WORK-IN-PROGRESS: EVALUATING THE STAGED DEVELOPMENT OF A NEW ROBOTICS ENGINEERING DEGREE

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Abstract:
This study presents observations from the implementation of a new Robotics Engineering degree program. Development of this degree was detailed in our recently published "Work in Progress" (*Development of a New Robotics Engineering Degree in Response to Industry Needs*, ASEE 2025). We have built an evidence-based foundation for continuous improvement on curriculum engagement, effectiveness of pedagogical methods, and student perceptions for this new engineering program. This ongoing research is aimed at refining assessment instruments, aligning performance indicators with program outcomes, and expanding data collection. New (freshman) students enrolled in the program are assessed using the thematic survey model from our recent article (ASEE 2025). Continuing (sophomore) students are reevaluated through the thematic survey model, reflective exercises, and focus groups. This varied approach allows the program to capture how students adapt to newer curricula, integrate prior knowledge, and apply skills in more challenging contexts. These data provide insight into the continuity and progression of learning across academic years, highlighting how students develop over freshman to sophomore courses. The assessment results will be employed as a guide for refinements to curriculum design, teaching methods, and student support strategies. In parallel with classroom and assessment activities, the outreach initiatives that create a stronger recruitment pipeline and promote interest in robotics among prospective student groups will be discussed.

1. Introduction and Background

1.1 Motivation

The rapid integration of robotics into manufacturing and automation industries generated a significant interest for cross-disciplinary expertise in electronics, integrated systems, mechanical design, and software technologies [1][2]. Developing relevant cross-disciplinary academic frameworks that include outcomes aligned with essential competencies is key to meeting this growing need. Systematic early assessments to identify core strengths and curricular gaps are beneficial means of refining continuous improvement practices [3][4]. Several studies identified that pedagogical practices and curricular effectiveness are critical in student retention and identity development, specifically for newly launched programs [5][6]. Student identity formation is a key factor influencing continuity and long-term success in engineering programs [7]; cross-disciplinary coursework can reduce student attrition rates [8]. Hamlin et al. and Machamer et al. reported the influence of the introductory engineering curriculum on students' initial impressions of engineering and the subsequent student success rates [9][10]. The goal of the present work is to present assessments of program effectiveness of a recently launched Robotics Engineering program.

1.2 Prior Work and Current Evaluation Focus

This research builds on our recent study published in ASEE 2025, which documented the program design, curricular structure, industry alignment and student perceptions of this newly launched Robotics Engineering degree program [11] at an R1, Land Grant institution. A major contribution from this earlier work was the development of a thematic survey model to evaluate freshman student engagement and to examine the learning interests of students in the program. While the aim of the previous work was to establish and evaluate program design and first-year student experiences, the current study extends towards understanding the impact of the newly developed curricula and pedagogical approaches on student identity formation. An extended multi-dimensional assessment that integrates both quantitative and qualitative evaluation methods was deployed in alignment with the themes in the original survey instrument [11].

The research indicates development of students' perceptions through freshman and sophomore years across multiple cohorts. This multi-cohort approach allowed for a deeper understanding of curricular consistency, learning pathways, and alignment between intended and implemented program objectives [12] evaluated through thematic survey instruments and focus group interviews.

2. Continued Program Implementation

2.1 Post Launch Developments

The Robotics Engineering program requires a total of 128 credit hours, primarily consisting of courses taught in the School of Computing, the Department of Electrical and Computer Engineering, and the Department of Mechanical and Materials Engineering. Of these, there are 10 interdisciplinary courses that focus on fundamental robotics topics, the "Robotics Core" [11]:

- COURSE 1: INTRODUCTION TO ROBOTICS
- COURSE 2: ROBOTICS TOOLS
- COURSE 3: ROBOTICS ANALYSIS CORE
- COURSE 4: CAREER EXPERIENCES
- COURSE 5: MOBILE ROBOTICS
- COURSE 6: ROBOT DESIGN AND CONTROL
- COURSE 7: ROBOTIC SOFTWARE AND ALGORITHMS
- COURSE 8: ROBOT SYSTEM INTEGRATION
- COURSE 9&10: CAPSTONE I & II

An inaugural cohort of fifteen students participated in Year 1 courses (COURSE 1 & 2) during the 2024-2025 academic year; several have continued to participate in the Year 2 courses (COURSE 3) offered during the 2025-2026 academic year. A cohort of sixteen students elected to participate in Year 1 courses during the 2025-2026 academic year. This undergraduate program gained formal approval from our state Coordinating Commission for Postsecondary Education in August of 2025.

2.2 Course Development and Pedagogical Approaches

In our recent article (ASEE 2025), the development of the first Robotics Core course was described. In this section, the development of further Year 1 and Year 2 courses will be discussed.

In Fall 2025, COURSE 1: INTRODUCTION TO ROBOTICS, was offered to the second cohort in a similar form to the previous year, with a weekly sequence of two lectures and one laboratory session. There were no changes to the course learning objectives; however, small improvements were made based on the feedback provided by the inaugural cohort. For example, the class meeting time for the weekly laboratory session was doubled (to approximately 2 hours) to provide more time for hands-on activities. Active learning strategies, such as Think-Pair-Share and peer teaching, were used throughout instruction. Again, state-of-the-art industrial robotics system demonstrations were organized by partners at our campus's Innovation Studio. Students also attended a robotics-themed industry conference to learn about opportunities and career pathways in the field. Finally, robotics-focused student organizations were invited to speak to the first-year students, sharing about their activities. Many students chose to pursue extracurricular involvement in these organizations.

In Spring 2025, the second Year 1 Robotics Core class, COURSE 2: ROBOTICS TOOLS, was offered to the inaugural cohort. Students were exposed to several robotics development environments, user interfaces, and software tools. The course had the following learning objectives:

i. Develop comprehension of working principles, hardware control units and programming methods of multi-axial robotic arms.

ii. Understand and interpret coordinate frames conventions, joint frame conventions and degree-of-freedom concepts using basic operational features and processes.
iii. Gain understanding of electrical, mechanical and software systems of robotic arms and mobile robots.
iv. Develop knowledge of fundamental concepts of mathematics related to kinematics of robotic arms.
v. Understand mathematical modeling approaches for implementing visual and kinematic models of stationary and mobile robots
vi. Develop skills in creating computer aided designs of components of robotic arms including links, joints and end effectors.
vii. Gain knowledge of fabrication techniques and assembly processes for building a prototype of robotic arm.
viii. Understand the key requirements for designing component selection, integration and prototype development processes using fundamental concepts of engineering economics.
ix. Understand the importance of software development platforms for creating robot control frameworks, development of robotic program routines and robot communication/networking processes.

A weekly instructional sequence similar to COURSE 1 was implemented (see [11]), with two lectures followed by a hands-on laboratory session. Project-based learning was incorporated wherever possible. The course included career awareness activities, such as site visits to industry partners. It culminated in a hands-on final project, where students designed their own 2 degree-of-freedom (DOF) planar robot first in simulation, and then through a design-build-test process.

The first Year 2 course was offered in Fall 2025, COURSE 3: ROBOTICS ANALYSIS CORE. This course covered topics pertaining to computational linear algebra and multivariate calculus, with the following learning objectives:
i. Develop comprehension of basic matrix operations and foundational concepts in linear transformation and linear systems
ii. Understand the basics of spatial mathematics including vector spaces, vector algebra, matrices, and spatial coordinate frames. Apply vectors to three-dimensional spaces.
iii. Compute partial derivatives of the functions of two or more variables. Determine the limits and continuity of functions of multiple variables.
iv. Apply calculus concepts to problems involving vector fields including line integrals, divergence, curl, and Green's Theorem, and use these concepts to understand the design of robotic systems.
v. Understand the different regression techniques, using interpolation and approximation methods as required for sensor data processing and interpretation.
vi. Develop skills in using mathematical modeling techniques to evaluate and analyze fitting models.
vii. Develop familiarity with basic search and optimization algorithms.
viii. Perform motion planning analysis and develop skills in using algorithmic approaches for trajectory mapping using mathematical models.

Because of the technical nature of the concepts, traditional lectures were the primary mode of instruction. However, weekly programming challenges were incorporated to apply mathematical concepts to robotics problems. Students had the opportunity to attend a robotics-themed industry conference where they could learn about the local robotics industry and network with other roboticists.

3. Assessment Frameworks and Data Collection

3.1 Thematic survey framework

Assessment activities were carried out longitudinally across cohorts to capture student advancement over time. The thematic survey framework is the primary assessment model for this study and was originally introduced in the ASEE 2025 Work in Progress paper [11]. The themes in the survey instrument were designed to align with that of ABET accreditation criteria as listed in Appendix A. Survey items were organized around recurring themes that aligned with course outcomes, career awareness, engagement in hands-on learning, sense of belonging, and emerging engineering identity.

Method: The program assessment plan utilized two complementary survey models with common themes to maintain consistency: (a) the existing thematic survey instrument introduced in the ASEE 2025 Work in Progress study for freshman level students [11] and (b) a new and expanded survey instrument for sophomore students designed to evaluate learning progression, confidence, and specialization (career pathway) choices. Table 1 shows the list of research objectives and survey questions from the instruments used for both freshman and sophomore groups. The survey tool for sophomores was substantially expanded within the themes of the original instrument.

Table 1. Research objectives and survey questions

Theme	Research Objective	Freshman survey instrument (ASEE 2025 [11])	Sophomore (Expanded survey instrument)
T1. Curriculum Engagement	Exploring the role of curriculum engagement in active learning environments.	• Which aspects of this course did you find the most engaging? Why? • Which aspects of this course did you find the most challenging? Why? • Which aspects of this course did you find the least engaging? Why?	
T2. Hands-On Experiences	Understanding the impact of hands-on experiences in experiential learning.	• Can you describe a hands-on activity or project that was particularly meaningful to you? What made it impactful to you and your learning?	• Can you describe a hands-on activity or project from a recent course that was particularly meaningful to you? What made it impactful to you and your learning?
T3. Practical Problem Solving	Quantitative evaluation of the effect of course activities on key ABET outcomes, such as problem-solving, analysis, and design skills.	• To what degree did the course contribute to your learning in the following areas: a. Ability to design and conduct experiments b. Ability to analyze and interpret data c. Ability to design components and systems	
T4. Self-Assessment	Exploring student's perception of acquired competencies and ability to connect with the field.	• What are the top three new skills that you attained from this course? • What did this course reveal about your skills and abilities, interests, confidence, or strengths and weaknesses?	• What are the top three new skills that you attained from the sophomore year courses in this major? • Which additional new skills have you particularly gained through the courses in the sophomore year? • What did the recent sophomore level courses reveal about your skills and abilities, interests, confidence, or strengths and weaknesses?
T5. Understanding the Field	Assessing the impact of diverse course content on students' expectations.	• To what extent have your experiences in this course increased your understanding and broadened your perspective on robotics engineering as a field?	• Which specialization/pathway of the Robotics Engineering program are you most interested in pursuing? • Describe in detail how the sophomore-year coursework prepared you to understand differences between specializations. • Which robotics-specific career pathways currently interest you the most? • Your experiences in the recent sophomore courses increased your

			understanding and broadened your perspective on robotics engineering as a field. (Likert scale)
T6. Career Influence	Understanding student's viewpoint of the major and its career pathways.	• To what extent has this course influenced your future career path or your professional interests?	• How clearly do you understand the career options available within your specialization? (Likert scale) • What motivates your interest in your chosen specialization? • How prepared do you feel to make an informed decision about your specialization? (Likert scale) • How confident are you in your understanding of what your specialization involves in professional practice? (Likert scale) • What challenges have you faced when trying to decide on a specialization?
T7. Improvements	Exploring student needs for curriculum enhancement.	• What specific improvements would you suggest for the course activities, and how do you think they would benefit future students?	• What types of additional support in this program would be most helpful? • What additional specific resources or guidance would you like the program to provide?

3.2 Sophomore reassessment: Focus group interviews

In addition to the thematic survey questions presented in Table 1, sophomore students were invited to participate in discussion-based reflective exercises conducted through focus groups. The aim of the focus group interviews was to allow students to provide qualitative insights into the ongoing curricular experiences and challenges. The focus group interviews included qualitative questions (Table 2) in accordance with a multi-dimensional data collection process [13][14]:

Table 2. Focus group questions and dimensions

Dimension of recognition	In which ways do you consider yourself a future engineer?
Dimension of interest	In which ways have your current study of robotics helped you develop a sense of feeling as an engineer?
Dimension of performance	Have you got any comments from people around you (family, friends, teachers) as engineering students or future engineers? If so, could you elaborate on it?
	What makes engineering interesting for you? In terms of your general interest, talk to us about how being in the robotics program connects with your interest in being an engineer. Do you find fulfilment in the robotics field of engineering?
	To what extent has your experience in the robotics program increased your understanding and broadened your perspective on robotics engineering as a field?

This focus group approach implemented a convergent parallel design that collected qualitative data simultaneously with quantitative data. This common research practice attains breadth and generalizability through quantitative analysis, while probing with depth, meaning and context through qualitative methods [15]. Focus groups can provide a rich complement in mixed method approaches through its social and interactive nature, allowing data to emerge through participant interactions and reactions, both as individuals and as groups [16].

Quantitatively, our survey aimed to identify patterns and trends across the dimensions that we investigated. We analyzed data from focus groups to confirm and explain the quantitative patterns. In remaining consistent with a convergent parallel mixed-methods design, we compared side-by-side the themes that emerged to clarify how and why students interpreted and experienced the measured constructs. Our focus group data contextualized explanations for our survey [17]. Our methods follow well established and commonly followed approaches in Engineering Education research [18][19].

This mixed method research study evaluates learning progression and identity development. The survey instruments were used to collect data on student perceptions on foundational coursework and continuity in the program while assessing retention and sense of belonging.

4. Results

The data collection plan was implemented on the current (2025-26 academic year) Sophomore (Cohort I – 9 students) and Freshman (Cohort II – 16 students) groups. Cohort I has 2 students who identify as women, and 1 student from under-represented groups. Cohort II has 4 students who identify as women, and 4 students from under-represented groups.

4.1 Learning progression (Cohort I)

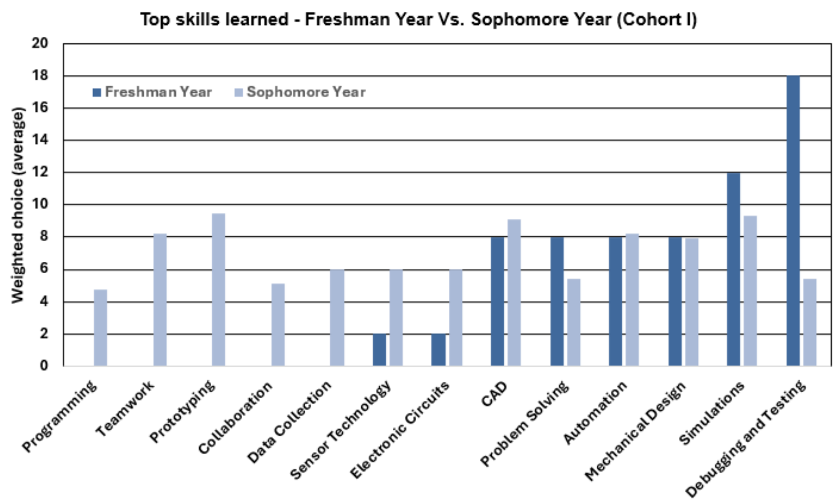
Students reported a strong continuity in skill advancement between freshman and sophomore years. Students in Cohort I consistently reported that continued experiential learning has positively influenced the learning processes. Table 3 shows the expansion of student experiences with hands-on activities from freshman through sophomore courses. Students portrayed confidence in learned skillset beginning with programming a pre-built robotic arm (freshman year) to being able to design, and code a robot (sophomore year) independently. One student (sophomore year) noted: *"we got to explore the hardware currently available to us at a very detailed level and make robots that operate the same way at the ones used in ROBO 100 (freshman course), but with a new method of embedded control."* Such development in learned skillset demonstrates continued student engagement through reinforcement of curricular topics across courses.

Table 3. Comparison of experiential learning (Cohort I)

Question 1: Can you describe a hands-on activity or project from a recent course that was particularly meaningful to you? What made it impactful to you and your learning?	
Cohort I (Sophomore Year)	***Cohort I (Freshman Year)***
Both of the wall-following projects in the embedded systems class were impactful because I was able to construct my own bot, learn about how IR and ultrasonic sensor function, then develop my own program to make the robot accomplish a task. I had to learn about how different sensors worked / were programmed and then implement that in my own code. *The robotics project from Embedded Systems was a lot of fun--we got to explore the hardware currently available to us at a very detailed level and make robots that operate the same way at the ones used in ROBO 100 (freshman course), but with a new method of embedded control.*	*One hands-on activity that was very impactful towards my learning was the pick and place lab on the robot lab simulator.* *I think the obstacle course for the rover was the most interesting, it really showed the importance of having a very well-tuned system as well as the value of repeatability in a system. Not to mention that many people used different methods to achieve very similar results. A good showcase of innovation and tuning.* *I really liked using the Arduino robotic arm and programming it, thar was fun and it also had a lot of its own problems. Plus having to make our own*

Embedded systems robot that could follow a wall and dodge objects was meaningful because I programmed it from scratch and it was cool seeing my actual code doing useful stuff	*claws was also fun. It made the most impact because there were a lot of unique problems that we would have to fix and go to our professors or our peers to try and fix.*

Research indicates that students make informed career decisions when exposed to foundational skills early in their academic program [20][21]. To understand the motivations behind student interest in specializations, data corresponding to the major skills attained by students in their transition from freshman to sophomore years were recorded using the survey instrument. Figure 1 illustrates the contrast in the skills attained by Cohort I across freshman and sophomore courses. Freshman students primarily identified Debugging/Testing and Simulations as the key competencies, whereas sophomore students reported a broader range of technical skills. This increased range of skills is clearly in alignment with their engagement with more advanced coursework.



Question 2: What are the top three new skills that you attained from this year's courses in this major?

Figure 1. Comparison of skills gained by Cohort I (Freshman Year vs. Sophomore Year)

It is also known that student self-perceptions capture learning dimensions that traditional assessments often miss [22]. Evaluation of student confidence and skill development via student self-assessments is used for understanding data retention and attrition [23]. The expanded survey instrument collected student self-assessments on student skills and abilities.

Table 4. Comparison of student self-assessments for Cohort I

Question 4: What did the recent (freshman/sophomore) level courses reveal about your skills and abilities, interests, confidence, or strengths and weaknesses?	
Cohort I (Sophomore Year)	***Cohort I (Freshman Year)***
This course reinforced my confidence in my abilities as a coder and highlighted my skills with planar and spatial awareness and it definitely highlighted an area of improvement in logical design for sensor systems during the obstacle course lab. I feel it was a good course for increasing my confidence in robotics in general and Arduino coding.	*I did very well in circuits and physics so I'm confident with electrical systems, but I think I'm still behind the curve when it comes to mechanical design. Physics had also opened up a research opportunity for me where I can further expand my knowledge of all three specializations.*

It showed that this is what I am good at, is working and prototyping robots, and that it is something that I have wanted to do and have an option to do. I feel more confident in getting a job in the field I want to know, and learned I am good with programming robots and mechanical design but maybe need to work on the simulations and circuits.	*I realized I might have more of an interest in electronics than I thought and that I am not particularly good at coding.* *I do not enjoy, and am not good at embedded systems type work*

Table 4 demonstrates student strengths development from freshman to sophomore year. During the freshman year, Cohort I identified foundational strengths in circuits and physics but acknowledged limitations in mechanical design and embedded systems. In the sophomore year, they reported increased confidence in coding and mechanical design, showing enhanced clarity about their strengths. One of the students noted that "*sophomore courses reinforced confidence as a coder*" and supported their ability for prototyping. Intentional curriculum design improves technical skills alongside self-awareness.

Survey data also indicated a shift in student confidence across the freshman and sophomore years (Figure 2). While 90% of freshman students strongly agreed they understood the field, this dropped to approximately 25% by sophomore year. A corresponding increase in students who "somewhat agreed" was also observed. This decline in strong agreement likely reflects students' growing awareness of the field's complexity and the breadth of advanced topics in Year 2. This shift in confidence shows how experiential learning promotes essential self-evaluation among students while retaining student motivation.

Question 5: Your experiences in the recent sophomore courses increased your understanding and broadened your perspective on robotics engineering as a field.

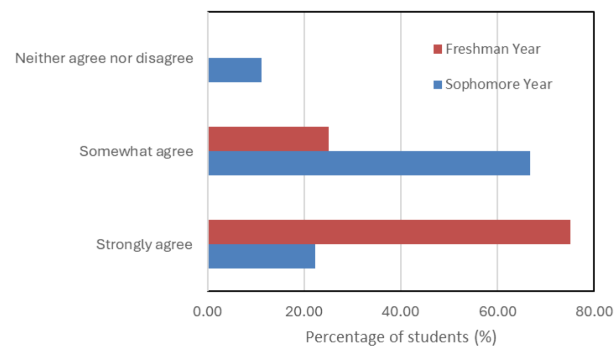


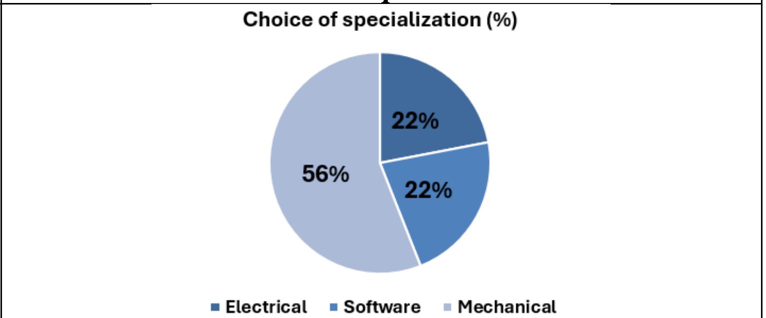
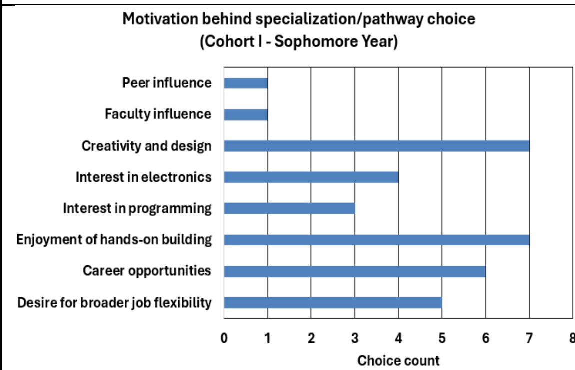
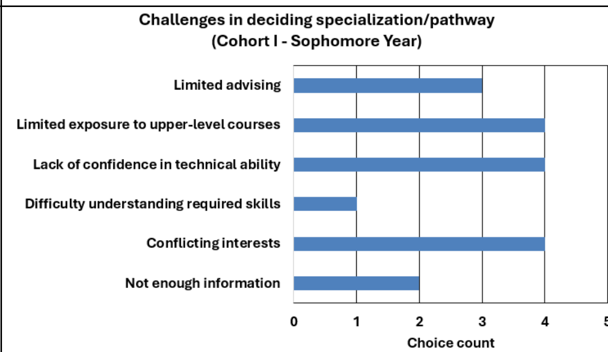
Figure 2. Student confidence (Cohort I: Freshman Year vs. Sophomore Year)

4.2 Specialization interests and motivations

Students of Cohort I demonstrated clear specialization preferences with the Mechanical pathway as the most preferred pathway (56%), followed by Software and Electrical (22% each), as shown in Table 5. 'Creativity and design' and 'Hands-on activities' are the strongest factors behind students' choice of specialization. Seventy-five percent of the students indicated that career opportunities influenced their decisions. The data also revealed that students' decisions are formed by in-class experiences and career interests, rather than external social factors.

Lack of confidence in technical abilities and limited exposure to upper-level courses were reported as the most frequently experienced challenges in selection of specialization/pathway. Difficulty in understanding the skillset essential for success in this major was indicated as the least significant barrier. The data trend indicates that while early skill exposure influences pathway selection, expanded advising focused on pathway requirements and career options would be beneficial.

Table 5. Specialization preferences and motivations (Cohort I – Sophomore year)

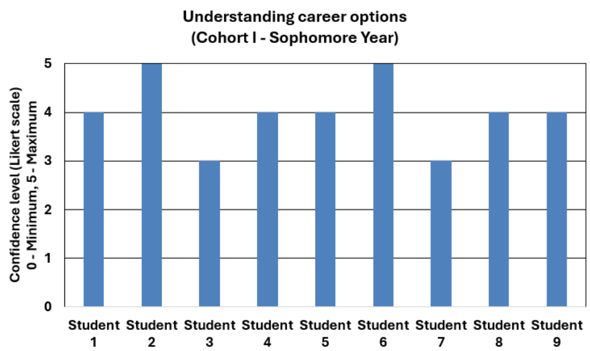
Survey question	***Student response data***
Question 1: Which specialization/pathway of the Robotics Engineering program are you most interested in pursuing?	
Question 2: What motivates your interest in your chosen specialization?	
Question 3: What challenges have you faced when trying to decide on a specialization?	

The survey also revealed that extracurricular activities are not a major factor influencing the pathway selection for most students. A majority of the students (60%) did not participate in any student groups or clubs. However, students who participated in these groups indicated that club activities and peer (junior/senior level students) interactions within these clubs had an increased influence on the selection of a program pathway. One of the students highlighted that "*Being in VEXU club has had a relatively large impact on my specialization decision.*" Another student indicated that exposure to technologies helped inform about the skills required for the pathways: "*I'm part of UAV in Aerospace Club and it showed me a lot of the technical side of sensors like LIDAR. It also slightly introduced me to ROS2.*" A lower percentage of students benefited from their participation in clubs, indicating that clarity of specialization is more relevant to coursework rather than extracurricular involvement. A larger sample size would be required to provide an accurate understanding of the relevant correlation.

4.3 Career awareness and pathway interest

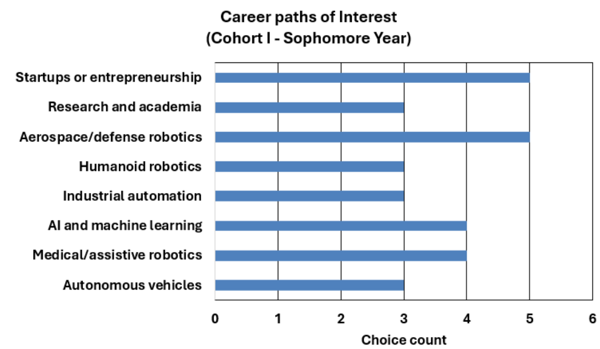
The survey data showed varying confidence levels in students' understanding of specialization-specific career options (on a 5-point Likert scale, Figure 3). A majority responded with confidence levels between 4-5 and nearly 22% of the students reported confidence levels of 3. This variability correlates with the limited advising on specialization pathways discussed earlier in Section 4.2.

Figure 4 illustrates Cohort I's diverse career interests within robotics. Aerospace and defense robotics and entrepreneurship are most preferred, while AI and machine learning appeal to approximately 50% of students. This diverse range of interests reflects the program's success in broadening student exposure to multiple robotics applications and emerging fields.



Question 1: How well informed are you regarding the career options available within your specialization?

Figure 3. Confidence levels in career option awareness



Question 2: Which career pathways currently interest you the most?

Figure 4. Specific career interests

4.2 Focus group Interviews

Four focus group interviews were scheduled and conducted with 7 students, where group sizes ranged from 1 to 3 students. To analyze the interview transcripts, two researchers applied thematic coding methods to identify patterns and emerging themes. This is a widely used technique to identify and analyze patterns to draw and report meaningful insights towards a concept or phenomenon [24]. The flexibility offered by this methodology allows for rich insights through the development of codes that are both data driven and theoretically sound [25].

Our pre-theme analytic process included two primary steps. First, we implemented an open coding process allowing for data to be broken down in an analytical way [26]. Second, we included a code frequency aggregation process as defined by Corbin & Strauss [26]. Code frequency aggregation is appropriate because frequency counts were used to support pattern identification across focus groups, rather than to infer statistical significance or generalizability.

The strongest theme from the analysis is "Learning Through Applied Experience." Students expressed that the curriculum offered various applied learning experiences that had a positive impact on their learning. Students in extra-curricular projects highlighted these practical experiences as significant in their learning development in robotics. Projects, practical engineering problems, and hands-on activities, perceived to be offered relatively early in the course of their studies, allowed them to connect their coursework to real-world problems. Students expressed appreciation and personal achievement towards the ability to apply what they learned. Some direct quotes include:

> *"You're applying a lot of the math and the physics that you learned earlier, instead of just seeing it on paper."*

"This semester we're doing more projects, and that helps because you actually see how it works in practice."

"Knowing how to read a circuit is really important, and you actually get to do that instead of just talk about it."

The second emergent theme is "Preparing to Become Engineers." Students felt a sense of confidence and perceived readiness to engage in capstone projects, be productive at potential internships, and ready to join the workforce. Students appreciated the interdisciplinary approach specific to the robotics curriculum to lay the groundwork for future opportunities and specialization. Students reported that the program prepares them to join the workforce and contribute meaningfully to the field in the future, in addition to reducing any worry towards internships. For example, students said:

"It makes me feel more confident about what I'm going to be doing, like what my job's going to be."

"The skills you're learning are things you can actually use in internships."

The third theme that emerged was "Developing an Engineering Identity." Students highlighted how the program provides intentional interactions with peers and faculty in an environment that supports their learning, as well as a desire to define a stronger place for robotics in the college as the program grows. This theme may seem to overlap with the second, yet emerged as distinct because the students began to view themselves as engineers. Some students shared:

"You start thinking of yourself as an engineer, not just a student in classes."

"Working with other students and faculty helps you feel like you belong in engineering."

"Being treated like an engineering student makes a difference in how you see yourself."

In following the mixed-methods convergent design, we evaluated alignment between the survey analysis (quantitative), and the focus group interviews (qualitative) across data sets. Emergent themes provide confirmation of our quantitative survey results as highlighted in Table 6 below:

Table 6: Integration of Quantitative Survey Results and Qualitative Focus Group Findings

Focus Area	Quantitative Survey Findings	Qualitative Focus group findings	Integrated interpretation
Learning progression and applied learning	Survey results indicated a clear learning progression, with students reporting continuity in skill advancement across courses. Students also reported that hands-on and project-based learning had a positive impact on their learning and understanding of engineering concepts.	A strong theme of "Learning Through Applied Experience" emerged. Students described how projects, practical engineering problems, and hands-on activities helped them connect coursework to real-world engineering problems and deepen their learning.	Together, the quantitative and qualitative results suggest that applied and project-based curricular design supports both perceived learning progression and meaningful engagement with engineering concepts. The qualitative findings help explain *how* hands-on experiences contribute to the learning gains observed in the survey data.

Career Awareness and preparation for engineering pathways	Survey analysis showed increased student confidence in understanding specialization-specific career options. Students reported feeling more prepared for the workforce	The emergent theme "Preparing to Become Engineers" captured students' perceptions of confidence and readiness to engage in capstone projects, succeed in internships, and transition into the engineering workforce. Similarly, their identity as an *engineer* grew as they progressed through their program	The qualitative findings provide explanatory depth for the survey results by illustrating how curricular experiences, skill development, and exposure to engineering practice contribute to students' confidence in career pathways and workforce readiness.

4.4. Cohort II Survey

Students in Cohort II were assessed using the freshman survey instrument reported in our recently published work [11]. There were 11 qualitative (open-ended free response) questions, and 4 quantitative (Likert scale and ranked choice) questions. The questions were designed to include broad points on student's perspectives and targeted points specific to course learning experiences, including content, benefits, challenges, and opportunities. In (ASEE 2025), four themes emerged in response to the qualitative questions:

1. Shift in students' understanding of the robotics field.
2. Student confidence, positive attitudes, and engagement derived from hands-on experiences.
3. Technical complexity when visualizing concepts.
4. A desire to expand applicable instructions.

Themes 1, 2, and 4 predominantly held true when assessing the responses of Cohort II. There was much alignment between the two cohorts in these thematic areas. Theme 3, however, was not prevalent in the Cohort II responses, possibly due to the timing of when the students were surveyed (a bit earlier in the academic year compared to the previous cohort). Projects pertaining to spatial reasoning, noted as one of the more technically complex topics, had not yet been assigned to the second cohort's students.

Theme 1: Students highlighted the expanded knowledge they learned through their participation in the program. One student shared "we talked about robots and concepts that I didn't know existed." Many valued the greater detail and formality of the topics covered, in contrast to their previous experiences.

Theme 2: Most students shared that the laboratory assignments were the most engaging to them, with some calling out specific projects that they found to be meaningful. Their experiences of debugging and troubleshooting on challenging aspects of these projects often contributed to a feeling of success or reward once they found a solution. This heavily overlaps with the previous cohort's reflections, both groups finding that their learning was significant by the end of the introductory course.

Theme 4: Students shared their desire for even more hands-on opportunities and increased lab time. Note that the weekly laboratory session was doubled after feedback from the previous cohort. When asked what they would change about the course, several indicated their interest in more complex robotics challenges and design prompts.

Next, data from the quantitative questions were analyzed. A small subset of students disagreed with the sentiments shown in Figure 5, a response not expressed by Cohort I [11]. Delving deeper, students who found the course did not impact their professional interests shared that they had already confidently made the decision to pursue robotics engineering previously. Additionally, some students shared that they had prior experiences that they felt were more impactful to their understanding and perspectives of the robotics engineering field. However, a majority of students agreed with both the career interest (83% in Cohort I, 75% in Cohort II) and robotics perspective (100% in Cohort I, 88% in Cohort II) sentiments.

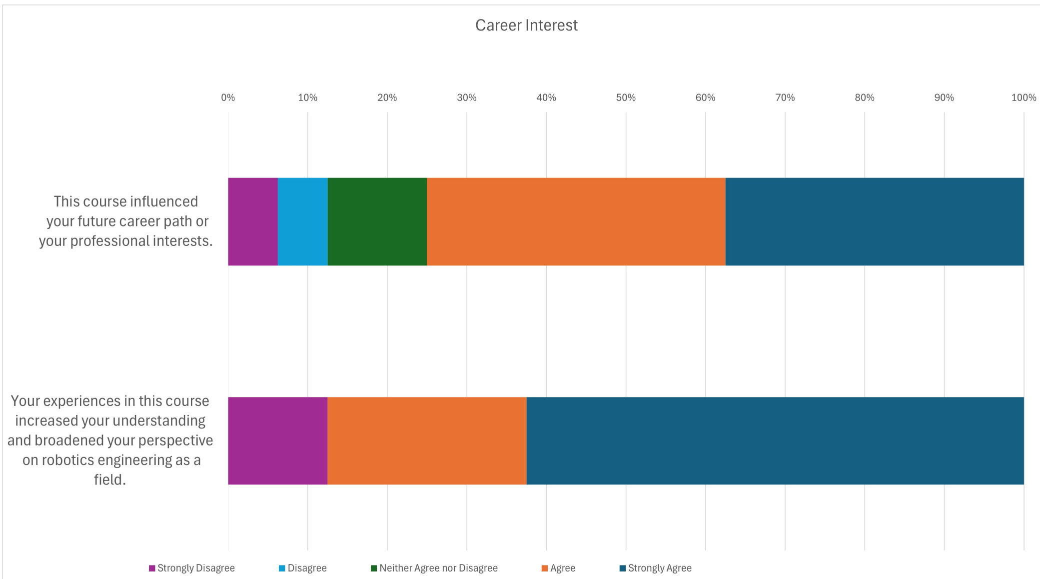


Figure 5. Students' understanding and interest in robotics was mostly affected in a positive direction by participation in the program.

There was more alignment between cohorts in student responses to the course's contributions to their learning in key ABET outcome areas. Both cohorts agreed that their 'Problem Solving Skills and Ability to Design Components and Systems' were most impacted by the course, whereas their 'Ability to Analyze and Interpret Data' and 'Ability to Design and Conduct Experiments' were less so. The largest difference between cohort responses was seen in the data analysis metric, with 69% of students agreeing in Cohort II, compared to the 92% who agreed in Cohort I. However, only a small number of students strongly agreed with this sentiment in both cohorts.

Finally, students were asked to rank in their top three newly learned skills. Students in Cohort II selected a wider variety of skills than in Cohort I. 'Debugging and Testing' was a top selection across both cohorts, but 'CAD' and 'Electronic Circuits' were more commonly chosen by Cohort II. Additionally, Cohort II students selected 'Teamwork,' 'Collaboration,' 'Programming,' and 'Prototyping', which had not been chosen by the previous cohort at all. The 'Simulations' and 'Mechanical Design' skills were selected less frequently by Cohort II when compared to Cohort I. These differences could possibly be due to the timing of when the students were surveyed (Cohort II was assessed a bit earlier in the academic year).

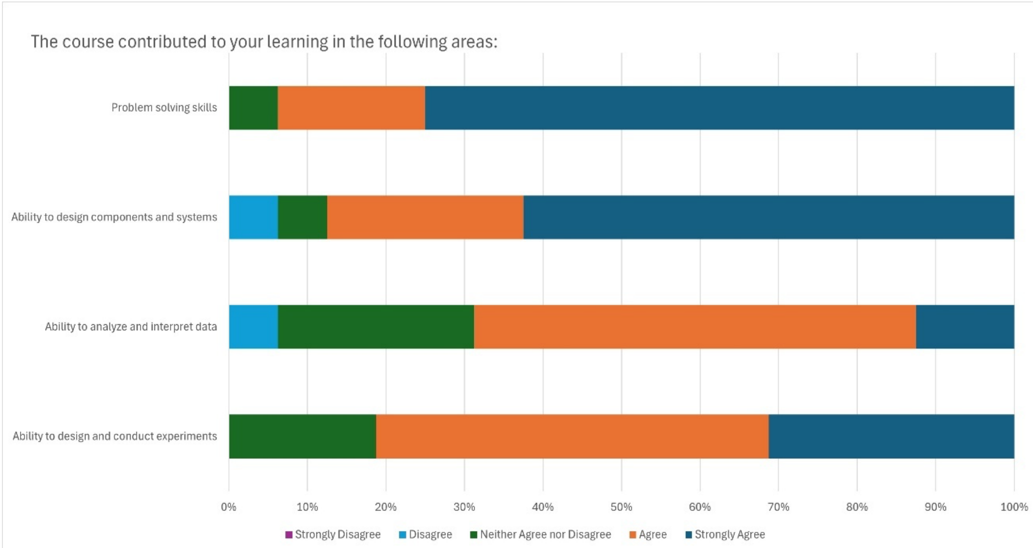


Figure 6. Students generally agreed that the program contributed to their learning in four ABET outcome areas, with "Problem Solving Skills" being the most impacted.

Overall, students in both cohorts came away from their early participation in the program with positive opinions about the robotics field. Students resonated with the project-based curriculum, wanting more opportunities for hands-on experiences to improve their understanding.

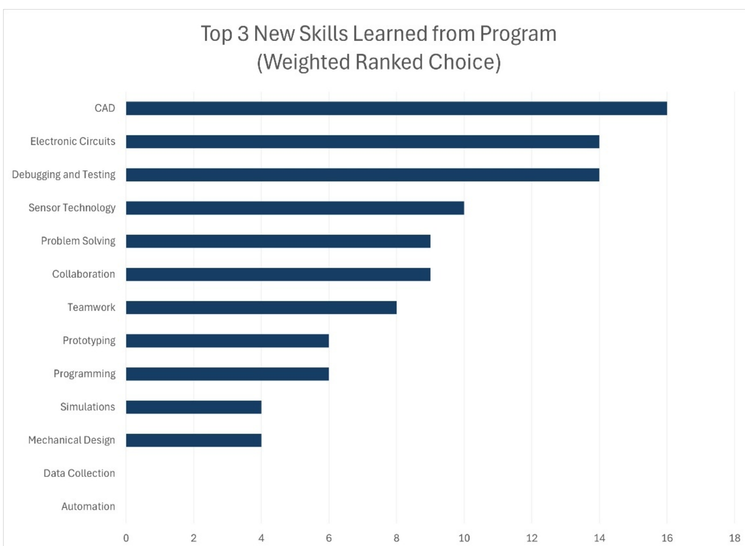


Figure 7. Students ranked the new skills they learned from their participation in the program, with "CAD," "Electronic Circuits," and "Debugging and Testing" being the most common responses.

5. Assessment-Driven Continuous Improvement

Enrollment data showed that Cohort I retained 79% of students from freshman to sophomore year, while the College of Engineering at UNL maintains a first-year retention rate of 85.7%. Some students have switched to other engineering programs while a small number have left the College of Engineering entirely. However, enrollment in sophomore-level courses has recently seen a slight increase as additional students switched into the program. This trend is expected to continue as program awareness further increases.

The college plans to implement the following measures of continuous improvement for current and future cohorts: (a) enhanced pre-enrollment advising with emphasis on creating awareness of the interdisciplinary focus and technical nature of the program and (b) course refinements focused on experiential learning, following positive student feedback about applied learning and (c) increased faculty support incorporating learning opportunities to clarify pathways and course sequencing. As this degree program is further implemented, continuous improvement will be driven by the various factors identified from the longitudinal assessments.

6. Outreach and Recruitment Initiatives

The recruitment efforts for this program were supported by outreach through multiple activities such as faculty-led national representation, student-led community engagement, and local educational activities. Faculty participated in national initiatives through leadership roles in ACM/IEEE International Conference on Human-Robot Interaction (HRI), International Conference on Autonomous Agents and Multiagent Systems (AAMAS), NASA's University Leadership Initiative, and the NSF Robotics Meeting in Washington, D.C. Locally, the group engaged the community through field demonstrations, workshops, and media features on agricultural robotics innovations. The student organization PROTO (Promoting Robotic Opportunities Through Outreach) grew as members engaged young students in local communities through robotics demonstrations. Faculty and students led educational outreach including hands-on robotics workshops and mentoring programs through our state EPSCoR office, strengthening the pipeline for the next generation of robotics engineers and innovators.

7. Limitations and Future Work

While Cohorts I and II represent a relatively small sample, the observed data trends are consistent with expected outcomes for introductory engineering programs. The patterns in skill development, specialization selection, and career awareness align with established benchmarks for student progression and engagement in project-based engineering curricula. Despite the small sample size, this consistency suggests that findings are reliable indicators of program effectiveness and student development. Future work will be focused on building a larger data set around the perceptions of students by inclusion of additional aspects such as the influence of student backgrounds, academic preparation levels and the effect of pre-college exposure to engineering topics.

8. Conclusions

This research examined how the hands-on, project-based Robotics Engineering curriculum supports early engineering identity development in students. The findings indicated that curricular structure contributes meaningfully to identity formation during first years of study. The findings highlight how intentionally scaffolded early curricula can accelerate the three central mechanisms of engineering identity formation. The framework for structured longitudinal feedback presented in this work may be of interest to others considering developing their own robotics (or other interdisciplinary) program.

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References:

1. A. Hirschfeld and C. Imamoglu, "Advanced manufacturing and industry 4.0: The role of engineering education," IEEE Access, vol. 6, pp. 47578–47588, 2018.
2. S. D. Sheppard, A. Colby, K. Macatangay, and W. M. Sullivan, "What is engineering practice?" Int. J. Eng. Educ., vol. 22, no. 3, pp. 429–438, 2006.
3. B. D. Sykes, "Continuous improvement in engineering education," J. Eng. Educ., vol. 94, no. 1, pp. 67–75, 2005.

4. T. Aronson, "Assessment in engineering education: A critical review of current practices and future directions," J. Eng. Educ., vol. 103, no. 4, pp. 532–551, 2014.
5. L. Maykish et. al., "WIP: “We Just Did That”: Building Engineering Identity and Sense of Belonging Through Team Accomplishment in First-Year Design Projects," *2024 IEEE Frontiers in Education Conference (FIE)*, Washington, DC, USA, 2024, pp. 1-5, doi: 10.1109/FIE61694.2024.10892885.
6. Brown, P. R., & Matusovich, H. M. (2013). *Unlocking student motivation: Development of an engineering motivation survey*. Paper presented at 120th ASEE Annual Conference and Exposition, Atlanta, GA, United States.
7. K. M. Tonso, "Student engineers and their identities: Concepts composed through design experiences," J. Eng. Educ., vol. 99, no. 1, pp. 27–42, 2010.
8. J. M. Sense and R. L. Sandler, "WIP: Evaluating the impact of an introductory first-year engineering design course in shaping students' experience and academic preparedness," in Proc. 2015 ASEE Annu. Conf. Expo., Seattle, WA, 2015, pp. 1–10.
9. K. A. Thiemann and B. H. Hamlin, "Implementation of Game-Based Programming as a Means to Engage and Excite Students in First-Year Engineering Courses," *2022 IEEE Frontiers in Education Conference (FIE)*, Uppsala, Sweden, 2022, pp. 1-5, doi: 10.1109/FIE56618.2022.9962382.
10. Lande, M., & Machamer, T. (2022, August), *What is Cool Stuff? Exploring Engineering Students’ Motivation to Be Excited About Their School Activities* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. 10.18260/1-2—41649.
11. Satyala, N., Wagner, R., Daher, T. A., Nelson, C. A., Riley, M. R., Garcia, R. C. C. (2025, June), *Work-in-Progress: Development of a new Robotics Engineering degree in response to industry needs* Paper presented at 2025 ASEE Annual Conference & Exposition, Montreal, Quebec, Canada . 10.18260/1-2—57525.
12. T. A. Aronson, "Assessment in engineering education: A critical review of current practices and future directions," J. Eng. Educ., vol. 103, no. 4, pp. 532–551, 2014.
13. R. A. Reeves, "Measuring learning outcomes in engineering education," IEEE Trans. Educ., vol. 49, no. 2, pp. 294–299, 2006.
14. Godwin, A., *et al.*, “Identity, critical agency, and engineering education,” Journal of Engineering Education, Year.
15. Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research* (3rd ed.). Thousand Oaks, CA: SAGE Publications.
16. Cyr, J. (2017). The Unique Utility of Focus Groups for Mixed-Methods Research. *PS, Political Science & Politics*, *50*(4), 1038–1042. https://doi.org/10.1017/S104909651700124X
17. Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Sage Publications.
18. Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). *Quantitative, qualitative, and mixed research methods in engineering education. Journal of Engineering Education*, 98(1), 53–66. https://doi.org/10.1002/j.2168-9830.2009.tb01005.x
19. Fairhurst, N., Koul, R. & Sheffield, R. Students’ perceptions of their STEM learning environment. Learning Environ Res 26, 977–998 (2023). https://doi.org/10.1007/s10984-023-09463-z.
20. D. E. Blacks, "Engineering identities," J. Eng. Educ., vol. 92, no. 4, pp. 301–311, 2003.
21. K. L. Meyers et al., "Factors relating to engineering student identity and persistence," in Proc. ASEE Annu. Conf. Expo., 2010, pp. 1–15.
22. Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). Engineering change: A study of the impact of EC2000. ABET.

23. Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1998). Characteristics of freshman engineering students: Models for determining student attrition in engineering. *Journal of Engineering Education, 87*(2), 139–149.
24. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101.
25. Xu, W., & Zammit, K. (2020). Applying thematic analysis to education: A hybrid approach to interpreting data in practitioner research. International Journal of Qualitative Methods, 19, 1609406920918810.
26. Corbin, J., & Strauss, A., Grounded theory research: Procedures, canons, and evaluative criteria. Qualitative Sociology*, 13*(1), 3–21, 1990.

Appendix A: Alignment of assessment with ABET Criteria

Assessment Focus Area	Survey Question(s)	Evidence Type	Use for Continuous Improvement
Experiential learning effectiveness	Meaningful hands-on activity or project and its impact on learning	Qualitative	Inform refinement of project-based learning and laboratory design
Skill acquisition and progression	Top three new skills attained; additional skills gained; insights into strengths, weaknesses, confidence	Qualitative	Validate scaffolded curriculum and adjust skill emphasis across courses
Learning gains and confidence	Increased understanding and broadened perspective on robotics engineering (Likert)	Quantitative	Monitor learning outcomes and student confidence trends
Career and specialization awareness	Clarity of career options; preparedness to choose specialization; confidence in understanding professional practice (Likert)	Quantitative	Identify gaps in advising, career mapping, and curricular transparency
Specialization interest and motivation	Intended specialization; motivation for specialization choice	Qualitative	Inform curriculum pathways and advising strategies
Curriculum role in specialization clarity	How coursework prepared students to understand specialization differences	Qualitative	Assess effectiveness of curricular exposure to subfields
Career pathway alignment	Robotics-specific career pathways of interest	Qualitative	Align coursework and experiential opportunities with industry pathways
Decision-making challenges	Challenges faced in selecting a specialization	Qualitative	Identify barriers and target program-level interventions
Student support and resources	Desired additional support, resources, or guidance	Qualitative	Guide enhancements to advising, resources, and student support mechanisms