Board 137: Interdisciplinary Convergence in Robotics and Autonomous Systems

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Work in Progress: Interdisciplinary Convergence in Robotics and Autonomous Systems

Abstract: While the demand for interdisciplinary knowledge is undeniable, there are formidable challenges when offering graduate education to Engineering students. To address that, we designed an educational research project that delves into the effectiveness of an interdisciplinary National Science Foundation (NSF) Research Trainee (NRT) program for engineering students studying robotics and autonomous systems. This newly funded NRT program aims to train next-generation scientists and engineers with professional skills through interdisciplinary courses such as leadership, business, and psychology in addition to cutting-edge technical knowledge in the field. We are using retrospective surveys and content analysis to identify student experience with interdisciplinary training and education programs. Both quantitative and qualitative analysis evidenced an increased level of confidence in soft skills such as interdisciplinary understanding, communication, and collaboration skills throughout participating in the interdisciplinary NRT program.

1. Introduction

In the rapidly evolving landscape of technology and innovation, the conventional boundaries that once confined individual fields of study are becoming increasingly blurred. Moreover, accelerated by the COVID-19 pandemic, the world of work is undergoing momentous change. Nearly half of all occupations (including those in production, transportation, extraction, agriculture, and maintenance/repair) are at risk of being automated within the next two decades [1]. At the same time, labor shortages within the U.S. have plagued post-pandemic recovery efforts and are particularly dire for jobs in harsh occupational environments with high health and safety risks [2-4]. Furthermore, engineering professionals of the future require more than just knowledge of technical design solutions to help address the grand challenges of the future of work at the human-technology frontier. Equally important to consider are the employee populations affected by the increasing incorporation of robots into the workplace (e.g., social justice and equity implications of technology-induced obsolescence), entrepreneurial skills to bring innovation to practice (in 2021 alone, more than $17 billion was poured into venture capital-backed robotic startups [5]), and the need to address the user experience through adaptive design of the human-robot interface.

Bridging the gap between these diverse worlds can be a complex endeavor, requiring innovative pedagogical approaches and a nuanced understanding of how to integrate this acumen into engineering curricula. Unfortunately, few graduate programs provide a truly convergent robotics training addressing all challenges to future STEM professionals. Thus, there is a great need for the development of a graduate robotics training program in the human-technology frontier that addresses both technical and societal needs.

2. Description of our National Science Foundation (NSF) Research Trainee (NRT) program

To be competitive in the global labor market through innovative technology, educational programs are needed to train students in the emerging areas of the engineering field, such as cyber-enabled systems, autonomous systems, mechatronics, robotics, and related advanced manufacturing

techniques for their fabrication and interfacing with support systems. Most leading engineering programs understandably focus on the development of strong technical skills (e.g., Carnegie Mellon's focus on the four core areas of perception, cognition, action, and math). Even cutting-edge programs with a specific emphasis on interdisciplinarity (e.g., Oregon State's Collaborative Robotics and Intelligent Systems Institute) do not provide training in disciplines outside of the primary areas of engineering, mathematics, and computer science.

Thus, we designed the **NRT-LEAD** program (NextGen Robotics Training – Leadership, Entrepreneurship, and Adaptive Design) at Washington State University for the development of a graduate robotics training program in the human-technology frontier that addresses both technical and societal needs (Figure 1).

Figure 1. NRT-LEAD program utilizing multidisciplinary lenses.

3. Interdisciplinary Courses for NRT Trainees

Interdisciplinary learning has been at the center of interest of educators because of its educational benefits which include fostering communication among people from different disciplines, increasing the awareness of other disciplines, and better decision making [6]. We designed a set of interdisciplinary courses as a means to nurture the soft skills of engineering students which involves three disciplines: Human Development, Business and Entrepreneurship, and Experimental Psychology (Figure 2).

Specifically, the Leadership course (offered through Human Development) provides professional leadership training that addresses the equity and justice implications of increasing automation and incorporation of robots into the workplace. Trainees will also gain exposure to the business environment and learn how to translate innovations into viable products through the Entrepreneurship course. Moreover, NRT trainees will develop a deeper understanding of the user experience that is critical for informing product design, thereby facilitating greater acceptance by employees working alongside robots and/or the technicians operating the robots by taking the

applied Psychology course focused on user experience research. Using these convergent lenses as an intentional backdrop to broaden the vision and impact of emerging technology, students will apply their training to the areas of fruit orchard automation, nuclear waste cleanup, and underwater manipulation.

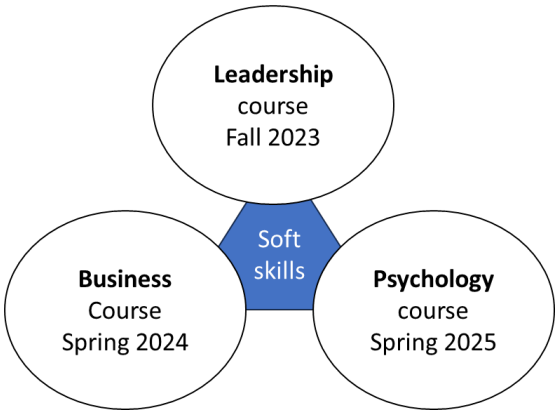

Figure 2. Interdisciplinary courses designed to nurture soft skills.

4. Research Questions

In order to understand the interdisciplinary learning experience of NRT trainees, we used pre- and post-tests as well as retrospective surveys to measure their interdisciplinary learning changes before and after taking those courses. We also analyzed the trainee's written comments about the program using a content analysis. In this work-in-progress study, our research questions are:

1. How do interdisciplinary courses influence the interdisciplinary understanding and mindset of students over the semester?
2. What dispositions and mindsets toward interdisciplinary learning are displayed in student reflections?

5. Methodology

We rely on retrospective survey methodology to obtain student reflections on the courses taken. The basis of the Fall 2023 Trainee survey was to gather data on improving students' experience and measuring progress toward program goals after taking the Leadership course. Students are currently enrolled in the Business course (Spring 2024), and will take the Psychology course in Spring 2025. Thus, the current study is based on our preliminary data from the Fall 2023 Leadership course. We will report further outputs from Business and Psychology courses in the future.

5.1 Participants

We had a total of nine Ph.D. students in the first cohort, who are majoring in Mechanical Engineering, Computer Science, Psychology, and Chemistry at the Washington State University. This study was reviewed and classified as exempt by our institution's Institutional Review Board (protocol# 20346-001) to collect data without identifying information. All participants gave consent to participate in this study. The survey was sent to ten (10) trainees with four reminders to non-participants over three weeks. An additional reminder was sent by the program leadership.

Nine (9) trainees completed the survey with a participation rate of 90%. See Table 1 for survey questions.

Table 1. Students rate their level of confidence before and after participation in the program.

Questions	before	after	Growth rate %
Understanding the market forces driving the development of new robotic and autonomous systems.	1.9	2.7	41%
Serving as a mentor to other graduate students or undergraduate students.	2.6	3.4	35%
Ability to present the results of my research to a diverse audience of stakeholders.	2.3	3.1	33%
Ability to apply interdisciplinary skills to a collaborative project.	2.8	3.7	32%
Understanding the importance of leadership skills.	2.9	3.8	31%
Understanding the impact of new robotic and autonomous technologies on affected worker and community populations.	2.8	3.6	28%
Taking a leadership role while working with people from various backgrounds to jointly accomplish project goals.	2.9	3.7	27%
Depth of knowledge in your discipline or field of study.	2.7	3.3	25%
Ability to work in a team with individuals trained in different disciplines.	2.9	3.6	23%
Ability to apply the approaches and tools from multiple disciplines to address a research question.	2.7	3.2	21%
Communicating with individuals from different disciplinary backgrounds.	2.9	3.4	19%
Ability to manage, analyze, and present research data.	2.9	3.3	15%
Ability to write a concise and compelling research proposal.	2.7	3.0	13%

5.2 Survey Procedure and Measurements

Each figure and table description delineates the basis of the questions asked. Survey items consisted of asking trainees to select responses from a variety of options provided or to indicate their level of agreement to statements presented, as well as soliciting written responses where appropriate. Reflective question responses were quantified to develop groups before and after weighted averages generating a percentage indicating growth in the topic. Some response options allowed trainees to select more than one choice. Questions with a selection of choices also allowed the respondent to provide an additional "other" written response if the options provided did not address their particular situation. Survey participants had the option of skipping questions. Open-ended questions were coded and themed by two trained coders [7]. Data was visualized as a percentage of mentions by the number of respondents along with theme descriptions and participant quotes. Both quantitative and qualitative methods are used to present the findings from trainees' survey data.

6. Results

We measured trainees' confidence levels before and after participation in the program and taking the leadership course using a retrospective survey. We found consistently positive growth rates ranging from 13% to 41%, evidencing significant growth in every aspect including

interdisciplinary learning, leadership skills, and communication skills (Table 1). Specifically, understanding market needs, as well as interdisciplinary understanding, and leadership skills demonstrated the largest increases before and after joining the program. For instance, students felt more confident in their ability to apply interdisciplinary skills to collaborative projects (31% increase) and in taking a leadership role while working with people from various backgrounds (27% increase).

We also measured the level of knowledge in terms of Interdisciplinary Research, Communication and Collaboration; Analysis and Modeling; Robotics, Autonomous Systems and Computer Science; and Data Analytics and Computing (Figure 3). Results suggest that students showed more confidence in their knowledge in Interdisciplinary Research, Communication and Collaboration, and Analysis and Modeling compared to other aspects. *About 33% responded they were confident in those areas, 44% were moderately knowledgeable, and only 22% indicated they were not knowledgeable in those areas.*

One thing to be noted is that NRT trainees rated less confidence in Data Analytics and Computing compared to other areas. More than half (56%) of the participants rated themselves as only "slightly knowledgeable" in Data Analytics and Computing, indicating the program needs to focus more on this area in the future. Data Analytics and Computing include skills related to data mining and visualization, data management, and data collection tools, which can be further emphasized in the program through courses, seminars, and immersive field studies.

Furthermore, we performed a content analysis of the written comments of students when they reflected on their experience with the program and course. Students expressed their increased confidence level in terms of leadership skills, communication abilities, and interdisciplinary understanding as shown in Figure 4. Several comments indicate that the program not only provided opportunities to delve into other disciplines but also fostered learning about teamwork and collaboration with individuals from diverse backgrounds, thus resonating with the program's objectives.

7. Conclusion and Implications

We are in the early stages of implementing an interdisciplinary educational training program for graduate students as a means to nurture their soft skills as well as technical skills which can meet the needs of today's industries. We utilized both quantitative and qualitative approaches to explore NRT trainees' experience during the first semester of the program and after taking their initial required interdisciplinary course. Even at this early stage, preliminary findings suggest that NRT trainees experienced an increased level of confidence in terms of interdisciplinary understanding, leadership skills, and communication abilities. Students also noted that they are confident in their knowledge in terms of Interdisciplinary Research, Communication and Collaboration, and Analysis and Modeling. On the other hand, we also found that they showed relatively less confidence in Data Analytics and Computing, which will be further emphasized in the rest of the program. By further assessing the impact of interdisciplinary education on the future creators of cutting-edge robotic technologies, we seek to illuminate the path toward a new breed of engineers – individuals who are not only technically proficient but also well-versed in the nuances of entrepreneurship, business acumen, and user experience design.

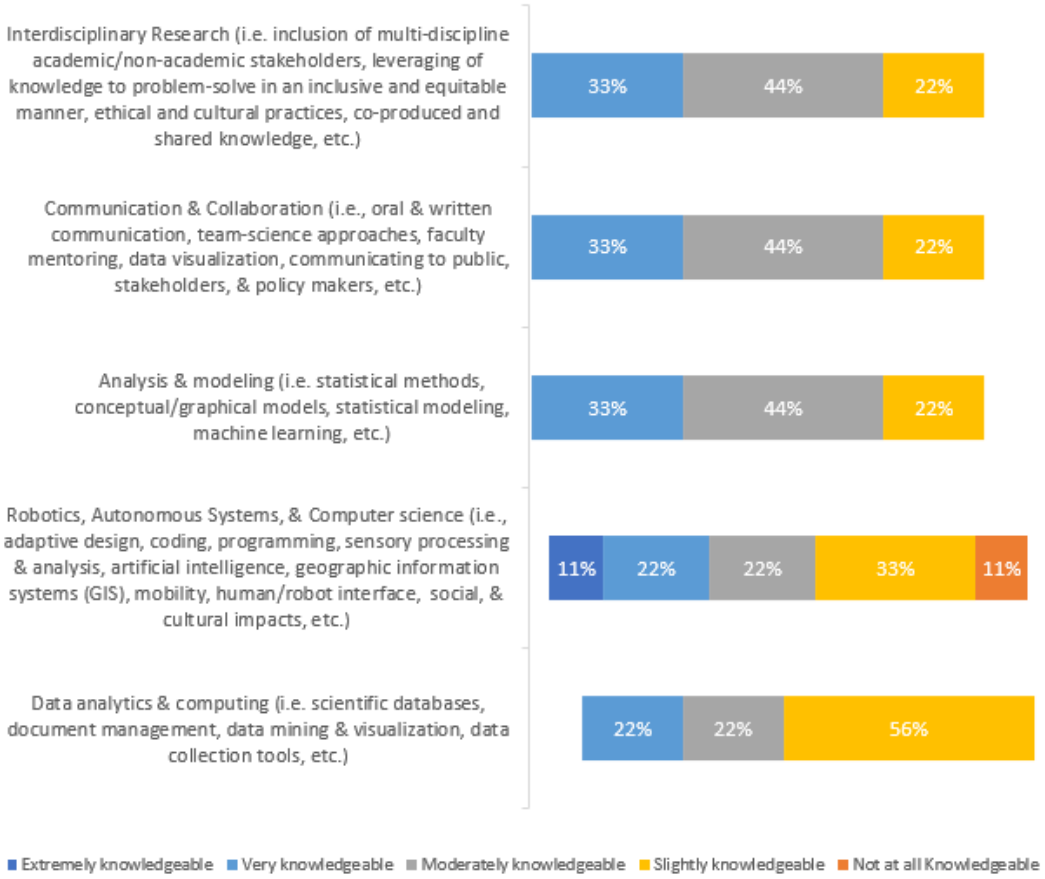

Figure 3. Trainee's level of confidence in targeted knowledge, skills, and ability domains.

Trainee responses:

*"Yes. Participating in this program will **help you grow into an effective leader**."*

*"Absolutely. I think this program is really **helpful for new research students to get funded** for high end research activities."*

*"Yes, it provides an **opportunity to build a community with other disciplines** and build **new skills** as well."*

Too soon to tell."

*"Yes. It is an extensive **opportunity to network through different disciplinary backgrounds**, extremely **valuable** not just in an **academic** light, but also **personal**."*

"It is too early to see the impacts necessary to decide whether or not I would recommend it."

*"I would say I probably would, as the **skillsets it works to build are very unique** in relation to my standard grad school department experience."*

*"**Sure**."*

*"Yes, it is **wide reaching program** that teaches many **diverse skills**"*

*"Yes, I think it can provide **great opportunities for students** that plan to work in industry."*

Figure 4. Students' reflections on their experience with the program and course.

8. Future Direction

In future years, students will take additional interdisciplinary coursework focused on training students in entrepreneurship and applied psychology to conduct user experience research for the purposes of integrating user feedback into the technical design features of the robots and autonomous systems in development. Replicating the design of the course evaluation, retrospective surveys coupled with content analysis of students' problem-based learning projects will be used to evaluate the development of an interdisciplinary mindset, communication, teamwork, research ethics, and project management skills. Together, this work will shed light on the pivotal role of interdisciplinary education in shaping the engineers of tomorrow, poised to transform the landscape of robotics and automation.

Acknowledgments

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References

1. Frey CB, Osborne MA: The future of employment: How susceptible are jobs to computerisation? *Technological forecasting and social change* 2017, 114:254-280.
2. A 'Climate of Fear' Accelerates Existing Labor Shortages on California's Farms [https://elementalreports.com/urbanization/2019/09/15/a-climate-of-fear-accelerates-existing-labor-shortages-on-californias-farms/]
3. The global labor shortage How Covid-19 has changed the labor market [https://www2.deloitte.com/us/en/insights/economy/global-labor-shortage.html]
4. Who will be left to respond? Amid our staffing challenges, fire chiefs must be creative and proactive in recruitment and retention efforts [https://www.firerescue1.com/recruitment/articles/who-will-be-left-to-respond-I6J5X91BtGVYMVuw/]
5. After Record Year, Robotics Investments Stays Strong Even In Shaky VC Market [https://news.crunchbase.com/ai-robotics/robotics-vc-funding/]
6. H. H. Jacobs, "The growing need for interdisciplinary curriculum content. In H. H. Jacobs (Ed.)", *Interdisciplinary curriculum: Design and implementation*, Association for Supervision and Curriculum Development, pp. 1–11, 1989.
7. J. Saldaña, *The coding manual for qualitative researchers*. Sage, 2015.