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Work-in-Progress: Development of a new Robotics Engineering degree in response to industry needs

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WORK-IN-PROGRESS: DEVELOPMENT OF A NEW ROBOTICS ENGINEERING DEGREE IN RESPONSE TO INDUSTRY NEEDS

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1. ABSTRACT

This "Work in Progress" highlights development of a new B.S. program in robotics engineering in response to local employer needs. As with many states, Nebraska has a dearth of workers available to support a growing manufacturing industry. Many companies are introducing automation onto their facility floors and now have a growing need for staff engineers who can design systems, organize updates, and design processes that fully utilize automation capabilities. In response to this need, the University of Nebraska-Lincoln faculty have designed a new B.S. degree program in robotics engineering to support automation, while at the same time incorporating robotics research and development in areas of agriculture and natural resources, manufacturing, biomedicine and human health, and transportation and infrastructure. This "Work in Progress" paper will outline the steps we have taken to utilize faculty input and established curriculum to develop an interdisciplinary program requiring a small number of new courses yet still meeting both ABET requirements for mechatronics and robotics and partner interest. Student reflections on the program and its first course offering are to be gathered, along with reactions from faculty, to drive ongoing continuous improvement.

2. INTRODUCTION

Digitally connected factories and robot-driven production processes have been highlighted as the future of the manufacturing industry [1]. A growing national interest in accelerating industrial capacity and modernizing education through capitalizing on advanced robotics systems supported by artificial intelligence tools redefines the role of educational institutions in paving the way for the projected technological transformations. Rapid technological developments accompanied by an immediate need for expansion of automation processes necessitate a high degree of collaboration between universities and industry for training the workforce [2]. To address the skills gap and the shortage of skilled workers across the nation, engineering schools have been investing in curriculum advancement aimed at supporting smart manufacturing and industrial automation [3].

Nebraska is ranked 11th in the nation for the strongest manufacturing environment by *Economic Leadership*, with an annual GDP contribution of over $21 billion [4]. The emerging technologies in robotics and automation are predicted to be key drivers of local agricultural, manufacturing, and logistics industries that are core to its economy. Following the lead from its industry partners, the University of Nebraska-Lincoln College of Engineering conducted a market analysis in 2021 to determine the current and future trends in these growing areas of technology. This analysis indicated a strong need for a technology-focused program in robotics and automation to support local industries. More specifically, this analysis showed that: (a) there is a lack of structured training programs to create skilled professionals for local companies in their projected growth, and (b) Nebraska's local industries could benefit from a degree/training program that focuses on experiential learning through capstone projects, internships, and directed studies.

Recognizing the need for development of such a program, a team called the Heartland Robotics Cluster acquired federal grant funds to in part create new training activities [5]. This grant funded program includes in-state community college partners developing 2-year programs to train the technical workforce while other partners are developing upskilling and re-skilling programs for working professionals. Through this funding, the University of Nebraska-Lincoln College of Engineering has developed a four-year Bachelor of Science degree program in Robotics Engineering. The program collaboratively connects outcomes from multiple majors, making it a unique multidisciplinary program aimed at the development of a pipeline of skilled engineering professionals. The intent is to pursue ABET accreditation.

2(a). Goal of this work

The new robotics engineering program is designed to meet the needs of local industry but also has a student population drawing from a region that hosts numerous robotics competitions for students in middle and high schools. Many incoming students begin with more than a basic understanding of robotics tools and technologies. To meet the learning needs of this diverse student population, we have implemented proven pedagogical approaches, such as project-based learning and evidence-based teaching strategies. The goal of the present work is to create an evaluation process to understand the impact of such teaching methods on this new program. The first step is to measure the impact of student learning with focused surveys [6][7][8]. We present a multi-theme inquiry-based approach to collect feedback from students, highlighting the industry-aligned interdisciplinary curriculum structure, paired with a continuous improvement strategy based on feedback from students. This inquiry-driven strategy will systematically acquire the perspectives and experiences of students in the curricular activities of this new program.

3. SCHOOL'S INNOVATIVE PROGRAM AND CURRICULUM

Presently, the College of Engineering offers a minor in Robotics Engineering that consists of courses in the areas of programming, controls and embedded systems. This program has an average enrollment of 20 students and the matriculation rate in the minor is small (averaging 3 students per year), due to the difficulty in completing the requirements on top of a nominal academic load. The proposed full-fledged Bachelor of Science major in Robotics Engineering provides an alternative where students can specialize in robotics design, controls, and applications (as opposed to layering robotics coursework on top of a separate major program of study). Building upon the foundation of the existing Robotics Engineering minor, this new major seeks to attract a diverse group of students who are motivated to pursue a career in robotics. The program blends foundational engineering courses with the core topics of robotics in the areas of software engineering, mechanical engineering and electrical engineering. The program is designed with ten courses unique to field while relying upon foundational courses from the more traditional disciplines.

To achieve this interdisciplinary approach, the major was collaboratively developed by a cohort of faculty of the School of Computing, Department of Electrical and Computer Engineering, the Department of Mechanical and Materials Engineering and the Department of Biological Systems Engineering. The college aims to officially launch this program in Fall 2025. Year 1 courses are currently being offered in the 2024-2025 academic year as part of a “soft launch” for this new major.

This new major offers a strategic combination of specialized courses in programming, controls, electronics, manufacturing and embedded systems. The program offers a separate pathway in three areas of specialization: Software Engineering, Mechanical Engineering, and Electrical Engineering. The program features interdisciplinary curriculum, research and development, and industry partnerships to focus on local needs. Students will gain hands-on experience in designing, implementing, and optimizing robotic systems through the curriculum, comprehensive projects, and experiential learning opportunities. The College will seek accreditation for the program from ABET. All other eligible University of Nebraska-Lincoln College of Engineering degree programs either have ABET accreditation or are currently seeking initial accreditation.

3(a). Curriculum Structure and Content

The resulting program has a total of 128 credit hours, including a combination of technical and general education courses. The outcomes are primarily focused on developing expertise in the design and operations of hardware, software and smart control systems for robotics. At the core of the program is a 10-course (30 credits) Robotics Engineering-focused curriculum, which covers the most essential topics and relevant hands-on training. The program also includes multiple elective offerings from each of the foundational disciplines, allowing students to specialize in one of these as they matriculate. The year-wise sequence of topics covered in the core curriculum is shown in Figure 1. This "Robotics Core" combines foundational topics and concentrated technical coursework supplemented by the requirements in foundational mathematics to meet a wide range of learning outcomes. Sample course outlines from the Robotics Core are shown in the Appendix section.

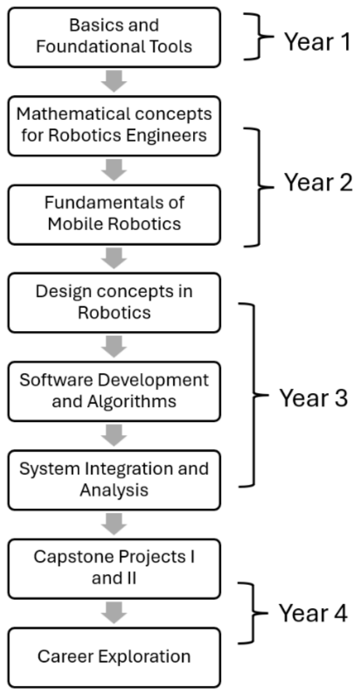

Figure 1. Core topics covered in the Robotics Engineering Major

All students in this program are required to enroll in the Robotics Core courses and a common set of foundational courses during Year 1 and Year 2 followed by a sequence of courses affiliated to their choice of specialization in Years 3 and 4 as listed in Table 1. Furthermore, Years 3 and 4 include multiple options for elective courses that allow for deeper exploration of topics. The program offers interdisciplinary projects as part Capstone I and II courses that would include designing, analyzing and solving real-world engineering problems related to robotics as the primary outcomes.

The following is the year-wise curriculum structure for all three specializations:

Table 1. Course summary of the Robotics Engineering Program

Year 1	Foundational Year	Basic courses in mathematics, physics, computer programming and Engineering seminar
Year 2	Core Engineering Knowledge Year	Courses focused on Embedded Systems, Electronic Circuits I, Data Structures, Statics and Differential Equations

Year 3	Specialized Discipline Year	*Common courses*: Dynamics and Control, Engineering Dynamics, Signals and Systems, and Statistics *Specialized pathway courses*: Software Engr.: Advanced Embedded Systems, Computer Organization Mechanical Engr.: Engineering Design, Kinematics Electrical Engr.: Electronic Circuits II, Microprocessor Systems Design
Year 4	Practical Application and Industry Exposure Year	*Common courses:* Capstone I and II, Career Exploration *Specialized pathway courses*: Software Engr.: Computer Vision, Software Engineering for Robotics, Operating System Kernels Mechanical Engr.: Robotics Kinematics and Design, Control Systems, Mechatronics Systems Design Electrical Engr.: Electric Machines, Embedded Microcontroller Design, Power Electronics, Linear Control Systems

The topics from the Robotics Core combined with the pathway courses (Table 1) bring together a comprehensive set of learning outcomes that will allow the students to identify, formulate, and solve complex engineering problems in the field of robotics and automation. This educational program is designed so that, within a few years of graduation, the Robotics Engineering graduates will:

- Have established successful careers in robotics, automation, or related fields, demonstrating their ability to apply principles of robotics engineering to responsibly solve complex problems.
- Engage in continuous learning and professional development to stay abreast of advancements in robotics and emerging technologies.
- Demonstrate leadership, ethical conduct, and effective communication in multidisciplinary teams, contributing to the progress of the robotics profession and society.
- Contribute to the advancement of robotics and automation through innovation, research, or entrepreneurial endeavors, showcasing the ability to push the boundaries of knowledge and technology in the field.

3(b). Program Pathways

Aiming to meet the multidisciplinary educational requirements and industry standards for a comprehensive skillset, the Bachelor of Science in Robotics Engineering degree program builds upon the Robotics Core curriculum (10 courses). The core curriculum leads into the three specialized pathways as shown in Figure 2. These pathways aim to satisfy the robotics field's multidisciplinary educational requirements and industry standards for a comprehensive skillset. The Robotics Core curriculum provides the necessary pre-requites for students to be successful in their chosen pathway. Students enrolled in this program are required to choose a pathway after the foundational stage (Year 1).

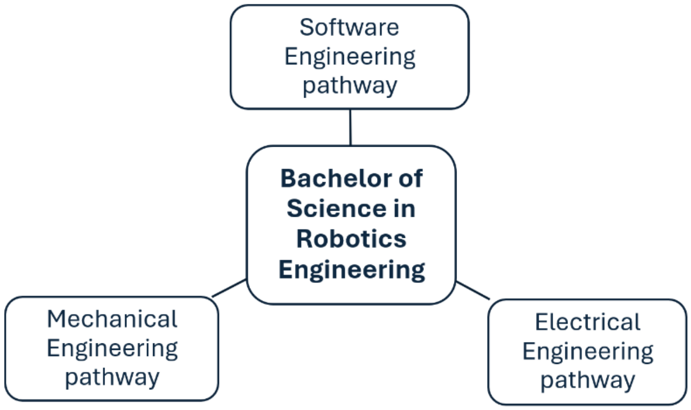

Figure 2. Robotics Engineering Pathways at University of Nebraska-Lincoln

Software Engineering pathway:	For students opting for expertise in software development, algorithms and programming methods
Mechanical Engineering pathway:	For students opting for expertise in mechanical design concepts and control systems
Electrical and Computer Engineering pathway:	For students opting for expertise in hardware programming, electronic circuits and system engineering

3(c). Sample Course Overview

The first course to be developed in the Robotics Core sequence was COURSE 1: INTRODUCTION TO ROBOTICS. An inaugural class of 15 students participated in its initial offering during the Fall of 2024, a "soft launch" of the new major. Students were exposed to various robotic platforms, including mobile ground vehicles, unmanned aerial vehicles, robotic arms, and cobots as an introduction to the field of robotics engineering. The course provided essential introductory skills and experiential learning opportunities through lectures, laboratories, and off-site learning visits. Project-based learning was incorporated into course activities, with the following learning objectives:

1. Describe and interpret basic components of robotic systems.
2. Comprehend the working principles of different types of robots (ground, aerial, and manipulators) and demonstrate their applications.
3. Assemble, program and operate various automation systems with programmable hardware for robotics applications.
4. Design, build, prototype, and test various robotic systems in conditions similar to real-world applications.

A weekly instructional sequence consisting of two lectures followed by one laboratory session was implemented. This allowed for structured coverage of topics, while incorporating time for students to perform relevant hands-on activities. The first half of the course was focused on teaching principles of motion and control of autonomous vehicles using basics of programming, electronics and sensors. Students applied these basic robot algorithms and control controls concepts to an autonomous mobile robot equipped with various types of sensors. A key learning outcome for students was the development of an algorithm to successfully navigate a customized maze using sensor-based obstacle avoidance. Later in the course, students worked in teams on a guided cumulative project to design, fabricate, and integrate a gripper for a 6 degree-of-freedom robotic arm. Students were assessed on the basis of their design and fabrication activities, programming and troubleshooting processes, and the demonstration and presentation of results. Finally, the course incorporated career awareness activities, such as site visits to university partners. State-of-the-art industrial robotics system demonstrations were organized by Nebraska Innovation Studio for students. Students also attended a Robotics-themed industry conference to learn about opportunities and career pathways in the field. Future course offerings would include industry tours and research lab visits as additional extracurricular activities.

3(d). Continuous Improvement Strategy/Approach

A data-driven strategy is implemented to evaluate and address student needs by way of feedback collection. The process began at the conclusion of the introductory course, with a survey inviting the students to provide input on their class experiences. The questions in this survey were designed to capture student input on several themes pertaining to learning outcomes. Such feedback in this early stage of the program will allow assessment of progress towards the broader goals of the new major.

A thematic survey model focused on outcome assessment and measurement of student satisfaction was developed as the data collection tool. The responses from the student cohort will be utilized for curriculum enhancements and feedback for faculty development. The objectives of this research and the survey question's respective themes are shown in Table 2. First investigated are students' impressions regarding the course and the effectiveness of project-based learning activities. Next assessed were the skills students acquired during the course, through the lens of required outcomes but also based on the students' self-perceptions. Finally, student perspectives on the field of Robotics and their future career paths were examined. On a broader scale, these themes support the goals of the new Robotics major, and its context within the local community. The survey questions consist of both open-ended and Likert-scale questions to appraise students' perspectives. The questions associated with each research objective are also shown in Table 2.

Table 2. Survey model: Themes and research objectives

Theme	Research Objective	Prompts to Students
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?
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?
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 d. Problem solving skills
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?
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?

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?
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?

3(e). Data Collection and Analysis

For this work in progress, student input around the themes shown in Table 2 were collected from the Year 1 courses. Both quantitative and qualitative data were obtained through post-course surveys for collection of actionable data for institutional and curricular enhancement. The data were analyzed to look for patterns indicating modifications or improvements for future course offerings.

The student perspectives survey contained several qualitative questions aimed at gaining a deeper understanding of students' experiences in the course and reflections on the robotics program. These questions gathered broad perspectives on robotics engineering students' learning experiences, established a baseline of students' prior knowledge, and asked direct questions about course content, benefits, challenges, and opportunities. Qualitative analysis was used to analyze 11 open-ended questions.

A thematic analysis technique was employed in line with the strong standing in the literature for use when interpreting patterns of meaning from text and is best suited for making sense of a phenomena or perspectives [9]. The thematic analysis allows a level of flexibility when generating codes, combining codes into themes, reviewing and naming themes and reporting on the results of the analysis. Two researchers independently coded the open response texts, compared themes and agreed on three emergent themes that are the result of the coding and re-coding process.

Theme 1: Shift in students' understanding of the robotics field. Students were able to affirm long-standing interests. One student said, "I've known for a while I want to go into the robotics field, but this course confirmed that decision for me." More specifically, within this theme, a strong sense of appreciation of robotics as its own specialty was evident. Students reflected on how it is connected to engineering disciplines and courses. Literature is supportive of this theme; students view programs with strong industry connections as leading to enhanced future opportunities [10].

Theme 2: A predominant theme that emerged from the analysis was students' confidence, positive attitudes, and engagement that derived from hands-on experiences. Literature heavily favors the use of evidence-based instructional strategies to promote learning and motivation. For example, Garcia et al. report on students' positive perceptions in motivation about their courses and related areas, and the ability to obtain higher-level skills through hands-on opportunities [11]. The emergence of this theme is also in agreement with the literature on Project Based Learning (PBL). Hands-on learning with PBL positively impacts engagement, motivation and overall student satisfaction. Typically, students felt better prepared for futures in the industry [12]. Students referenced labs and evidence-based instructional strategies as central to their learning and as a driver of their technical growth in the field. Many students viewed their own learning in the course as significant. For example. one student stated, "The final project... was satisfying seeing our creation come to life and work."

Theme 3: Technical complexity when visualizing concepts. This particular theme emerged from the researchers' desire to gain insight into students' challenges. Students reported difficulty with spatial reasoning when applying formulas such as degrees of freedom, for example. Some insight into this theme comes from Garmendia et al., who posit that reasons for learning deficiencies and difficulties may be due to gaps in procedural instruction or explaining forms of reasoning [13]. They suggest looking to increase the interactions of multiple representations of these models. As part of this theme, our students reported that any part of their learning experiences that lacked immediate application or visual reinforcement was viewed as cognitively draining. The literature reports that students with high spatial skills allow more time for problem design and feasibility analysis, and this might impact course design moving forward [14].

Theme 4: A desire to expand applicable instruction. Themes 3 and 4 build on each other in that students provided recommendations for increased engagement with circuitry, sensors, in-class robot demos, and end-to-end design projects to strengthen their understanding of concepts. “The more time in the lab the better,” one student stated. Students wanting to have even more hands-on experiences are in line with the literature. For example, McNeill et al. found that students see increased experience as essential to solving more complex problems [15].

The student perspectives survey additionally contained quantitative questions. Likert scales and ranked choice questions were used to probe student’s career interest in the robotics field and their general impressions about their learning thus far in the program.

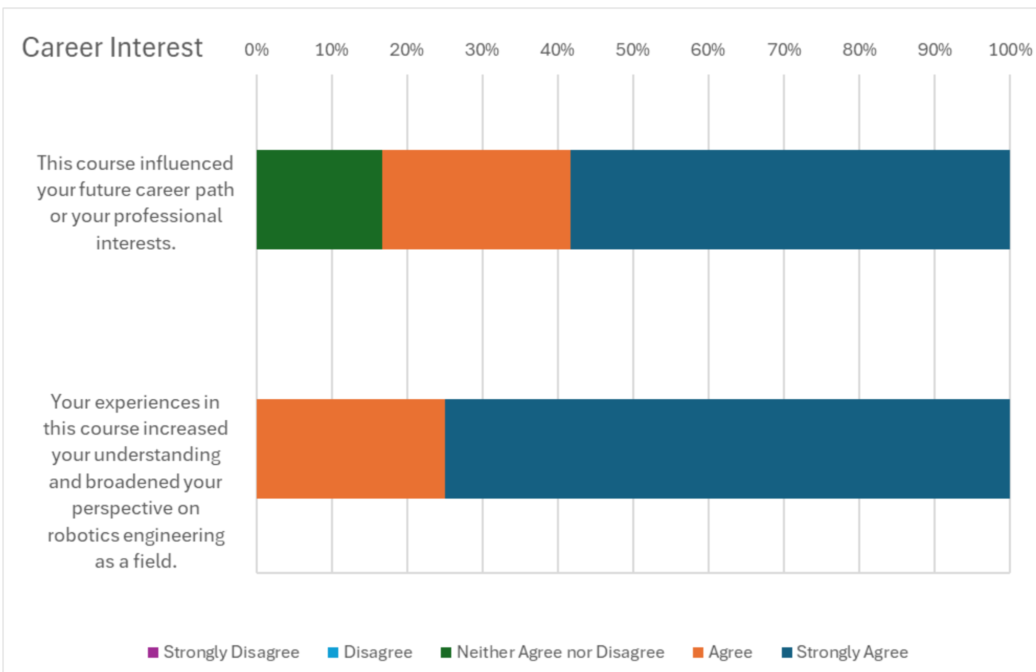

Figure 3. Student’s understanding and interest in robotics was positively affected by participation in the program.

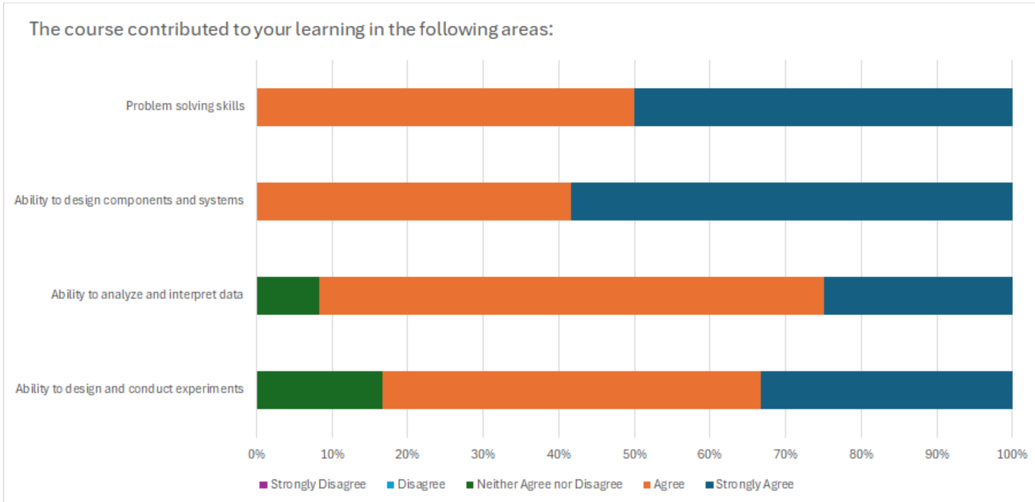

Figure 4. Students generally agreed that the program contributed to their learning in four ABET outcome areas, with Problem Solving Skills being the most impacted.

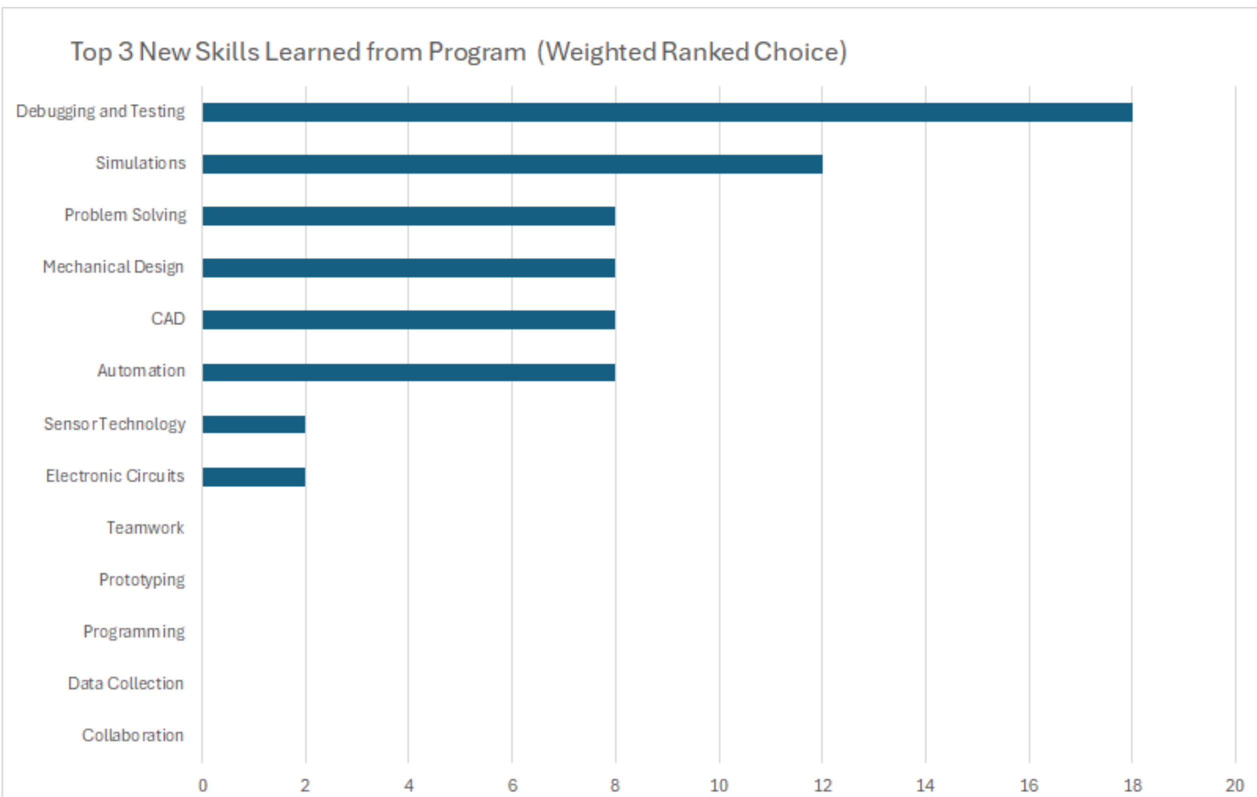

Figure 5. Students ranked the new skills they learned from the program thus far, with "Debugging and Testing" outpacing many other key skills. Problem Solving, Mechanical Design, CAD, and Automation tied for the third-most acquired skills.

In conclusion, the themes identified in this study collectively provide a comprehensive overview of student experiences within this new engineering program at the University of Nebraska-Lincoln. These findings highlight how a structured, programmatic approach was implemented to systematically incorporate and fulfill multiple student-focused course outcomes. This approach not only ensured consistency and coherence across the new curriculum but also aligned closely with the learning objectives and competencies outlined by ABET accreditation standards. The results underscore the effectiveness of intentional project-based curriculum design in enhancing student learning, promoting skill development, and ensuring that graduates are well prepared to meet the demands of the engineering profession. The University plans to expand and utilize this data collection tool as needed for future courses in the program.

4. Strengths of the Program

With an industry-aligned and outcome-focused combination of foundational courses and core curriculum, the primary features of this new program are:

1. The three pronged (specializations) customizable curriculum supported by the robotics core offers a dedicated pathway into each specialization.
2. With established support from various partners of the Heartland Robotics Cluster, such as the Nebraska Innovation Studio, and Nebraska Manufacturing Extension Partnership, the program features extended local career exploration opportunities to students.
3. Hands-on learning through state-of-the-art laboratories, design projects, and internships with industry partners, allows students to apply their knowledge to real-world challenges. The laboratory component for each course will be taught using equipment purchased through the U.S. Economic Development Agency's recent Build Back Better Regional Challenge (BBBRC) award to the University of Nebraska-Lincoln for development of this new robotics program [5].
4. Supporting students through opportunities in research and development activities in the College of Engineering.
5. Engagement through competitive robotics activities for skill development, innovation and networking.
6. Faculty teaching in the program participate in evidence-based instructional strategies training on curriculum design. These training programs are offered through the Engineering and Computing Education Core (ECEC), a core facility in the college focused on faculty training for post-secondary education excellence and curriculum development.

The laboratory components of the courses are designed to provide students with extensive hands-on experience in alignment with industry skills, while emphasizing critical thinking, problem solving and collaboration skills.

4(a). Experiential Learning

Students graduating from this program should attain a diverse set of engineering skills due to the curated coursework aligning with the emerging needs of the robotics industry. As such, the activities in the Robotics Core courses follow a Project-Based Learning (PBL) approach with emphasis on experiential learning, industry exposure, and extracurricular activities. This pedagogical approach focuses on students constructing knowledge through meaningful learning experiences that focus on real world problems. Our decision to follow the recommendations of PBL is in part due to the strengths this learning model presents. PBL fosters self-regulated learning, directs students to reflect on their learning, and promotes engagement [16]. The Year 1 courses offered in Fall 2024 and Spring 2025 include several hands-on activities aimed at developing skills in design, troubleshooting, and problem-solving. This is in line with key outcomes focused on skill development by application of concepts to hardware and software systems. A similar approach will be implemented for future core courses with focused course objectives integrating theoretical knowledge with hands-on experience. For example, the Capstone I and II courses in Year 4 will be designed with guidance from local industry experts and partners from the Heartland Robotics Cluster, enabling curriculum relevance. Leveraging the University of Nebraska-Lincoln's partnerships with private-sector entities across Nebraska will additionally further students' preparation to enter the job market. Students will be involved in several career exploration activities, such as internships and job shadowing, in Year 4.

4(b). Interdisciplinary Research Focus

University of Nebraska-Lincoln's active research environment is an added advantage to the students in this program. Students will have the opportunity to collaborate and learn from faculty and graduate students about their cutting-edge research across multiple departments. Faculty expertise in robotics research extends to areas such as medical robotics, aerial robotics, ground robotics, multi-robot systems, agricultural robotics and educational robotics. This collaborative environment not only ensures that students are able to identify areas of career interest but also pursue graduate education and gain insights into the research and development aspects of Robotics Engineering.

5. CONCLUSION

The launch of the Robotics Engineering program at the University of Nebraska-Lincoln is a timely and strategic response to the evolving needs of local industries. By equipping students with cutting-edge skills and fostering strong ties with industry, University of Nebraska-Lincoln is not only addressing a critical workforce gap but also laying the groundwork for a more innovative and prosperous Nebraska. By means of diverse teaching approaches, such as project-based learning and experiential learning, the course curriculum encompasses a wide range of skill development processes. The program development, accompanied by a custom methodology for continuous improvement, creates a unique structure for implementation of a data-driven evaluation process. This initiative exemplifies the university's commitment to its land-grant mission of serving the state and its people, ensuring that Nebraska remains competitive in an increasingly technology-driven world.

ACKNOWLEDGEMENTS

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APPENDIX

Sample course outlines from the Robotics Core:

COURSE 1: INTRODUCTION TO ROBOTICS (3 Credits)
Overview of robotics as an engineering discipline. Provides essential introductory skills and experiential learning opportunities through lectures, laboratories, and development of a robot prototype to solve a real-world problem. Incorporates foundations of sensing, actuation, movement, and control presented through design, build, and operation of robotic systems. Introduction to basic robot fabrication and prototyping techniques. Students work in teams and construct a mobile and manipulator robot. This course establishes an ethical foundation for robotics engineers.

COURSE 2: ROBOTICS TOOLS (3 Credits)
Introduces foundational tools for design, simulation, and code management in robotics including SolidWorks, Matlab, ROS, IDE, Github, Altium. Principles are applied to problem scenarios in utilization of robotics and automation to address practical challenges. Introduction to basic computer programing and embedded systems. Provides an introduction to engineering economics and covers topics in CAD, discrete math, and Boolean logic.

COURSE 3: ROBOTICS ANALYSIS CORE (computational linear algebra) (3 Credits)
Mathematical fundamentals of robotic systems, including vectors, matrices, spatial coordinates, and data processing techniques such as regression. Application of calculus and linear algebra with computational methods and concepts to topics of search and optimization algorithms, positions and trajectories, and robotic sensing.

COURSE 4: CAREER EXPERIENCES (1 Credits)
Student participation in hands-on experience in a professional setting which may include participation in areas of robotics, mechanization, or automation-related industries of agriculture, environment, manufacturing, or medicine.

COURSE 5: MOBILE ROBOTICS (3 Credits)
Introduction to the primary issues spanning the field of mobile robotics, including: robot system design considerations, robot and world coordinates, low-level control (feedback control) and robotics control architectures. The lab focuses on the practical implementation of autonomous robot control on a real mobile robot using behavior-based methods in the C language.

COURSE 6: ROBOTIC DESIGN AND CONTROL (3 Credits)
Fundamentals of mechanical and electronic design, control, and fabrication essential for realizing robotic systems. With an emphasis on both analysis and hands-on skills, students engage in practical applications of rigid-body motion, machine elements, and interfacing sensors and microcontrollers.

COURSE 7: ROBOTIC SOFTWARE AND ALGORITHMS (3 Credits)
Algorithms and programming for robotics and artificial intelligence in C++ and high-level scientific programming languages; autonomous navigation and search algorithms; introduction to models of computing through graphs and graph algorithms. Robot Operating System (ROS) and challenges students to develop and implement algorithms in ROS. Mapping, localization, data fusion, Simultaneous Localization and Mapping (SLAM), vision processing, communication, and controls.

COURSE 8: ROBOTIC SYSTEMS INTEGRATION (3 Credits)
Focuses on the practical application of robotics by building on core skills with application of analog and digital electronics for robotics including prototyping, testing, debugging; interfacing microcontrollers; and embedded systems that support integrated robotic design. Students create robotic solutions to address a topic in automation. Provides deeper academic support in the subject of engineering economics.

COURSE 9: CAPSTONE I (3 Credits)
The first of two courses in the capstone sequence. Definition, scope, analysis, and synthesis of a comprehensive design problem in a team project focused on utilizing robotic concepts to create solutions. Course includes design reviews and reports. Professional practice through familiarity and practice with current tools, resources, and technologies; professional standards, practices, and ethics; and oral and written report styles used in the robotics field.

COURSE 10: CAPSTONE II (3 Credits)
Provides students with the opportunity to showcase advanced skills and knowledge in a final capstone project, demonstrating their readiness for the professional world of robotics. Includes a substantial robotic engineering project requiring hardware-software co-design, planning and scheduling, teamwork, written and oral communications, and the integration and application of technical and analytical aspects of robotics.