An Interdisciplinary Program in Human-Robot Interaction between Japan and the United States: Integrating Technical, User Centered Design, and Business Perspectives

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Abstract

Japan is one of the global leaders in robotics, emphasizing deep technical innovation, while the United States has traditionally focused on applied robotics education. However, effective Human-Robot Interaction (HRI) education requires more than technical execution; it demands the integration of human-centered design and economic feasibility. International programs attempting this face multifaceted challenges: addressing uneven technical preparation among students, managing a lack of time for iterative development, and overcoming students' struggles to articulate the market viability of their systems. The primary purpose of this paper is to evaluate a joint interdisciplinary program between a U.S. and a Japan university designed to address these challenges.

The core innovation is a five-week hybrid-plus-immersion model structured explicitly around a holistic Business (B), User (U), Robot (R), and Technology (T) framework. To address interdisciplinary disparities, a three-week remote phase establishes a foundational "shared technical language" in Python and ROS 2 across all majors. This preparation culminates in a two-week intensive hackathon in Japan, where cross-cultural teams design and develope functional prototypes using the Turtlebot3 platform and multimodal sensing technologies. The curriculum grounds the B-U-R-T dimensions through company visits to real-world deployments in cafés, healthcare, and manufacturing settings, directly informing the development of market-justified prototypes.

To assess the efficacy of this integrated approach, we employed a mixed-methods evaluation utilizing pre- and post-program surveys, assessment of project artifacts, and qualitative instructor observations. Our findings indicate that the hybrid structure significantly enhanced deep technical skill development, team cohesion, and confidence in framing robotic solutions within real-world economic contexts.Specifically, the program's success demonstrated that the functional integration of Business (B), User (U), Robot (R), and Technology (T) dimensions relies on the development of a shared technical language. This B-U-R-T driven model offers a replicable and scalable educational framework for global multidisciplinary HRI education.

1 Introduction

Robotics education is increasingly expected to prepare students not only to build technically functional systems, but also to reason about how robots interact with people, organizations, and societies. This expectation is especially pronounced in Human-Robot Interaction (HRI), where technical performance alone is insufficient to ensure adoption, trust, or long-term impact. Effective HRI education must therefore integrate technical depth with human-centered design, cultural awareness, and an understanding of real-world constraints such as deployment environments and economic feasibility.

International educational collaborations offer a powerful mechanism for addressing these needs. Japan and the United States, in particular, represent complementary traditions in robotics research and education. Japanese robotics emphasizes long-term investment, precision engineering, and social integration of robots, while U.S. programs often emphasize rapid prototyping, interdisciplinary collaboration, and applied problem solving. Leveraging these complementary strengths, we previously developed a two-week immersive robotics course hosted in Japan that brought together undergraduate and graduate students from the University of Washington (UW) and the Shibaura Institute of Technology (SIT) to design and prototype service robots using ROS 2 and the Turtlebot3 platform.

While the initial iteration achieved strong engagement and intercultural collaboration, its compressed structure revealed limitations in technical depth, iterative design, and students' ability to articulate the broader purpose and feasibility of their robotic systems. These observations motivated a comprehensive redesign of the program, described and evaluated in this paper.

2 Related Work

This work builds on prior research in three intersecting areas: international engineering education, project-based robotics pedagogy, and Human-Robot Interaction (HRI) education. Prior studies have shown that international and cross-cultural learning experiences can significantly enhance students' professional identity, global awareness, and collaborative skills, particularly when programs emphasize active, project-based engagement rather than passive observation[1,2,3,4,5,6,7].

Within engineering education, short-term study abroad and global design programs have been widely adopted to expose students to international contexts[8]. However, persistent challenges related to uneven preparation, limited technical depth, and constrained opportunities for iteration have impacted the success of these programs[9]. The limitations are especially pronounced in technically complex domains such as robotics, where meaningful learning requires time for system integration, debugging, and reflection. Several studies have argued that hybrid or guided approaches can mitigate these issues by redistributing instructional load and better aligning student preparation prior to immersive experiences[10,11,12,13,14].

Project-based learning has long been recognized as an effective pedagogical strategy in robotics education, supporting the development of both technical competence and teamwork skills. Prior work has demonstrated that hands-on robotics projects can improve student motivation and retention, particularly when teams are interdisciplinary. However, many robotics curricula emphasize technical performance while giving less attention to human-centered design, cultural context, or real-world deployment constraints. As a result, students may successfully build functional systems without developing a deeper understanding of how those systems interact with users or fit within broader social and economic ecosystems.

HRI education has increasingly emphasized the importance of integrating technical and human-centered perspectives. Researchers have called for pedagogical approaches that explicitly address usability, trust, transparency, and cultural expectations in robot design. Nevertheless, business considerations and deployment feasibility are often treated as peripheral concerns, introduced late in the design process or omitted entirely. This gap can limit students' ability to translate HRI concepts into sustainable, real-world applications [15,16,17,18,19,20,21,22,23].

The program described in this paper contributes to this literature by combining a hybrid-plus-immersion structure with an explicitly holistic HRI framework that integrates technical development, user interaction, cultural context, and business justification. By embedding these dimensions throughout the design cycle, rather than treating them as isolated topics, this work extends prior models of international robotics education and offers a replicable approach for preparing students to design interactive robotic systems that are not only functional, but also contextually appropriate and viable.

3 Motivation for Program Redesign

The first iteration of the program demonstrated that short-term, intensive international experiences can effectively foster student motivation and cross-cultural teamwork. Students successfully formed interdisciplinary teams, learned new technical tools, and produced working robotic prototypes within a limited timeframe. However, multiple sources of feedback including student reflections, faculty observations, and discussions with engineering education colleagues revealed structural constraints that limited learning depth.

One major challenge was the lack of time for iterative development. Students often prioritized achieving basic system functionality over refining interaction design or evaluating usability. Debugging and integration tasks consumed a disproportionate share of the schedule, leaving limited opportunity for reflection or redesign. This pattern is common in short robotics courses but is particularly problematic in HRI, where meaningful learning depends on iteration and user-centered evaluation.

A second challenge involved uneven technical preparation. Students entered the program with widely varying backgrounds in programming, robotics middleware, and systems integration. As a result, some teams became dependent on a small subset of technically experienced members, limiting broader participation and learning.

Finally, while students were enthusiastic about their prototypes, many struggled to explain why their robots should exist in real-world contexts, particularly in terms of deployment feasibility or economic justification.

These limitations motivated a redesign focused on extending the timeline, redistributing technical instruction, and explicitly integrating business and contextual considerations into the HRI design process.

4 Learning Objectives

The redesigned program articulated explicit learning objectives that spanned technical, human-centered, cultural, and professional domains. These objectives served as the foundation for curriculum design and assessment alignment.

Technically, students were expected to demonstrate proficiency in Python programming, ROS 2-based system integration, and mobile robot operation. From an HRI perspective, students were expected to apply human-centered design principles to analyze user needs, interaction modalities, and system usability. Culturally, students were expected to recognize and articulate how environmental and societal factors influence robot design and adoption in different national contexts.

In addition, the program emphasized professional competencies. Students were expected to collaborate effectively in interdisciplinary, cross-cultural teams and to communicate their ideas clearly to diverse audiences. A central objective was the ability to articulate a coherent business justification for a robotic system, including its value proposition, stakeholders, and feasibility. Together, these objectives reflected a holistic view of HRI education that extends beyond technical implementation alone.

5 Course Structure and Pedagogical Design

The redesigned program adopted a five-week hybrid-plus-immersion structure consisting of three weeks of remote instruction followed by two weeks of intensive, in-person engagement in Japan. The in-person phase was conducted over two consecutive weeks, five days per week, with daily sessions running from 10:00 to 17:00, including scheduled breaks of up to two hours.

This structure was intentionally chosen to balance accessibility, technical preparation, and experiential learning.

During the remote phase, students engaged in structured modules covering Python fundamentals, ROS 2 concepts, and introductory HRI frameworks. These modules included asynchronous materials, guided exercises, and synchronous check-ins with instructors. By front-loading foundational technical content, the program reduced the cognitive load typically experienced during in-person intensives and enabled students to arrive with a shared baseline of knowledge.

The in-person phase emphasized hands-on development, interdisciplinary collaboration, and cultural immersion. Students worked in mixed teams, received daily feedback from faculty, and participated in site visits to Japanese robotics companies and deployments. This phase provided the experiential context necessary to connect abstract concepts with real-world practice.

5.1 Differentiated Onboarding and Cohort Integration

To bridge the technical gap for the UW cohort's non-engineering majors, the program initiated a three-week online foundational sequence focused on ROS 2 and Python. Following this preparation, the SIT participants joined their American counterparts for the final two weeks of immersive, on-site learning in Japan. This arrangement recognized that the SIT cohort already possessed a robust technical foundation in robotics and system integration through their specialized degree programs. By integrating these distinct preparation paths, the program ensured that both cohorts reached a functional baseline before commencing high-intensity prototyping tasks. This alignment facilitated a productive collaborative dynamic, allowing for immediate on-site knowledge transfer and technical synergy within the teams.

5.2 Integration of Business Justification into HRI Design

A central innovation of the redesigned curriculum was the explicit integration of business justification as a core component of the HRI design cycle. Rather than treating business considerations as an afterthought, the program introduced them early and revisited them throughout the project lifecycle.

Students were introduced to the "elevator pitch," a structured business pitch framework, that included problem identification, stakeholder analysis, value proposition, and feasibility considerations. Faculty demonstrated this framework through live examples, explicitly linking technical design decisions to market and deployment constraints. Teams were then required to apply the framework to their own projects, iteratively refining both their technical designs and business narratives.

This approach addressed a recurring student question: "We have a robot, but what do we do with it?" by grounding technical development in market analysis and context. It also encouraged students to consider trade-offs between functionality, usability, and feasibility, reinforcing the interconnected nature of HRI design decisions.

6 Assessment Methodology

Assessment of learning outcomes employed a mixed-methods approach combining pre- and post-program surveys, evaluation of project artifacts, and qualitative observations by instructors. Surveys measured self-reported confidence and competence across technical skills, teamwork, cultural awareness, and professional communication.

Project artifacts, including code repositories, prototypes, and final presentations, were evaluated by instructors from both participating institutions using institution-specific rubrics aligned with a common set of program learning objectives. Technical performance was assessed based on system functionality and integration, while human-centered and business outcomes were evaluated through design rationales and contextual analyses.

This alignment between objectives, activities, and assessment supported a more coherent evaluation of student learning and provided actionable insights for future iterations of the program.

7 Technical Depth and Team Balance

The hybrid format played a critical role in addressing uneven technical preparation among participants. By providing foundational instruction prior to the in-person phase, the program enabled broader engagement with code-level tasks and system integration during the intensive development period. As a result, students reported increased confidence in participating in technical discussions and implementation activities, even when these areas were outside their prior experience.

Team composition was intentionally designed to balance technical depth with interdisciplinary participation. Rather than assuming uniform technical readiness, the program adopted a grouping strategy that ensured baseline technical feasibility while supporting collaborative learning across engineering, design, and business-oriented roles. Faculty observations indicated that this structure, combined with hybrid preparation, supported distributed problem-solving and reduced the risk of technical work becoming concentrated in a single individual.

A total of 25 students participated in the program as an elective course, including 11 from the University of Washington (UW) and 14 from Shibaura Institute of Technology (SIT).

The cohort from SIT comprised 14 participants with a diverse academic distribution: 10 students from Computer Science, and one student each from Materials Science, Mechanical Engineering, Design Engineering, and Mathematical Sciences. The students' seniority ranged from third-year undergraduates to second-year master's candidates. To ensure technical feasibility across the six interdisciplinary teams, a strategic grouping logic was applied. Each group included at least one SIT participant with prior ROS 2 development experience to provide a technical baseline and to support early-stage system integration.

Importantly, the presence of these technical anchors did not imply exclusive responsibility for implementation tasks. Hybrid preparation and team-level expectations encouraged broader participation in technical work, allowing non-engineering participants to engage meaningfully with coding, debugging, and system-level reasoning over the course of the project.

The UW participants (N=11) represented a highly diverse set of majors, specifically: Applied Physics, Master of Science in Information Management, Mechanical Engineering, International Studies and Japanese, Information Technology, Computer Science, Computer Science & Software Engineering, Industrial Engineering, and Human Centered Design and Engineering (alongside one undeclared major). These participants were intentionally distributed across teams to complement the technical foundations provided by the SIT cohort and to lead the interdisciplinary integration during both design and implementation phases.

7.1 Cultural and Environmental Context in HRI Design

The redesigned curriculum explicitly addressed cultural and environmental factors influencing HRI. Lectures introduced concepts such as cultural expectations of autonomy, social presence, and trust, with examples drawn from Japanese service robotics deployments.

Students were required to incorporate these considerations into their final project presentations, explicitly discussing how cultural context informed their design choices. Company visits during the Japan immersion phase reinforced these lessons by exposing students to real-world deployments in cafés, healthcare facilities, and manufacturing environments.

7.2 Communication and Language Considerations

Despite initial concerns, language differences did not appear to affect project outcomes significantly. Teams relied heavily on shared technical artifacts (code, diagrams, and prototypes) which provided a common medium for collaboration and communication. Presentation materials were jointly developed, and students demonstrated effective cross-linguistic problem-solving.

These observations suggest that technical tasks with constraints and shared design artifacts can mitigate communication barriers in international engineering education.

While shared technical artifacts bridged the functional requirements of the projects, linguistic fluency influenced the specific distribution of contributions to the team narrative. In cohorts where SIT participants possessed limited English proficiency, digital translation tools and shared technical artifacts, such as ROS 2 code repositories and shared design and interaction maps, functioned as a critical "universal language." This facilitated a high degree of alignment between technical logic and the design of human-robot interaction, ensuring that the programmed behaviors remained consistent with the shared conceptual goals of the teams.

However, a specialization of roles was observed in the integration of the dimensions of Business (B), User (U), Robot (R), and Technology (T). While communication was sufficient to ensure that the robot's implementation did not decouple from the design intent, the SIT students focused their primary efforts on the software logic and the technical realization of the interaction. In contrast, UW participants typically took the lead in synthesizing the project "story," particularly regarding the business model and specific environmental interaction scenarios. This resulted in a collaborative dynamic where technical execution and narrative justification were well-integrated in the final outcomes, even though the SIT students were less vocal in proposing the conceptual non-technical dimensions.

8 A Holistic Framework for HRI Education

The redesigned program implicitly advanced a holistic framework for HRI education, integrating Business (B), User Interaction (U), Robot Interaction (R), and Technology (T). Rather than treating these dimensions independently, the curriculum emphasized their interdependence throughout the design process.

Students were encouraged to define indicators of success across all dimensions, considering not only system performance but also user experience, cultural fit, and economic feasibility. This framework informed both instructional activities and assessment criteria.

In an effort to make concrete improvements in the program in its second year of execution, program objectives, learning goals, and skill development assessments were planned and implemented to provide additional data points with which to evaluate the effectiveness of the program design.

This data will then support the development of a clearly defined framework that will serve as a guide for Human-Robot Interaction coursework development.

8.1 Rationale for an HRI Education Framework

The prudent question at this point is relating to the necessity of a framework in this specific topic and what purpose it would serve in being more widely implemented.

Rationale 1: The specific topic of Human-Robot interaction is not a widely covered one. Only a very small number of Universities worldwide list social robotics or Human-Robot interaction coursework. Initial research was conducted to identify programs that mention Human-Robot Interaction or social robotics in the United States, Europe, China, Korea, and Japan.

Searches were conducted in English, Mandarin Chinese, Korean and Japanese to attempt to gain an approximate overview of universities that offer clear coursework in this area.

The initial findings are that few courses offer any focused coursework in the area of Human-Robot interaction other than introductory courses, which are the most common. Inconsistencies also appear in the degree programs or concentrations that feature this coursework, with some falling under a dedicated robotics curriculum, while others are housed within subsets of Human-Computer Interaction programs.

Further analysis of these courses also begins to identify differing focus areas and supporting coursework based on each region's specific approach to the topic.

Additionally, while there are a few consistent themes that emerge in Human-Robot Interaction programs, there is not a firmly established set of topics other than a few technical topics[18].

In particular, very few courses were identified that included business curriculum to analyze business practicality of robotics solutions, though some evidence of project-centric tasks working closely with industry partners shows promising results [24].

Specific HRI-education topics differ according to a number of different regional and cultural concerns, but given that many robotics companies are multinational and offer products worldwide, the need for coursework that can be standardized and also topically or regionally adjusted emerges. A framework model with core components and flexible add-on modules for specific concerns could be a potentially effective approach to standardization and overall consistency and improvement in this area.

Rationale 2: Though other work has been done in the general area of Inter- or Multi-disciplinary Human-Robot Interaction coursework, success is commonly measured in the successful achievement of learning objectives, which though indicative of success in specific circumstances around individual courses, create a challenge in building future courses which are not able to replicate the exact circumstances of previous courses. Therefore, we propose to go one step further and begin to build these conclusions into a framework which could form the basis of future course development, and assist instructors or departments interested in offering coursework in Human-Robot Interaction a base with which to begin engagement of the interdisciplinary resources that would be required.

8.2 HRI Education Framework Details

8.2.1 Technical Knowledge Levels

Human-Robot Interaction, as previously established, is an inherently interdisciplinary field, thus it follows that accomplishing a successful Human-Robot Interaction design project would require a set of team members with diverse skills. Building on suggestions for frameworks to engage interdisciplinary teams in HRI interaction research[25] it follows that a logical and consistent structure would also improve outcomes in instructional coursework.

Though the task to be executed by the robot being utilized in the project has a great degree of variability, as a technology product, there are unavoidable technology features and electronic components utilized in any robotic platform. In this case, we define 'technical knowledge' as that which is typically contained within traditional engineering coursework, to include: Mechanical Engineering, Computer Science/Software Engineering, Electrical Engineering, and Computer Engineering.

To this end, we attempted to establish a defined set of technology skills that were deemed essential to effectively design and deploy an HRI model on a robotic platform. If all team members had a "common language" and shared understanding of hardware capabilities and limitations, it serves to follow that even those not responsible for primary technical development and implementation on the project will be able to more effectively complete their areas of responsibilities.

For example, one important step of an interaction design process is detection of a human 'user' when robots are operating in shared human/robot occupied spaces, and having an understanding of what information can be gathered by robot sensing systems can fundamentally influence the interactions that are possible, e.g. if the robot is not equipped with appropriate sensing and processing technology to detect a human face, it is not reasonably possible to attempt to determine the identity of a human user, if desired by the interaction design.

In order to determine this information and create a framework, two primary aspects were considered:

First, the categories of required skills should be determined, followed by determining the appropriate depth of knowledge of each of these skills to allow the most effective contributions.

To complete the first phase of this analysis, we broke down the development process as defined in the final hackathon project, focusing on the key deliverables, and then worked backwards to determine the skills (both technical and non-technical) at each step or development milestone. A skill expertise matrix was then created to more clearly delineate skill levels in each area.

This resulted in the following table which was then used to build a skill assessment structure.

- Novice: No/little experience
- Conversant: I know the basics of this area, but not enough to be able to contribute or operate on my own

- Competent: I can do some functional work in this area but am not self-sufficient
- Fluent: I am knowledgeable enough to operate and progress in this area without guidance - but still have areas to learn more about
- Expert: I am fully self-sufficient, and do not need significant additional training. I can teach others if necessary.

8.2.2 Key Knowledge Goals

Utilizing the same basic approach as detailed above with the technical skills, we then conducted the same approach as was utilized with the "technical knowledge" defined above, but in this case determining the remaining skills that were considered necessary to meet the defined deliverables of the HRI Hackathon.

These skills include the following:

- Computer Programming Languages (General knowledge)
- Software Development (Programming, Software Projects)
- Robotics: Basic Construction/Operation Principles (Identifying common robot parts and components)
- Robotics: Autonomous Principles (Perception, Navigation)
- Robotics: Manipulation Principles (How robots pick up and place objects)
- Robotics: Application areas (Where robots are being used)
- Robotics: Robot strengths and weaknesses (What tasks are robots effective or efficient for)
- Robotics: Implementation practices/challenges (What spaces can robots operate in, What environmental challenges do they have)
- Robotics: Programming Basics

8.2.3 Key Non-Technical Knowledge for Hackathon Prompt

After defining the two above categories that were deemed essential parts of an effective HRI development framework, the specific knowledge that would be relevant in this particular hackathon was identified: these areas are specific to the particular prompt and situation found in this project, which includes a number of cross-cultural considerations which were determined to not necessarily be essential to a universal HRI development framework.

After applying the process above to the "non technical" skills defined above, the aspects unique to this project were then identified and separated out in the interest of making the analysis as comprehensive as possible - these could be considered one of perhaps many 'optional appendices' that could be applied to other highly specific or specialized use cases. These areas are as follows:

- Robotics: Business and Market Spaces

- Effective Group Dynamics and Project Management
- Cross-Cultural Communication
- User Research/Needs Assessments
- Cognitive Science/Applied Psychology
- Interaction Design (Physical)
- Prototyping Processes

8.2.4 Equipping Groups for Hackathon Tasks

The final set of skills and knowledge that was also deemed critical for program and hackathon success was developing clear guidelines and expectations for the hackathon process - though the hackathon as a concept is fairly well known in technical spaces, it is not commonly utilized in other spaces, and the exact experiences may also differ depending on the individual, as well as work styles and communication may have different cultural aspects.

Additional Skillset Framework:

- Hackathon Fundamentals
- Development Timelines and Milestones
- Prototype Fidelity

In these areas, operating with the assumption of no prior knowledge or experience required, and giving general and universal instructions as the hackathon progressed helped students regardless of background understand the goals and work processes that should be occurring at each stage of the hackathon. As a result the level of knowledge was not assessed, since this was presented as a structure, rather than a knowledge area.

As this is not only an interdisciplinary project, but also an intercultural one, there was a conscious effort to clearly define as much as possible in the hackathon stage, including details around end deliverables, expectations. This ensured that all members of each team were able to operate off of a clearly defined hackathon structure, and were able to align around clearly define development tasks and timelines.

8.2.5 Class Deliverables

Early in the instructional design process, a clear goal of having a deliverable appropriate to an interdisciplinary design project was identified. There has been evidence that project-based learning in HRI tasks is typically very effective, even with a number of team members with limited technical experience[26].

Based on developed and established technology product development process deliverables utilized in the University of Washington's Master of Science in Technology Innovation program, each deliverable should contain:

- Demonstrated User Research and Needs Assessment (Considering US and Japanese potential user spaces)
- Demonstrated feasibility of technical concepts
- Understanding of market spaces and competitive environments in the United States and Japan
- Creation and testing of a low fidelity prototype able to demonstrate one or more of the considerations above

These considerations were chosen not just because of their previously successful employment at the University of Washington, but because students are able to clearly engage different skills at each stage of the development process, and require each interdisciplinary team to communicate and coordinate their work according to their individual skills.

The clear definition of these deliverables was identified as a key point of improvement from the previous year, as several projects with relatively unrealistic problem spaces or business cases were seen not only as affecting how "interdisciplinary" a design was in its nature, but also lacking clearly defined cultural considerations.

Since the primary purpose of designing an intercultural HRI design workshop is to evaluate the perspectives of multiple cultures in the interaction design, this was seen as one of the most critical areas to improve in the iteration of this program.

9 Results and Discussion

Analysis of pre- and post-program survey data indicates a clear overall improvement in student self-reported skills across technical, professional, and intercultural domains. Across all measured skill categories, the mean self-rating increased from 2.12 to 2.95 on a five-point Likert scale, representing an average gain of +0.83. This shift corresponds to a cohort-wide movement from ratings between "Conversant" and "Competent" toward solidly "Competent," suggesting meaningful learning gains over the duration of the program.

As expected, the largest improvements were observed in robotics-specific knowledge areas. Students reported substantial gains in understanding robotics applications, strengths and limitations of robotic systems, implementation considerations, robotic manipulation, business and market contexts for robotics, and basic robot construction. In many of these categories, the proportion of students rating themselves at or above "Competent" increased by approximately 35 to 71 percentage points from pre- to post-program. Similarly, the proportion of students reporting "Fluent" or higher competence increased by approximately 14 to 43 percentage points, indicating not only broader baseline competence but also emerging expertise among a subset of participants.

Teamwork and cross-cultural collaboration skills showed a different but equally important pattern. Students entered the program with relatively strong self-ratings in these areas, reflecting either prior experience or self-selection into an international program. Nevertheless, post-program results indicate further improvement, with 100% of respondents rating themselves at or above "Competent" in both teamwork and cross-cultural skills. Notably, approximately 57% of students rated themselves at “Fluent” or higher post-program, suggesting that the immersive, interdisciplinary team structure strengthened already-existing competencies.

In contrast, programming-intensive skill areas exhibited more modest gains. Self-ratings in software development increased by only +0.34 on average, while programming basics increased by +0.57. Self-assessed competence in computer programming languages showed minimal change overall (+0.03). Additionally, the proportion of students rating themselves at “Fluent” or higher in software development declined by approximately four percentage points. We interpret this not as a regression in skill, but as a recalibration of student self-assessment following exposure to more demanding, real-world development tasks. Several students explicitly noted that the hackathon-style culmination highlighted gaps in their preparation and underscored the complexity of large-scale software integration.

Logistical and experiential aspects of the program were rated positively overall. Students reported high satisfaction with accommodations, instructional staff support, and communication infrastructure (e.g., online coordination platforms). However, two recurring points of critique emerged: insufficient hands-on time with robotic hardware and limited time to complete the final hackathon. Multiple students commented that these constraints restricted opportunities for deeper iteration and testing. These findings align with instructor observations and suggest that, even with an extended timeline, balancing ambition and available hands-on time remains a critical design challenge in intensive robotics programs.

Taken together, these results support the effectiveness of the hybrid-plus-immersion model while also revealing important tensions. The strong gains in robotics knowledge, business context, and intercultural competence suggest that integrating technical, human-centered, and contextual perspectives can substantially enhance learning outcomes. At the same time, the more modest gains in programming-heavy areas highlight the need for continued refinement of guidelines and expectations, particularly as students transition from foundational instruction to high-pressure, integrative project work.

9.1 Qualitative Feedback: Industry Engagement and Program Intensity

Open-ended post-program survey responses provided additional insight into student experiences, reinforcing both the strengths of the hybrid-plus-immersion model and areas requiring refinement.

Company and lab visits were consistently described as “very useful,” as they helped students ground abstract concepts in tangible practice by observing real-world service robot deployments in Japan. However, some suggested that future iterations should include more hands-on interaction during these visits rather than purely observational tours.

Preparation and technical depth elicited mixed responses. While students felt prepared for high-level design, multiple participants expressed feeling underprepared for low-level implementation tasks, such as hardware integration and Arduino-based components. This exposure to authentic development pressure led students to reassess their technical readiness, supporting the “recalibration effect” observed in the quantitative data.

Hackathon structure and timing emerged as a recurring theme. Students valued the

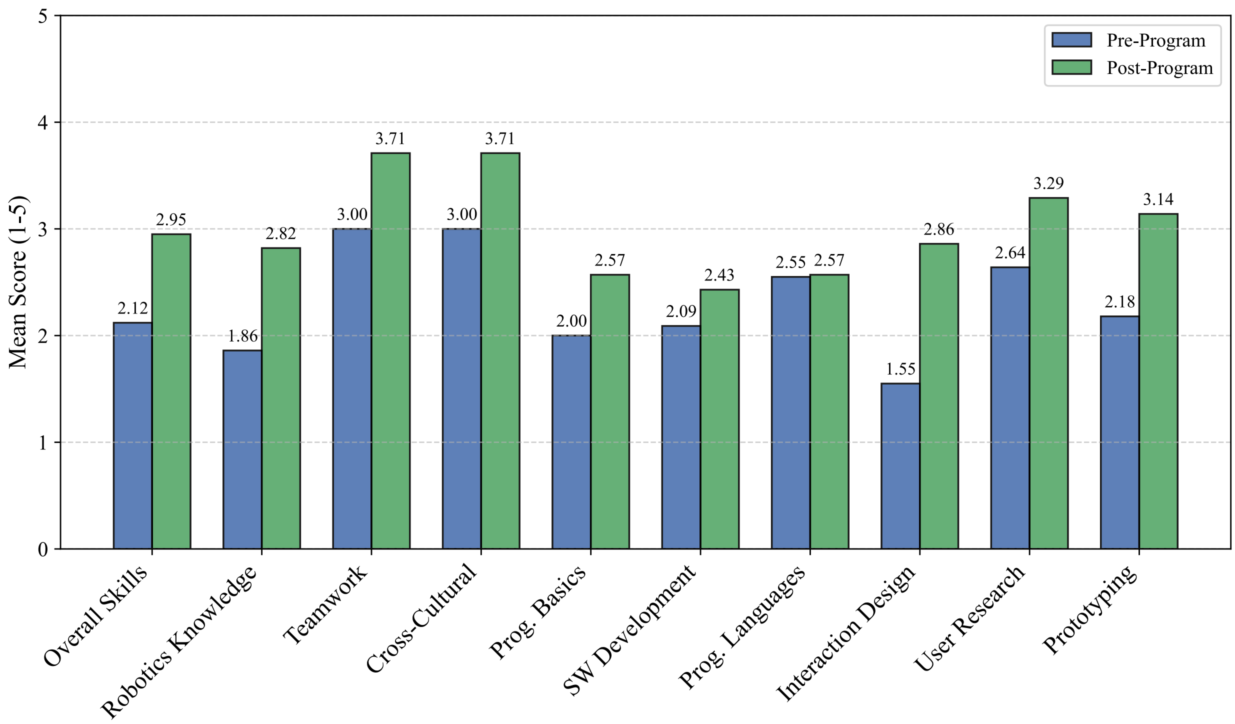

Figure 1: Summary of Pre- and Post-Program Self-Reported Skill Changes

collaborative intensity but desired more uninterrupted time for prototype iteration. Respondents frequently suggested concentrating lectures earlier in the in-person phase to dedicate the final week exclusively to project work and iteration.

Regarding **team dynamics**, while the use of shared artifacts bridged communication gaps (as discussed in Section 7.2), students qualitatively highlighted the importance of "rapport" and "trust" built through sustained collaboration. Some participants suggested earlier team formation or opportunities to engage with a broader pool of students to support early-stage ideation.

Finally, students offered **forward-looking suggestions** including deeper ROS 2 coverage, expanded discussion of Japan-specific HRI ethics, and clearer structures for non-technical contributions. Despite the program's intensity, participants described it as a formative and highly rewarding academic experience.

9.2 Pre–Post Comparison of Self-Reported Competencies

To more closely examine learning gains, we compared pre- and post-course self-reported competencies across technical, professional, and human-centered domains. Survey items used an ordinal five-point scale (Novice, Conversant, Competent, Fluent, Expert). Because individual identifiers were anonymized and not reliably linkable across instruments, the analysis focuses on cohort-level shifts rather than paired per-student comparisons. This approach is consistent with prior engineering education studies using self-assessment data.

Across nearly all robotics-related categories, the post-course distribution shifted substantially toward higher competency levels. In the pre-course survey, many students— particularly those from non-engineering or design-focused majors—self-identified as “Novice” or “Conversant” in areas such as robot construction, autonomous principles, manipulation, and implementation challenges. Post-course responses showed a pronounced movement toward “Competent” and “Fluent” ratings, indicating increased confidence in understanding how robotic systems are built, deployed, and constrained by real-world environments.

The largest relative gains were observed in conceptual and contextual robotics knowledge, including application areas, robot strengths and weaknesses, implementation practices, and business and market spaces. These findings align with the course’s explicit emphasis on situating technical work within real deployment contexts, reinforced through company visits, case discussions, and business justification activities. Students who initially expressed concern about their lack of robotics background frequently reported post-course competence in these areas.

Programming-related domains exhibited more nuanced patterns. While overall self-ratings in programming basics and software development increased modestly at the cohort level, the proportion of students rating themselves as “Fluent” did not increase commensurately. In some cases, it decreased slightly. We interpret this pattern as a recalibration effect: exposure to large-scale integration, ROS 2 workflows, and time-constrained development during the hackathon appeared to sharpen students’ understanding of the gap between introductory proficiency and professional-level software development.

Professional and interpersonal competencies showed consistently high outcomes. Pre-course ratings in teamwork, group dynamics, and cross-cultural communication were already strong, reflecting either prior experience or self-selection into an international program. Even so, post-course responses indicated consolidation at higher competency levels, with all respondents rating themselves at or above “Competent” in teamwork and cross-cultural communication. These results underscore the value of sustained, immersive collaboration with international partners.

Taken together, the pre–post comparison suggests that the redesigned program was particularly effective in building robotics literacy, contextual understanding, and interdisciplinary confidence, while simultaneously exposing the depth and complexity of advanced software development in real-world robotics practice.

Table 1: Cohort-Level Pre–Post Comparison of Self-Reported Competencies

Skill Category	Pre Dominant Level	Post Dominant Level	Observed Shift
Robotics Construction & Operation	Novice–Conversant	Competent	Large
Autonomy & Navigation	Novice–Conversant	Competent	Large
Manipulation Principles	Conversant	Competent	Moderate
Robotics Applications	Conversant	Fluent	Large
Robot Strengths & Weaknesses	Conversant	Competent–Fluent	Large
Implementation Challenges	Conversant	Competent	Moderate
Business & Market Spaces	Novice–Conversant	Competent	Large
Programming Basics	Novice–Conversant	Conversant–Competent	Modest
Software Development	Conversant	Conversant–Competent	Modest
Teamwork & Project Management	Competent	Fluent	Moderate
Cross-Cultural Communication	Competent	Fluent	Moderate
User Research & Interaction Design	Conversant	Competent	Moderate

9.3 Qualitative Reflections and Technical Recalibration

The qualitative reflections from the SIT cohort provide an essential interpretive lens for the quantitative trends observed in the UW data, particularly the modest self-reported gains in software development (+0.34) shown in Figure 1. While the SIT assessment was primarily limited to post-program qualitative feedback due to institutional scheduling, their experiences as the "technical anchors" within each team offer a direct validation of the challenges faced during the intensive. SIT participants reported that the two-week on-site phase required an intense "recalibration" of their professional identity, as the reality of ROS 2 integration and system debugging proved significantly more complex than prior theoretical coursework.

Furthermore, the observations suggest that the most effective interdisciplinary integration occurred in teams with distributed technical expertise across both institutions. In teams where UW participants also possessed engineering backgrounds, a 'technical synergy' emerged that catalyzed the development of the project. These teams utilized code repositories and shared design and interaction maps as a shared language to bridge the dimensions of Business (B), User (U), Robot (R), and Technology (T) more fluidly. While the SIT students led the software realization, their technically-literate UW peers ensured that the design intent remained grounded in technical feasibility while pushing the boundaries of interaction logic. This collaborative dynamic demonstrates that the hybrid-plus-immersion model is most successful when technical proficiency exists on both sides of the international partnership, enabling a deeper synthesis of HRI concepts.

10 Limitations and Future Work

This study is limited by its relatively small cohort size and reliance on self-reported measures. Future work will incorporate objective assessments of technical proficiency and longitudinal tracking of student outcomes. Additional refinement of the business framework may further support students with limited prior exposure to entrepreneurship.

Regarding the SIT cohort, a primary limitation was the reliance on post-program qualitative feedback due to institutional scheduling constraints, which precluded the longitudinal pre-post comparison available for the UW data. To address this in future iterations, we plan to align the academic calendars more closely, enabling consistent quantitative tracking of technical and professional growth across both institutions.

Furthermore, to alleviate the pronounced time pressure and the "recalibration effect" reported by SIT engineering students, future versions of the program will require SIT participants to join the initial three-week remote instructional phase alongside their UW counterparts. This adjustment is expected to establish a stronger conceptual baseline across all four B-U-R-T dimensions before the intensive on-site phase begins.

For institutions seeking to replicate this model, we emphasize the importance of selecting accessible, low-cost hardware to ensure program scalability. The use of the TurtleBot 3 Burger platform(approx. $550 USD per unit) provided a cost-effective solution that balances technical capability with fiscal accessibility for multidisciplinary labs. The findings suggest that the most integrated HRI solutions emerge when a baseline of technical literacy—facilitated by such accessible platforms—is distributed across all participating cohorts. This underscores the necessity of a "common language" that enables non-engineering participants to engage more critically with technical feasibility, while allowing technical students to ground their work in complex user narratives.

11 Conclusion

The pre–post comparison highlights a productive tension in immersive robotics education: while students achieved measurable gains in robotics knowledge and interdisciplinary collaboration, increased exposure to authentic development constraints led to a critical recalibration of technical self-efficacy. Rather than indicating a deficit, this shift reflects a more mature and realistic understanding of professional robotics complexity. This effect was most pronounced among "technical anchors," whose self-assessments stabilized as project demands intensified.

The program's success further demonstrates that the functional integration of Business (B), User (U), Robot (R), and Technology (T) dimensions relies on a shared technical language. By utilizing artifacts such as ROS 2 repositories and interaction maps, international teams successfully bridged linguistic gaps to ensure technical execution remained aligned with design intent.

This paper presented a redesigned hybrid-plus-immersion program that integrates technical rigor, human-centered design, and business justification. The observed outcomes suggest that this model, characterized by distributed technical expertise, provides a replicable and scalable framework for holistic HRI education in global contexts.

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