty, 2014). This discovery is consistent with the research conducted by Daymont et al. (2011), which investigated the influence of learning advantages, flexibility, and compensatory adaptation. The study

revealed that certain students might encounter difficulties engaging in traditional classroom courses due to work commitments, travel schedules, or residing at a considerable distance from the campus.

The current research makes a significant contribution to addressing the gap in knowledge regarding pre-engineering programs specifically at commuter campuses. This involves examining the need to enhance academic advising within the PENG college environment while considering students' perspectives through their narratives. The outcomes can be utilized to enhance academic advising and support services delivery in the PENG program.

Finally, need five dealt with providing a better connection to campus resources, additional support for career exploration, and better information sharing on different programs, classes, and student organizations. According to Greenwald et al. (1996), school resources substantially impact student achievement, emphasizing their educational significance. Ibukun et al. (2011) found a significant association between resource utilization and students' perceived learning outcomes. These findings underscore the importance of maximizing resource utilization in educational settings to enhance students' learning outcomes and overall educational experiences.

In the current study, resource availability and utilization were identified as another challenge faced by PENG students. Disparities in access to learning tools and resources were a significant issue raised during the interviews. Some students lacked basic supplies such as pens and pencils, while others had access to more advanced tools like iPads. This disparity in resource availability can impact students' ability to engage in their coursework fully and may contribute to inequities in learning outcomes. Participants also stressed the significance of providing students

with resources such as tutoring services, study materials, and academic workshops to enhance their learning experience.

Furthermore, the findings strongly suggest mandatory resource checkout for students, emphasizing the importance of utilizing available resources. Participants recommended making it mandatory, especially for new students, to access resources such as the Math Learning Center. By enforcing the use of these resources, students can benefit from the academic support and additional guidance they provide. This highlights the significance of promoting resource availability and ensuring students are aware of the support services available to them. Another important aspect discussed in the findings is documenting program information and setting clear student expectations. Participants suggested creating an application that provides comprehensive information about clubs, organizations, and general program details. This indicates the importance of transparent and accessible information to help students make informed choices and actively engage in their program. By addressing these needs, the University can empower students with the necessary knowledge to navigate their academic path successfully.

One primary form of resource for first-year students is the support for career exploration, specifically for first-year students as they navigate the challenges of choosing a career path and establishing a career identity (Kleine et al., 2021). There is a critical need for comprehensive information sharing regarding the available engineering pathways specifically for students in the pre-engineering stage who are exploring their options and deciding on the specific engineering discipline they wish to pursue. For instance, Main et al. (2022) found that student demographic factors and academic achievement measures, such as AP scores and GPA, are associated with choosing an engineering major. Other studies suggest that social influences, STEM involvement, career considerations, and peer and university personnel significantly impact students' major

choices during early college years (Godwin et al., 2016; Cruz & Kellam, 2018; Matusovich et al., 2010; Tan et al., 2021). Insufficient information or misconceptions about various engineering disciplines can lead students to make poor major choices, resulting in frustration and potential abandonment of the field (Ngambeki et al., 2008). Thus, information and availability of adequate information sharing can be pivotal in empowering pre-engineering students to make well-informed decisions about their academic and career paths.

Institutions face the ongoing challenge of maximizing their resources and services' effectiveness to improve student outcomes (Robbins, 2009). First-year college programs aim to help students make informed decisions by introducing them to various engineering disciplines (Ngambeki et al., 2008). To address this challenge, there is a need to critically evaluate and identify the resources and services that have a positive association with enhancing student outcomes. The current work provides a comprehensive approach to this evaluation assessing various aspects of resources and services provided to students to make informed career choices.

This dissertation study provides insights into students' learning experiences, attitudes, and challenges in the PENG program. It utilizes a concurrent mixed methods design to examine the factors contributing to a successful PENG program at UM-Dearborn. The three-phased approach provided a comprehensive understanding of the program and aimed to understand and improve the PENG program's effectiveness to enhance student experiences and success. The study aims to make recommendations for a successful PENG program that gives students more opportunities to follow academic and professional paths. The findings suggest that a successful PENG program should include adequate academic advising, support for balancing work and academic commitments, and opportunities for collaboration, including workshops, seminars, and hands-on activities. Additionally, the study highlights the importance of frequent engagement with

students during PENG college admission and its effect on their college access and success perception. These findings have implications for improving PENG programs at the University and beyond.

Moreover, the study's focus on enhancing student experiences and success through the PENG program at UM-Dearborn has the potential to inform strategic planning and goal-setting processes in other institutions/universities. The study's insights can also be used to develop strategic recruiting models to address the barriers that limit student learning and engagement. This study contributes to the ongoing conversation about improving PENG programs' effectiveness and providing academic and professional success opportunities. The ToC framework and mixed methods approach offers a unique and comprehensive understanding of the PENG program at UM-Dearborn. This study provides insights that can guide future research and program improvements by identifying factors associated with PENG program success and offering potential solutions.

This work has centered on the question, how do Pre-Engineering students at the University of Michigan Dearborn describe their program experiences, and how can we redesign the program to support them better? While the findings of this research can offer valuable insights for policymakers regarding the benefits of implementing a human-centered design approach, it is essential to acknowledge that UM-Dearborn is a commuter campus, and the findings of this study may vary for other types of institutions. Commuter campuses are educational institutions where most students are nonresidential, meaning they do not live on campus (Clark, 2006). The distinctive characteristics of commuter campuses result in significant variations in students' needs and preferences. These campuses cater to diverse student populations with differing schedules, responsibilities, and lifestyles. Clark (2006) identified three

primary challenges urban commuter college students face: limited campus interactions and peer networks, silent acceptance of inappropriate college challenges due to uninformed beliefs, and difficulties in maintaining classroom-based friendships due to changing schedules. It is imperative for educational institutions to acknowledge and understand the variations in needs among students from different commuter campuses. This recognition enables institutions to deliver customized support, resources, and services that effectively address their respective student population's distinct challenges and aspirations.

The application of the HCD methodology offers opportunities to address additional research inquiries. While the specific findings may not be generalizable, the methodology employed in this study can be applied in different contexts. It can undoubtedly aid in understanding and improving program outcomes based on the user needs in any educational program. For instance, future studies could include comparative analyses among various institutions, examining the perspectives of undergraduate and postgraduate students and faculty members from diverse departments involved in instructing first-year students. Such investigations can help identify areas for improvement, enhancing the effectiveness of orientations, seminars, resource allocation, and meeting students' specific needs. Viewing this work as a foundational step in assessing students' requirements, challenges, and program outcomes is essential. Combining this approach with a broader policy analysis supported by quantitative data can generate more robust and concrete results.

Similar studies can be conducted to analyze further the impact of academic resources such as libraries, research facilities, and technological infrastructure on student success using the same approach. Institutions can examine the influence of support services like tutoring programs, counseling, and career guidance in facilitating positive student outcomes. This information can

guide them in allocating their resources effectively, prioritizing investments, and implementing targeted interventions to maximize student benefits. This research sets an example of fostering a culture of continuous improvement, which involves gathering feedback from students, faculty, and staff to gain insights into the effectiveness of existing resources and services and identify improvement areas.

In conclusion, this study's contribution to the literature provides insights into the effectiveness of the PENG program at UM-Dearborn, identifying areas for improvement and addressing student pain points/challenges. By combining quantitative and qualitative data, the study provides a comprehensive understanding of the program's challenges and opportunities to enhance student experiences and success. The study's findings have important implications for improving college access and success for students from historically marginalized communities and informing strategic planning and goal-setting processes in other institutions/universities.

Chapter 7: Conclusion

Several colleges in the United States have implemented and supported the college-level PENG program. Much research has not been done to determine how effective these programs are or what elements are responsible for their effectiveness. This work attempts to expand the current state of knowledge on successful PENG programs. This study discusses student experiences in the PENG program and identifies the elements expected to improve their experiences.

This work has shed light on the importance of PENG programs in higher education and the need for further research to identify the key elements contributing to their success. The study conducted at UM-Dearborn has provided valuable insights into the experiences of PENG students, highlighting the obstacles they face and the improvements that could be made to support them better.

One of the key findings of this study is the importance of a comprehensive approach to supporting PENG students attending commuter colleges. This approach includes academic support services, assistance in registration, financial aid, individualized early warning systems, and other forms of support that can help students overcome their challenges.

In addition, the study has identified several areas where improvements can be made to the PENG program. These include orientation, advising, peer mentoring, and hands-on activities, which can help students feel more engaged and connected to the program. The study also suggests using data more effectively to better track, identify, and support students.

Overall, this work has important implications for PENG students' success. By implementing the recommendations discussed in this dissertation, educational institutions can better support PENG students and improve their overall academic experiences. Future research can build on these findings to explore the effectiveness of these interventions and assess their impact on student outcomes.

Additionally, the study highlights the importance of listening to the voices of PENG students in developing and improving PENG programs. By engaging with PENG students and seeking their input and feedback, educators can better understand their experiences and identify areas for improvement. This can help create a more inclusive and supportive environment for PENG students, ultimately leading to better outcomes for these students.

Moreover, the study emphasizes the need for data-driven approaches to PENG education. Educators can identify patterns and trends by collecting and analyzing data on PENG students' experiences and outcomes and develop targeted interventions to improve student success. This approach can help ensure that PENG programs effectively support all students, regardless of their background or circumstances.

The study underscores the importance of collaboration and partnership in PENG education. By working together, educators, administrators, industry leaders, and policymakers can create a more supportive and inclusive environment for PENG students and develop programs and initiatives that meet the needs of diverse students. In summary, the study presented in this dissertation provides a valuable contribution to PENG education. The findings suggest that PENG programs can be more effective when they comprehensively support students and provide more opportunities for engagement and hands-on learning. By improving PENG programs in these ways, we can help ensure that all students, regardless of background or

circumstance, have access to the education and opportunities they need to succeed in engineering. These exploratory findings yield new insights into understanding PENG students' experiences at UM-Dearborn. This includes redesigning the PENG program to support students better and use data more effectively to track, identify, and support students.

Furthermore, the findings of this study have practical implications for both PENG educators and policymakers in higher education. For educators, the study highlights the importance of fostering a supportive and inclusive environment for PENG students and provides recommendations for improving the PENG program. For policymakers, the study demonstrates the importance of investing in programs and initiatives that support PENG students.

In addition, the study contributes to the growing body of literature on diversity and inclusivity in engineering education. The findings suggest that the experiences of PENG students are shaped by a complex interplay of factors, including academic preparedness, social support, and institutional culture. As such, interventions designed to support PENG students must take a comprehensive approach that addresses all of these factors.

Finally, the study points to the need for further research. While the findings of this study are informative, they are limited to the experiences of PENG students at UM-Dearborn. Future research should aim to replicate and extend these findings in other settings to develop a more comprehensive understanding of the factors contributing to PENG programs' success.

In conclusion, this dissertation provides essential insights into the experiences of PENG students and the factors that contribute to the success of PENG programs. The findings suggest that a comprehensive approach to supporting PENG students is necessary and that improvements can be made to PENG programs in several areas. It provides a roadmap for educators and policymakers seeking to improve PENG programs and increase diversity and inclusivity in

engineering. The study's findings and recommendations have important implications for the success of PENG students and the future of the engineering profession. Further research is needed to build on these insights and improve PENG programs.

Chapter 8: Future Work

This study offers valuable insights into the experiences of PENG students and the factors that contribute to the success of PENG programs. However, several areas for future research can build upon the findings presented in this dissertation.

Firstly, future research can examine the effectiveness of specific interventions to improve PENG programs at commuter colleges. The recommendations presented in this study offer a starting point for program improvement, but further research is needed to determine the efficacy of these interventions and identify additional strategies for supporting PENG students.

Secondly, future research can explore the experiences of PENG students from a broader range of institutions and geographic regions. It can help confirm and extend the study's findings and provide a more comprehensive understanding of the factors contributing to the success of PENG programs across different contexts.

Thirdly, future research can investigate the impact of PENG programs on the long-term career outcomes of students. It can help determine whether PENG programs effectively promote diversity and inclusivity in the engineering profession and identify areas for improvement in this regard.

Lastly, future research can examine the intersectionality of barriers faced by underrepresented PENG students and the effectiveness of interventions designed to address these barriers. While this study did not focus specifically on underrepresented students, future research can explore the experiences of underrepresented PENG students and the obstacles they face and

identify effective strategies for supporting their success. It can include investigating the impact of financial constraints, lack of social support, and systemic racism and discrimination on PENG student success and developing comprehensive interventions to address these barriers in an integrated way. By taking a holistic approach to supporting PENG students, future research can ensure that all students have access to the education and opportunities they need to succeed in engineering.

In conclusion, this dissertation provides a foundation for future research into PENG education. Building on the findings presented in this study, future research can continue to identify strategies for improving PENG programs and ensuring that all students, regardless of their background or circumstances, have the opportunity to succeed in the field of engineering.

Appendices

Appendix A: Survey Information Shared with PENG Students.

You are invited to participate in the research study titled “Using Human-Centered Design and Data analytics to improve student access and success in an undergraduate Pre-Engineering program.” This study aims to better understand students’ attitudes and perceptions toward the Pre-Engineering program at UM-Dearborn. This includes focusing on their learning experiences and struggles with the support provided in a Pre-Engineering program, specifically from an advising standpoint.

Should you agree to participate in this portion of the study, you will be asked to answer written and multiple-choice questions totaling 10 to 15 minutes of your time. You are not eligible to participate in this survey if you are/were not a Pre-Engineering student at UM-Dearborn.

Potential Benefits of our Research: Your survey responses will allow the researcher to determine how effective the Pre-Engineering program at UM-Dearborn is or what elements are responsible for its effectiveness. Doing so yields data about the strength of factors suggested by the students that may contribute to the success of the Pre-Engineering program.

Risks of Participation: No significant risks are expected to result from your participation in this survey.

Compensation: At the end of the survey, a raffle will be held to award five participants with a \$50 gift card.

Your involvement in any portion of this research is entirely voluntary. You may change your mind about your participation at any point in time. Additionally, you may choose not to answer one or more of the survey questions for any reason.

The information collected from this survey will be for research purposes only. Your identity is not required, and any confidential information obtained will not be revealed. Data collected in this project may be shared with other researchers. The results of this study could be published in a journal/conference or presentation.

If you have any questions or concerns about this research study, please contact Aishwary Pawar (pawara@umich.edu)

Appendix B: Students Survey Questions

1. What was your age at the time of Pre-Engineering admission (i.e., admission to UM-Dearborn)?
 - 19 or younger
 - 20-23
 - 24-29
 - 30-39
 - 40-55
 - Over 55

2. Which race/ethnicity best describes you? (Please choose one)
 - American Indian or Alaskan native
 - Asian/Pacific Islander
 - Black or African American
 - Hispanic
 - White/Caucasian
 - Other (Please Specify) _____.

3. What is the ZIP code of your primary residence during your engineering program?

4. What is the highest level of education your parents/guardian received?
 - Did not finish high school.
 - Graduated from high school or equivalent (GED).
 - Graduated from high school and attended a two-year school (such as vocational or technical school, a junior college, or a community college), but did not complete a degree.
 - Graduated from a two-year school (such as a vocational or technical school, a junior college, or a community college).
 - Graduated from a high school and went to college, but did not complete a four-year degree.
 - Graduated from college.
 - Completed a master's degree or equivalent.
 - Completed a Ph.D., M.D., or other advanced professional degree.
 - Don't know.

5. What is your current class standing?
 - First year student
 - Sophomore
 - Junior
 - Senior

6. Are you a transfer student?
 - Yes
 - No

7. Please indicate your unweighted High School GPA (*Weighted GPA: usually calculated using a 4.0 Scale where you can exceed a 4.0 GPA for AP course*) or GPA from your previous institution.
 - 2.0 or lower
 - 2.0-2.25
 - 2.26-2.50
 - 2.51-2.75
 - 2.76-3.0
 - 3.01-3.25
 - 3.26-3.5
 - 3.51-3.75
 - 3.76-4.0
 - 4.01 or greater

8. What is your (intended) academic major?
 - College of Art, Sciences and Letter (CASL) Major
 - College of Business (COB) Major
 - College of Education, Health, and Human Services (CEHHS) Major
 - College of Engineering and Computer Science (CECS) Major
 - Other _____

9. What were your first math and chemistry courses you took at UM-Dearborn? (choose all that apply)
 - MATH 080
 - MATH 090
 - MATH 105
 - Calculus I (MATH 115)
 - Calculus II (MATH 116 or equivalent)
 - Chem 134
 - Chem144

10. How would you describe your employment status?
- Employed full-time
 - Employed part-time
 - Freelance/contract employee
 - Self-employed
 - Unemployed
11. What is the name and location of your high school? (Example: Metro high school, Canton, Michigan)
- _____
12. When were you first contacted by UM-Dearborn?
- High School Career Fair
 - Mailer
 - UM-Dearborn Campus visit
 - Other _____
13. In which year did you enrolled at UM-Dearborn?
- 2019
 - 2020
 - 2021
 - 2022
14. What month and year did you complete (intend to complete) the PENG requirements to move to a CECS major?
- MM/DD/YYYY
15. What month and year do you expect to graduate with your undergraduate degree? (Fill in graduation date if already graduated)
- MM/DD/YYYY
16. Which other colleges were you considering before applying at UM-Dearborn?
- _____
17. What other programs were you considering before applying for the Engineering program at UM-Dearborn?
- _____
18. The University did everything they could to make my admission process as easy as possible.
- Strongly disagree
 - Somewhat disagree
 - Neutral
 - Somewhat agree
 - Strongly agree

19. How satisfied are you with the University engagement at the time of admission?
- Extremely dissatisfied
 - Somewhat dissatisfied
 - Neither satisfied nor dissatisfied
 - Somewhat satisfied
 - Extremely satisfied
20. How likely are you to recommend UM-Dearborn to family, friends, or colleagues based on PENG support and offerings?
- Extremely unlikely
 - Somewhat unlikely
 - Neutral
 - Somewhat likely
 - Extremely likely
21. How satisfied were you with your Pre-Engineering experience at UM-Dearborn?
1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10
22. Please rate the orientation for the Pre-Engineering students on the following scale?
1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10
23. How easy is it to register for Pre-Engineering classes at UM-Dearborn?
- Extremely difficult
 - Somewhat difficult
 - Neither easy nor difficult
 - Somewhat easy
 - Extremely easy
24. On a scale of 1 to 10 how confident do you feel about the Pre-Engineering coursework you have completed?
1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10
25. How much support did professors in Pre-Engineering provide while teaching the courses?
- Much more than expected.
 - Somewhat more than expected.
 - As much as expected.
 - Somewhat less than expected.
 - Much less than expected.
26. How helpful is/was your academic advisor?
- Extremely helpful
 - Very helpful
 - Somewhat helpful
 - Not so helpful
 - Not at all helpful

27. How often do you meet/consult with your advisor?
- Almost never
 - Monthly
 - Once or twice per year
 - Weekly or more
 - Every few months
28. How well maintained are the facilities (Labs/classrooms) at this University?
- Extremely well maintained.
 - Very well maintained.
 - Somewhat well maintained.
 - Not so well maintained.
 - Not at all well maintained.
29. What factors, in your opinion, contribute for success in Pre-Engineering?
_____.
30. If you could change one thing about how UM-Dearborn engaged with you at the time of admission, what would it be?
_____.
31. How did the Pre-Engineering experience help you prepare for the engineering program?
_____.
32. Please share any other comments, questions, or concerns you may have about the Pre-Engineering at UM-Dearborn?
_____.
33. Is there anything you would like to see for PENG students in the future. (For example: visits to CECS labs, hands-on activities to highlight Engineering and Computer Science, intros by CECS organizations, better connections to campus resources, etc.)
_____.
34. Would you be interested to participate in a follow-up interview?
- Yes → Provide email id
 - No

Thank you for your participation!

I appreciate your time and participation in this study. If at any point you have questions, concerns, or would like to get involved in future stages of this research, please email me at: pawara@umich.edu

Appendix C: Interview Protocol

DEBRIEFING

(READ ALL OF THE FOLLOWING ALOUD.)

Thank you very much for coming this morning (afternoon). Your time is very much appreciated. The purpose of this interview is to better understand students' attitudes and perceptions towards the Pre-Engineering program at UM-Dearborn. This includes focusing on their learning experiences and struggles with the support provided in a Pre-Engineering program specifically from an advising standpoint.

The interview will include questions about your experience in the Pre-Engineering program at UM-Dearborn. Taking part in this survey and the interview is voluntary. You can withdraw at any point during the study.

We are interested in your opinions and your reactions. In no way is this interview designed to individually evaluate a person's abilities. The task is not diagnostic, nor can it provide a measure of the "quality" of your performance. The results of this research will provide useful information to engineering educators, in helping them to structure educational programs that students consider to be most effective and ideal in helping them through college.

Your identities will be kept anonymous during all phases of this study including any experimental writings, published or not. Procedures for maintaining confidentiality are as follows: (1) Personas will be used instead of real identities; and (2) Identifiers such as email, specific birth data, address, etc. will not be used/shared in the final findings/report. For instance, email addresses will be used to only contact participants (In case, more information is needed).

TAPE RECORDER INSTRUCTIONS

If it is okay with you, I will tape-record our conversation. The purpose of this is so that I can get all the details but at the same time be able to carry on an attentive conversation with you. I assure you that all your comments will remain confidential. I will be compiling a report which will contain all participants' comments without any reference to individuals.

Appendix D: Student Interview Questions

1. Tell me about yourself.
2. What brought you into Engineering program?
3. What is the most important thing you look for in a Pre-Engineering support/offering?
4. Walk me through your Pre-Engineering admission procedure.
5. Tell me about your interactions with program coordinators/counselors/advisors during the admissions process?
 - Follow up Question: Tell me about a challenge or conflict you've faced at the time of admission, and how you dealt with it.
6. What change might lead to better and/or efficient communication at the time of admissions?
7. Tell me about the drawbacks or shortcomings in the current admissions process for the Pre-Engineering at UM-Dearborn?
8. What did you think about your orientation program?
 - Follow up Question: Which part of the orientation was most helpful?
9. What kind of academic and nonacademic support is/was provided to you during Pre-Engineering? For instance, academic support can include career guidance, coursework selection help etc. and nonacademic support may include food resource etc.
10. How effective are the Instructional materials and teaching methods in the Pre-Engineering at UM-Dearborn?
11. Walk me through the most helpful experience, best experience, and worst experience in Pre-Engineering?
12. What are some things you like about Pre-Engineering at UM-Dearborn and what do you dislike?
13. If you could redesign the program. What changes would like to see for PENG students in the future.
14. Please feel free to make any comments regarding the Pre-Engineering support and experience at UM-Dearborn.
15. Would you be interested in participating in a Co-design session with academic advisors, professors and other Pre-Engineering students aimed to improve the Pre-Engineering experience and support?
16. Is there anything else I should know?

Appendix E: Faculty/Advisor Interview Questions

1. Tell me about yourself.
 - Follow up: What is your job role? What subjects do you teach? Are your classes in-person, recorded or virtual?
2. What are some things you like about Pre-Engineering at UM-Dearborn and what do you dislike?
3. What factors, in your opinion, contribute to a successful Pre-Engineering program?
4. What is the greatest challenge you face with Pre-Engineering students?
5. What techniques do universities use to support students from different backgrounds (Race/gender/socioeconomic status)?
6. How do you use technology in the classroom?
7. Do you use any hands-on learning activities for students in the classroom?
8. What is your preferred mode of communication with students? (emails/text/canvas) Do students face any issues with it?
9. Do you think students are different than they were before COVID-19? What changes have you observed, and how have you dealt with them in your classroom?
10. Do you feel the need for any resources you need specifically to deal with pre-engineering students?
11. How could the Pre-Engineering student experience at this university be improved?
12. Do you have any final thoughts or questions for me?
13. Would you be interested in participating in a Co-design session with other advisors, professors and some Pre-Engineering students aimed to improve the Pre-Engineering experience?

Appendix F: Student Survey and Interview Codes

	CODE	DESCRIPTION	SOME EXCERPTS
1	IMP-PERSONAL-WARNING	Implementing better personalized early warning system.	“And if anybody is struggling at that point, a better early warning system is needed. So, I will say that I had at periods of time gone through early warning. But it doesn't really do anything. No one really reaches out and an email is very unprofessional. So, I would have loved, I probably would have benefited if an engineering advisor or faculty to have reached out and really talk to me to understand where, what's going on and to help advise me, mentor me at that point.”
2	MANDATORY-RESOURCES	Making it mandatory for students to checkout available resources.	“Getting students set up, explain to them that they have all these different resources. I would make it mandatory specially for the first couple of classes that you do, go to those resources as well. You know, you go to the Math Learning Center, you spend at least an hour.”
3	RESOURCE-ADVOCACY	Advocating for resource availability.	“Need better connection to campus resources.” “Need better connection to resources to figure out what engineering field is right for them.”
4	ADVISING-SUPPORT	Need more support from advising. This includes better advising in selecting courses and major, extra support for career exploration and showing available pathways in engineering.	“I had to figure out my second semester out all on my own and it set me up for failure, I did not get the help I expected from my advisor on what I was supposed to take and understand next steps.” “I needed that extra support for someone telling me like, okay these are different routes that you could take, that I didn't feel when I began PENG.” “Well, my advisor just said things that I already knew”

5	DOCUMENTING- INFORMATION	Documenting program information: Students need more information on different programs, classes, major, and student organizations.	<p>“I would recommend creating an app that has all the info about club/organizations and general info about programs and how to participate.”</p> <p>“I feel like I don't know, maybe if they could make a document for each major, like documenting those things. So sometimes it doesn't have to be like you physically have to tell the students. Okay. You are in this specific position here, maybe like a document for incoming students letting them know, you know, if you're an undergrad or if you're like, you know, like whatever, if you're a master's student. whatever, wherever they're at that point in college, letting them know. For this major, here's what you should be focusing on. I think that could be helpful. And then maybe to have them reiterate that could help us better understand and maybe explain if they have any questions. So, one document that can be sent to the students could help or guide.”</p>
6	IMPROVING- STUDENT- ENGAGEMENT	Improving student engagement.	<p>“Somehow make engaging through online methods better.”</p> <p>“Offer more engagement opportunities prior to admission.”</p>
7	FINANCIAL-AID- SUPPORT	Better info and help with financial aid.	<p>“Help simplify the financial aid process.”</p> <p>“Talk more about how to get scholarships.”</p>
8	CLASS- REGISTRATION- SUPPORT	More help in class registration.	“More clear instructions regarding the registration process”
9	FAST-TRACK- APPLICATION	Fast track application process.	“Send the package faster and have it include private scholarships. It took a while for the financial aid package to come in.”
10	IMPROVED- COMMUNICATION	Improve communication and information sharing with students.	<p>“I would like communication to be a bit clearer and more obvious.”</p> <p>“Communication with students consistently.”</p>
11	CLEAR- EXPECTATIONS	Mention clear expectations from students.	<p>“More information on what we need and what is expected.”</p> <p>“Make it more clear on the requirements.”</p>

12	COORDINATED-INFO-SHARING	Counselors and faculty members to share the information with each other.	<p>“You see a counselor should pass on the information to faculty members.”</p> <p>“The counselor who runs the tutoring schedule should give the schedule to professors so that they can pass it on to students.”</p>
13	UPDATED-LECTURE-SLIDES	Update lecture slides.	“Majority of classes have lecture slides from too long ago.”
14	RE-ACCESS PRE_REQ & CO_REQ	Need for changes in pre-req and co-req.	<p>“I feel that some of the pre-req courses aren’t needed for my major.”</p> <p>“Certain classes need skills in these to such a degree they should be pre-req and not co-req.”</p>
15	REVIEW-LECTURES	Need for short review lectures.	“Perhaps small review lectures that go through information never fully covered.”
16	NEW-APPROACH WEEKLY-ASSIGNMENTS	Introduce weekly assignments with feedback.	“I found that if you're doing homework online or you're turning it in weekly or bi-weekly, and the teacher actually checks it to help you check your understanding. You're better off. So generally, I recommend some homework without being too much homework and doing in such a way that the students can check their understanding, but also keep them on track.”
17	FLEXIBLE-CLASS-OFFERINGS	Need multiple class offering times. For instance: availability of afternoon class or evening classes.	<p>“Evening lab sections”</p> <p>“Need to have better time management available for athletes trying to create a class schedule.”</p> <p>“Dearborn and Metro Detroit are blue collar cities now, everybody has to work, so even for PENG students those afternoon and evening classes are important.”</p>
18	HANDS-ON-ACTIVITIES	More hands-on activities.	<p>“May be hands-on coding or gaming team would be very interesting in my opinion.”</p> <p>“More hands-on experiences or outside visits”</p> <p>“Lectures should incorporate some hands-on activities to make sure that the students are actually participating in the course.”</p>
19	LAB-VISTS	More lab visits	<p>“Visits to more CECS labs to get them more engaged and interested.”</p> <p>“More laboratory involvement, stronger foundational courses to build off on”</p>

20	WORKSHOPS-SEMINARS	More workshops and seminars. For example: More events like CECS Blue Carpet Day, introduction to CECS organizations and more engagement.	<p>“Interactive engineering meetings/seminars”</p> <p>“More workshops or sessions providing students with the resources available to them.”</p> <p>“More intros by CECS organizations”</p>
21	MSEL-SUPPORT	Better support in MSEL.	<p>“Being in MSEL, it's a little bit daunting not knowing how the machines work. So, I guess maybe a little bit more instruction with the machines rather than just walking you through each machine and explaining what they do, makes sure that they really explain how the machines work and especially safety precautions. More focused on like, Yeah, here's how you turn it on or turn it off..”</p>
22	IMPROVE-ORIENTATION	Improve orientation. Students suggest a need for an improved orientation process.	<p>“Need better orientation.”</p> <p>“I feel like it was kind of rushed because it was a few people, a few students coming in sitting down registering and like, okay, you can step out. So, I think having that initial help for those students like okay, are you on the right track? Like what does that look like for you? And going like that.”</p>
23	REDUCE-WEEKLY-EMAILS	Avoid weekly student emails.	<p>“Weekly student emails seem unnecessary it could easily be made a webpage for those interested. The important dates are helpful in emails but weekly is not necessary.”</p>
24	SUPPORT-NON-CECS-MAJORS	More support for non-engineering CECS major.	<p>“Stronger support for non-engineering CECS major”</p>

25	PENG-LIKES	PENG program likes. This includes Engineering learning center, good faculty and advisors, fair program, good projects, MSEL, SI Leader, math support, foundation, good instructional material, and teaching methods etc.	<p>“Helped establish a solid understanding of mathematics.”</p> <p>“It laid a good base foundation.”</p> <p>“Good professors”</p> <p>“They focus a lot on making sure you understand how to do the steps necessarily rather than memorizing, which is really helpful.”</p>
26	PENG-DISLIKES	PENG program dislikes. This includes discouraging teachers, higher math expectations, not having flexibility in class offering times, poor advising, shortage of jobs on campus etc.	<p>“Had a math professor at one point tell me I should quit engineering over struggle in the class due to work/school balance at the time.”</p> <p>“Shortage of on-campus jobs”</p>
27	START-ADVISORY-UNHELPLEFUL	Code to indicate students’ unhelpful experience with START advising.	<p>“I didn’t see START as extremely helpful for me.”</p> <p>“I was contemplating maybe even doing architectural or something like that kind of goes with engineering but isn't necessarily a stream in engineering. Advisor response to me was just like we don't have that here, what if you look at other programs at other colleges? So right off the bat, it was like she didn't know how to help me here. And I was like, well, I would like to stay at Dearborn because that's where I decided to come. Then instead of trying to look at ways to stay at Dearborn, it was more of like, Okay, well, maybe you're at the wrong college type of thing. So that wasn't the greatest experience.”</p>

			<p>“The START advisors I talked to in my freshman year was not helpful at all, I’ve heard other people have the same problem as well.”</p>
28	ACADEMIC-SUPPORT	<p>Academic supports provided to PENG students at UM-Dearborn. This includes Career Services, Math Learning center, Programming, SI Leaders, Writing centers.</p>	<p>“I like the SI program, it’s really helpful for students and I hope they keep on doing that.”</p> <p>“Career services is definitely a good place.”</p>
29	UM-Dearborn-SELECTION-REASONS	<p>Reasons why students selected UM-Dearborn. This includes Fast Response, Scholarship, Clear Communication, Connection to engineering companies nearby.</p>	<p>“It seems they have lot of great connections to engineering focused companies nearby. And so, I just figured it would be best to come to school here.”</p> <p>“Fastest response”</p>

Appendix G: Faculty Members and Advisors Interview Codes

	CODE	DESCRIPTION	SOME EXCERPTS
1	BUSY- OVERWORKED- CHALLENGE	Students express being very busy.	“Students are overly busy”
2	HIGH-EXPECT- CHALLENGE	University has high expectations for PENG students in academics, specifically math.	“University have high expectations for the mathematical preparation of the students.”
3	INATTENTIVE- CHALLENGE	Students show disinterest/disengagement in classroom activities and towards the course.	“Not paying attention to the structure or details of the course”
4	MATH-CHALLENGE	Description of math challenges faced by PENG students.	“Covering pre-calculus material is a challenge, students’ have very different strengths and weaknesses.” “Many of them learned math based on memorizing rules in the past. It’s kind of hard to get past that and get comfortable with focusing on how things work and why they work the way they do”.
5	RESOURCES UNAVAILABILITY	Availability and utilization of resources for PENG students	“Some of them don’t even have a pen or a pencil, whereas some students have an iPad, they keep track of everything, and because of the tool they can create colorful diagrams that can help them understand better”
6	UNDERPREPARED- CHALLENGE	Students are underprepared academically or experiencing challenges due to limited knowledge	“PENG students are the ones that are most likely to feel overwhelmed underprepared”
7	LOW-VALUE-PENG- CHALLENGE	Students do not understand the importance of PENG courses	“They don’t have any real motivation to learn the material because they don’t see why they need it.” “Students feel like it’s kind of waste of time”

8	NO-CREDIT-RECEIVED-CHALLENGE	PENG credits do not count towards their degree	“It doesn't count towards their degree, but it shows up on their transcripts.”
9	SUCCESSFUL-PENG-PROGRAM	prioritize effective communication, enhancing students' mathematical proficiency and academic performance, identifying the root causes of students' struggles, providing mentorship, valuable resources, and academic support, promoting time management skills, offering comprehensive math preparation, and the program should align with students' goals and expectations	“Making students feel that they are the part of the program.” “At least from the math perspective, I think a program which identifies reasons for students struggling.” “Robust academic support system”
10	FACULTY-PENG-NO-INFORMATION	Faculty members are not (or little bit) aware/informed about the PENG program at UM-Dearborn	“I am not super familiar with the program.” “I don't really know, what is PENG program?” “Can you define for me what you mean by PENG student?”
11	PROG-IMPROVE-ADVISING	Advising PENG students will improve their PENG experience.	“I think advising plays a major role, advising not only about the courses they take, but how to manage everyday life related things”
12	PROG- IMPROVE -ANALYZE- DATA	Analyzing students' data and then utilizing it to suggest program changes will improve PENG experience.	“I think moving forward, we're going to really hone-in and look at that data on how many students successfully complete the program starting in a particular semester and you know, what are the barriers that prevented them.”
13	PROG- IMPROVE -BLUE CARPET PROGRAM	Introducing the Blue carpet program in PENG will improve PENG experience.	“I think more of those type of programs could be really beneficial, again to all of our 1 st year students, but specially our PENG students.”

14	PROG- IMPROVE - CREATE OPPORTUNITIES	Creating opportunities for students to work together/ collaborate will improve PENG students' experience.	“If there's ever an opportunity for students to come together and to receive support or support together. Whether that's in a seminar with a guest speaker, or if that's lunch with upper-class students like the juniors and seniors, or if that's a meet and greet with faculty or practice sessions apply and doing math or whatever. I wonder if there's a way to make the program have more structure.” “Create an opportunity for those students to continue, to get to continue an engineering project. Whether it's a hobby or to join a club or a competition that occurs in their first or second year.”
15	PROG- IMPROVE - EARLY ALERT	Designing a system to create an early alert will improve PENG students' experience.	“Early alert system is really important”
16	PROG-IMPROVE - GRAD STUDENTS’ SUGGESTIONS	Taking suggestions from students who have successfully graduated from the PENG program will improve PENG students' experience.	“That would be a good question for students who have already completed the Pre-Engineering program. What has been really helpful for them in the program, or what could have been added to make the experience even stronger.”
17	PROG- IMPROVE - GROW MENTORSHIP	Mentoring students will improve PENG students’ experience.	“I think the mentorship is so important there to form a connection. So that they feel connected to engineering, to our college”
18	PROG- IMPROVE - INTRO TO CECS	Including a seminar course to introduce students to CECS will improve PENG students' experience.	“I would say making intro to CECS mandatory”
19	PROG- IMPROVE - MEASURE IMPACT	Measuring the impact of the PENG program will improve PENG students' experience.	“a cohort model in a way of measuring the impact of the program, even in the short term, 6-12 months will be helpful”
20	PROG- IMPROVE - NEED FOR RESOURCES	This includes resources needed to improve PENG, such as providing faculty members	“I would like to know how many of them actually are graduating. Like how many? Like what percentage? Yeah. It would be helpful for me to have that information.”

		with the access to the student's data, advocate different support and strategies availability, improving tutor availability in math learning center, introducing a new website with practice math problems, and identifying the needs of PENG students.	<p>"If advising or whomever is over it, could give us strategies for how to connect these students across their main, their first-year classes."</p> <p>"Group study session leaders"</p> <p>"Online site with practice questions for each math course associated to the topics in that course would be helpful for students."</p>
21	PROG-IMPROVE-POINT SYSTEM/PASSPORT SYSTEM	Creating a requirement for students to meet with career services, math learning center, and student organizations to help improve PENG experience.	"a point system or a passport program where like Pre-Engineering students could be required to meet with the Math Learning Center or career services. Of course, required to meet with their advisor, but have different things that they must do during their first semester. One of those could be reaching out to a student organization or attending a student-org meeting."
22	PROG-IMPROVE-PROVIDE SUPPORT/ ADVISING	Providing intrusive advising and physical support will help improve the PENG experience.	"More support, more intrusive advising geared specifically toward Pre-Engineering issues."
23	PROG-IMPROVE-PROVIDE RESOURCES - CREATE EQUALITY	Creating equality by providing resources such as providing iPad to students with a deposit will help improve the PENG experience.	<p>"I think engineering should provide all students with iPads with those pens. With a deposit. It still would be the departments iPad. Students will return them if they leave the program or when they graduate."</p> <p>"I think more encouragement from advising or their mentor would help"</p>
24	PROG-IMPROVE-PULLING OFF ON TIMELINE	If a student doesn't meet a timeline doesn't mean they can't be successful.	"Kind of pulling off on a timeline, I think that puts a lot of pressure on students within their first year. Just because they don't meet a timeline doesn't mean they can't be successful."

25	PROG-IMPROVE-SUMMER BRIDGE PROGRAM	There is a need to re-introduce summer bridge program.	“I would love to see summer bridge program return.”
26	PROG-IMPROVE-SUPPLEMENTAL INSTRUCTORS	Launching a SI for each course, even for early level courses will be helpful.	“More early level courses that can be supported with supplemental instruction or some type of analogous program.”
27	STRAT-IMPLEMENTED-HANDS-ON-ACTIVITIES	Implementation of hands-on activities such as including case studies, conducting discussion boards and group discussions, group worksheets and quizzes with partners etc.	“Asking students to explore and think about questions on their own in small groups and in class discussion, So I try to lecture as little as possible.” “We do group worksheets and sometimes quizzes with partners”
28	STRAT-IMPLEMENTED-ADVISOR/FACULTY AVAILABILITY	Availability and schedule flexibility of advisors and faculty members	“I try to make sure that I’m flexible”
29	STRAT-IMPLEMENTED-CASE BY CASE STRATEGIES	Providing support and strategies on individual basis	“Not assuming every student is the same.” “If they're getting to a point where it's they're either not going to make it. And we have that conversation of what what's going on? Is there a program that is a better fit or what's going on with that? We evaluated each semester for the students where they're at.”
30	STRAT-IMPLEMENTED-COFFEE HOURS	Coffee hours where student can meet the faculty member to ask any questions	“I also changed my office hours are no longer called office hours they are coffee hours. So, we host them outside my office. I bring the department coffee wreck and we can have coffee and snacks while they asked me questions. So, I have found more students come to the coffee hours and then when there were in office hours.”

31	STRAT- IMPLEMENTED- CREATING INTRODUCTORY VIDEOS	These videos help students to familiarize themselves with the concept before it is taught	“And that's just a strategy I use to help the students get into the rhythm of, of doing, watching a course video, doing an assignment and go, or go into lab and doing an assignment during the lab.”
32	STRAT- IMPLEMENTED- MANDATORY ADVISING	PENG students are required to meet the advisors	“We do have required advising, so all students are required to meet with us in their first semester”
33	STRAT- IMPLEMENTED- MOVING AWAY FROM EXAMS	Introducing concept maps, portfolios etc.	“Create an e-portfolio of their engineering work.” “I ‘m moving away from lots of exams. So, I don’t have any major exams anymore, I have a mid-semester concept map.”
34	STRAT- IMPLEMENTED- PAIRING STUDENTS WITH STRONG WEAK TEST SCORES	Pairing students with strong and weak test scores in the same group	“So, after the first test, I pair students up. I usually like to look at their test scores and their quiz scores, and the students who are strong, I pair up with the students who are weak. And I ask them to submit test corrections for a few of the points back on their tests.”
35	STRAT- IMPLEMENTED- SHORT SURVEY	Survey to understand the student’s subject knowledge (done in week 1)	“I have them fill out a short little survey. The first semester, the first week of the semester, so it's basically one page survey. What's your name? You know, are you a freshman, sophomore, whatever. Where did you go to high school? Are you working? part-time job? If so, where? What other courses are you taking? You plan to transfer?”
36	STRAT- IMPLEMENTED- SPOTLIGHT ON	Brief story of individuals who successfully graduated from this course	“What I've started doing them as two years. I'd begin every lecture with what are called spotlight on. So, I highlighted individual graduated. Tell a brief story. It's, it's a PowerPoint, 3-4 or five slides of what these students stem.”
37	STRAT- IMPLEMENTED- RECITATION	Providing suggestions on what courses to take and student progress	“I do the lecture and there's something called recitation, 15 min once a week, right? You need a smaller group and assign them problems are supposed to come to recitation for the problem-solve. Tell them to go to the board and put up the solution and answer.”

Appendix H: Student Needs Included in Card Sorting Activity

Improving orientation experience. [create an app or a pamphlet with all the info and distribute it].	Better personalized early warning system.	Better connection to campus resource availability.	More student engagement opportunities specially during pre-admission.
Web page for weekly student emails/announcements.	Class schedule time flexibility.	Better advising support and clear direction to stay on track.	More clear registration instructions & Course selection help.
More introductory coding classes.	Update lecture slides.	Reassess pre-requisite and co-requisite requirements.	Short review lectures that cover fundamentals.
Fastrack admission and financial aid process.	Better information sharing on different program, classes, and student organizations.	Re-evaluate homework strategy. [Replace yearly assignments with weekly or bi-weekly homework with feedback].	More hands-on activities in lectures.
More workshops, seminars, and career events.	Additional support for career exploration [Information on available pathways in engineering].	Clear expectations from students regarding requirements.	

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