Integration of Robotics Codes and Standards into the Occupational Safety Engineering Curriculum

Final Project Report

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Abstract

This project aimed to develop publicly accessible and customizable instructional modules on collaborative robotics safety codes and standardization for two upper-level courses: "Occupational Safety Engineering" (undergraduate/master split level) and "Human Factors Applications" (upper-level undergraduate).

Over the past decade, there has been continuously growing interest in the application of collaborative robotics in the industry, leading to rapid advancements in standardization in this area. A better understanding of safety standardization by both workers and system designers in human-robot interaction is critical to supporting the broader adoption of such technologies. Robotics developers, integrators, and end-users all require sufficient awareness of related standards and codes. Additionally, there is a strong need to educate STEM students on the importance of robotics safety codes and standardization, making this knowledge a strategic asset for their future careers.

Accordingly, the developed course modules included: (1) A 4-week student-driven program for Occupational Safety Engineering, and (2) A 2-week module for Human Factors Applications, featuring clear guidelines, engaging content, and rich personalized support.

The course modules covered the most essential industry robotics standards (i.e., ISO 10218-1, ISO 10218-2, ISO/TS 15066:2016, and ANSI/RIA R15.08-1-2020) in a highly interactive manner to foster better learning outcomes. Furthermore, the modules were designed with an open-source approach in mind, with highly modularized content to facilitate easy replication by other institutions.

Throughout the first year of the project, we worked closely with industry partners to identify real-world examples of worker-robot interaction, design challenges, and applications. These examples were documented and integrated into both the instructional modules and the evaluation materials.

Project Rationale and Significance

Although robotics technology has been growing rapidly worldwide, the projected workforce in the United States remains insufficient to meet the future demands for robotics applications across various industries. Robotics development is recognized as being in the national interest, and providing training in robotics standards literacy for the next generation is an essential component for fostering the skills needed in the robotics industry.

This project addressed this national need by developing publicly accessible and customizable instructional modules focused on collaborative robotics and automation safety standardization. The primary development work was conducted at the Department of Industrial and Systems Engineering (ISE) at the University of Florida (UF), with the materials disseminated to partnering institutions of higher education, non-profit organizations, and industry enterprises through multiple mechanisms.

The new instructional content was integrated into two existing UF courses: (1) Occupational Safety Engineering (EIN6216), a graduate/undergraduate split-level course, and (2) Human Factors Applications (EIN4245), an upper-level undergraduate course.

Both courses are part of the Safety Engineering Graduate Certificate program offered by UF ISE, a program co-founded by PIs Hu and Giang. All courses included in the Safety Certificate are available both on-campus and through the UF EDGE (Electronic Delivery of Gator Engineering) online program, making the new modules accessible not only to on-campus students but also to distance learning participants, industry professionals, and federal agency employees.

During the first year of the project, all UF students enrolled in the targeted courses gained access to these new instructional modules. In the second year and beyond, a specific website and materials were established for disseminating teaching materials to peer institutions to ensure broader accessibility and sustainability.

The motivation for this project stems from the increasing integration of collaborative robotics in industrial settings, particularly manipulators and mobile robots. According to a report by the

International Federation of Robotics, 1.7 million new robots were implemented in factories between 2017 and 2020, with at least a 15% annual increase in adoption rates. Despite this rapid growth, fatal and non-fatal injuries involving industrial robots also rose significantly during this period.

Research from NIOSH and other organizations highlighted numerous robotics-related incidents, underscoring that human safety must be a top priority in human-robot collaborative environments. Without a strong emphasis on robotics safety education and standardization literacy, workers may face elevated risks of injury or death when interacting with autonomous systems.

At the same time, negative public perceptions surrounding robotics, particularly concerns about safety deficits and job displacement, remain widespread. Many of these barriers can be addressed through improved public education, better robotics safety standardization training, and equipping future system designers with the necessary tools to create safe human-robot collaborative workspaces.

A substantial knowledge gap in occupational safety regulations and collaborative robotics applications still exists, and bridging this gap is critical for enabling humans and robots to routinely and safely share environments. Furthermore, as robotics applications extend into unstructured, dynamic settings, such as logistics, healthcare, agriculture, construction, and mining, the ability of workers to interact safely with increasingly autonomous systems becomes even more vital.

Recognizing these needs, this project focused on embedding robotics safety standardization education into STEM curricula at both undergraduate and graduate levels. Robotics developers, integrators, and end-users all require foundational knowledge of relevant codes and standards, and strengthening this educational foundation will serve as a strategic asset for future employers and society at large.

Importantly, for educational institutions to strengthen their robotics safety curricula, they require collaboration and support from industry. Educators must also have access to resources and training opportunities in robotics safety disciplines. By developing modular, open-source course content based on real-world examples and essential industry standards (ISO 10218-1, ISO

10218-2, ISO/TS 15066:2016, and ANSI/RIA R15.08-1-2020), this project contributed to filling this emerging and critical gap.

Through the development and delivery of these modules, the project specifically addressed several key barriers observed by the PIs in prior teaching experiences: (1) Application to real-world scenarios: Students often struggled to absorb safety codes and standards without clear, applied context. Embedding standards into real-world case studies helped bridge this gap. (2) Developing a systems-level perspective: Safety engineering requires cross-disciplinary collaboration, yet students frequently compartmentalized problems as "outside the scope." The course modules emphasized collective learning and interdisciplinary problem-solving to cultivate this critical systems thinking mindset.

Overall, this project significantly advanced robotics safety education at UF and provided a scalable, replicable model for broader adoption across institutions and industries.

Project Course Design

Two course modules were developed to support the integration of collaborative robotics safety standardization into existing curricula. The first module was designed for the Occupational Safety Engineering course and was structured as a 4-week student-driven program, while the second module was designed for the Human Factors Applications course and delivered as a 2-week industry case-study-driven program.

Both modules were created with clear guidelines, engaging content, and rich personalized support mechanisms to maximize student learning outcomes.

The content and structure of the two modules are summarized below (Figures 1 and 2).

Project Results and Discussion

(1) Course enrollment summary

EIN 6216 / EIN4216 (Occupational Safety Engineering): (1) In 2023 Fall, there are 63 students registered for the EIN4216 section (undergraduate), and 13 students registered for the EIN6216 section (graduate). The total course enrollment exceeds even the most optimistic estimate by the PIs. We had initially expected between 35-45 students based on previous years' records. This outcome reflects the diligent efforts of the PIs in actively promoting the course through various channels and holds the potential to enhance the impact of the proposed work. (2) A total of 50

students registered for the EIN4216 (undergraduate) section and 19 students registered for the EIN6216 (graduate) section. Although there was a slight shift in the distribution between undergraduate and graduate enrollment, the overall enrollment remained stable compared to the previous year, indicating the sustained interest and institutionalization of the course content.

EIN4245 / EIN6905 (Human Factors Applications): (1) The first offering of the module in 2023 Spring had a course enrollment of 27 students. This was a large increase over the first offering of the course in 2022 spring which only had 11 students (7 undergraduate, EIN4245, and 4 graduate, EIN6905). The large enrollment increase was a result of great student interest in the human systems engineering track at the undergraduate level, and interest in the presented course topics (including the human-automation and human-robot module). (2) Course enrollment increased again in Spring 2024 to 33 students, showing the steady growth of the track and interest in the topics presented in the human-robot module. (3) While outside of the performance period, course enrollment has continued to increase with another substantial jump in enrollment in Spring 2025 to 48 students and the impacts of the new revisions on course content and module revisions that has happened year on year.

Lecture Unit	Document Number	Content
1	N/A	Orientation session
2	ISO 10218-1:2011	Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots
2	ISO 10218-2:2011	Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration
2	ISO/TS 15066:2016	Robots and robotic devices — Collaborative robots
3	ANSI/RIA R15.08-1-2020	Industrial mobile robots - safety requirements - Part 1: Requirements for the industrial mobile robot
4	N/A	Domain expert guest lecture series

Figure 1. Course module structure and content for the Occupational Safety Engineering Course.

Lecture Unit	Document Number	Content
1		Domain Topic: Safety Standards for Industrial Human-Robot Interaction
2		Human Automation Interaction Topics
3	ISO 10218-1:2011, ISO 10218-2:2011, ISO/TS 15066:2016, ANSI/RIA R15.08-1-2020	Using Technical Standards to Support Design
4		Case Study Presentation

Figure 2. Course module structure and content for the Human Factors Applications Course.

(2) Course evaluation

Overall, the evaluation results reflect very positive student feedback, indicating high levels of instructor effectiveness, course relevance, and educational value (Table 1 and 2). Key findings from both undergraduate and graduate sections are summarized below.

Summary for EIN4216 / EIN6216

Highlights for Fall 2023: (1) Graduate students (EIN6216) reported exceptionally high satisfaction, with most categories scoring above 4.4/5.0. (2) Instructor enthusiasm and responsiveness were particularly praised across both sections. (3) Undergraduate scores were slightly lower but still reflected strong perceived value, especially regarding meaningful feedback and instructor accessibility.

Highlights for Fall 2024: (1) Instructor enthusiasm received the highest possible rating (5.00/5.00) from graduate students. (2) Undergraduate responses were consistently strong across all categories, with most scores above 4.0/5.0. (3) Students particularly appreciated the responsiveness, feedback quality, and engaging classroom environment.

Summary for EIN4245

Highlights for Spring 2023: Evaluations were very strong across all metrics, especially for instructor enthusiasm (4.64/5.0) and responsiveness (4.73/5.0). The group-based human-automation/robotics case study was well received, though students raised concerns about unequal group work.

Table 1. Combined Course Evaluation Summary (Fall 2023 and Fall 2024)

Metric	EIN4216 Fall 2023	EIN6216 Fall 2023	EIN4216 Fall 2024	EIN6216 Fall 2024
Response Rate	49%	77%	28%	37%
Instructor Enthusiasm	4.03 / 5.00	4.70 / 5.00	4.71 / 5.00	5.00 / 5.00
Material Clarity	3.61 / 5.00	4.40 / 5.00	4.21 / 5.00	4.57 / 5.00
Standards for Response/Availability	4.13 / 5.00	4.50 / 5.00	4.50 / 5.00	4.43 / 5.00
Positive Learning Environment	3.61 / 5.00	4.40 / 5.00	4.21 / 5.00	4.57 / 5.00
Meaningful Feedback	4.00 / 5.00	4.20 / 5.00	4.43 / 5.00	4.43 / 5.00
Instructor Instrumental to Learning	3.42 / 5.00	4.20 / 5.00	4.21 / 5.00	4.29 / 5.00
Course Content Relevance	3.68 / 5.00	4.50 / 5.00	4.07 / 5.00	3.71 / 5.00
Overall Educational Experience	3.26 / 5.00	4.40 / 5.00	4.00 / 5.00	3.86 / 5.00

Highlights for Spring 2024: Spring 2024 introduced more individual assignments, readings, and reflections to promote accountability and ensure broader engagement with the material. However, the increased volume of assessments was seen by students as time-consuming and not always directly useful to the core evaluation pieces (e.g., the case study projects). This contributed to lower ratings in categories such as meaningful feedback (3.29/5.0) and overall learning experience (3.21/5.0).

Based on this feedback, the course was further refined to include more targeted individual quizzes, in-class activities for applied practice, and embedded knowledge checks in recorded lectures for the human-robot standards module. These changes aim to balance individual

accountability with meaningful engagement, while keeping workload reasonable and aligned with key course objectives.

Table 2. Combined Course Evaluation Summary EIN4245 (Spring 2023 and 2024)

Metric	EIN4245 Spring 2023	EIN4245 Spring 2024
Response Rate	40.7%	51.5%
Instructor Enthusiasm	4.64 / 5.00	4.35 / 5.00
Material Clarity	4.36 / 5.00	4.00 / 5.00
Standards for Response/Availability	4.73 / 5.00	3.94 / 5.00
Positive Learning Environment	4.00 / 5.00	3.65 / 5.00
Meaningful Feedback	4.18 / 5.00	3.29 / 5.00
Instructor Instrumental to Learning	4.09 / 5.00	3.24 / 5.00
Course Content Relevance	4.18 / 5.00	3.24 / 5.00
Overall Educational Experience	4.00 / 5.00	3.21 / 5.00

(3) Project Website and Dissemination Platform

To further support public accessibility, sustainability, and broader dissemination of the developed instructional materials, a dedicated project website was created: https://nistufl.netlify.app/.

The website serves as a centralized platform to host and share the collaborative robotics safety instructional modules, project outcomes, and related resources. Designed with an open-access philosophy, the site allows students, educators, industry professionals, and other interested stakeholders to easily access, download, and adapt the educational materials for their own teaching, training, or organizational needs.

Key features of the website include: (1) Instructional Modules: Summaries and downloadable content covering robotics safety standards such as ISO 10218-1, ISO 10218-2, ISO/TS 15066:2016, and ANSI/RIA R15.08-1-2020. (2) Real-world Case Studies: Practical examples and applications drawn from industry collaborations, illustrating the importance of robotics safety codes in operational environments. (3) Project Overview: Background on the project's motivation, goals, and development process. (4) Updates and Announcements: Information on module updates, upcoming workshops, or new dissemination efforts related to robotics safety education. (5) Contact Information: Channels for visitors to reach the project team for collaboration, feedback, or further inquiries.

The development of this website ensures that the impact of the project extends beyond the University of Florida, enabling a wider audience to benefit from the instructional content. It also establishes a framework for continued updates, collaborations, and resource sharing, supporting the ongoing growth of robotics safety education nationally.

Through this dissemination strategy, the project not only addresses immediate educational needs but also contributes to long-term workforce development and standardization literacy in the rapidly evolving field of collaborative robotics.

Conclusion

This project successfully addressed a critical gap in robotics safety education by developing and integrating publicly accessible, customizable instructional modules focused on collaborative robotics safety standardization. Through the creation and implementation of two course modules, one in Occupational Safety Engineering (EIN4216/EIN6216) and one in Human Factors Applications (EIN4245), the project significantly enriched the educational offerings at the University of Florida and provided a scalable model for broader dissemination.

The enrollment growth and strong course evaluation results across two consecutive years clearly demonstrate the effectiveness and impact of the new modules. Students at both undergraduate and graduate levels reported high levels of engagement, instructor support, and educational value, validating the relevance and importance of incorporating robotics safety standards into STEM curricula.

In addition to enhancing student learning outcomes, the project fostered a stronger connection between academic instruction and real-world industry needs, by emphasizing hands-on applications, systems thinking, and professional standards literacy. The collaborative efforts with industry partners to integrate real-world examples further strengthened the applied learning experience.

Overall, the project met and exceeded its original goals, laying a strong foundation for continued sustainability and broader dissemination to other institutions, industry professionals, and public sector stakeholders. It contributes meaningfully to national workforce development efforts in robotics safety, and prepares future engineers and system designers to integrate safety and standardization principles into next-generation human-robot collaboration environments.