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Preparing Students for Successful Industrial Collaborations in Engineering (Work in progress)

Mr. Chun Kit Chan, The University of Hong Kong

Mr. Ryan Chun Kit Chan is a Senior Technical Assistant in the Tam Wing Fan Innovation Wing, Faculty of Engineering at the University of Hong Kong after graduation. Before graduation, Ryan served as an undergraduate research assistant in Innovation Wing and has involved in the design and implementation of a world-record-holding robotic fish. Ryan received his Bachelor's degree in Mechanical Engineering from the University of Hong Kong. Ryan's research focuses on robotic systems, navigation, rapid prototyping methods, and integrating project-based learning experiences beyond the regular syllabus.

Dr. H.H. Cheung, University of Hong Kong

Dr. H.H. Cheung is a Senior Lecturer in the Department of Industrial and Manufacturing Systems Engineering at the University of Hong Kong. He obtained his B.Eng., M.Phil., and Ph.D. degrees at the University of Hong Kong. Prior to joining the University of Hong Kong, he has worked in manufacturing and IT industries as a consultant for a number of years. He has gained substantial experiences in developing and managing RFID-based solutions, and the provision of consultancy services to implement RFID applications to various industries/enterprises. Dr. Cheung has also participated in a number of industrial application projects of RFID and IoT technologies, including RFID-based systems for product anti-counterfeiting, food processing management, manufacturing and logistics management of a global printing enterprise, governmental project for inventory management, and baggage management of a major international airport.

His research interests include CAD/CAM, Layered Manufacturing (3D Printing), Virtual Prototyping and Virtual Manufacturing, Smart Manufacturing, Product Development, Digital Twins, AI, IoT and Robotics applications.

Dr. Match Ko, University of Hong Kong

Dr. Match Wai Lun Ko is a Senior Lecturer and MSc(Eng) in Mechanical Engineering Programme Director in the Department of Mechanical Engineering, the University of Hong Kong. He is also fractionally appointed in Innovation Academy, Faculty of Engineering of HKU. Dr. Ko obtained his B.Eng and Ph.D. in Mechanical Engineering from the Hong Kong University of Science and Technology. Before joining HKU, he was an Assistant Professor in Nazarbayev University, Postdoctoral Fellow in the Hong Kong Polytechnic University, Visiting Scholar in the Chinese University of Hong Kong, Visiting Professor and Scholar in the University of Warwick. Dr. Ko's research focused on the engineering education, biomechanics, biomedical image processing, biomechanical properties characterization, finite element modeling, design and fabrication of related medical device to assist the clinicians to preform disease diagnosis and decision making regarding screening of disease and treatment management.

Dr. Chun Kit Chui, University of Hong Kong

Dr. Chun Kit Chui serves as the Director of the Tam Wing Fan Innovation Wing in the Faculty of Engineering at the University of Hong Kong (HKU). Innovation Wing aims to unleash students' creativity by entrusting them to spearhead ambitious innovation and technology projects that will shape the future. The iconic facility is located at the heart of the campus, offering 2400m2 of space with state-of-the-art resources and a supportive environment to enhance hands-on and experiential learning for undergraduate students.

He also holds the position of Senior Lecturer in the Department of Computer Science at HKU. His research interests include database and data mining, as well as pedagogical research in computing education. Dr. Chui has received several education awards, including the University Outstanding Teaching Award (Individual Award) at the University of Hong Kong for the 2015-16 academic year and the Faculty Outstanding Teaching Award (Individual Award) in the Faculty of Engineering for the 2012-13 academic

year. Additionally, he has been honored with the Teaching Excellence Award in the Department of Computer Science for the academic years 2011-12, 2012-13, 2013-14, 2014-15, and 2015-16. Furthermore, he was a shortlisted candidate for the UGC Teaching Award (Early Career Faculty Member).

Dr. LEI YANG, The University of Hong Kong

Lei Yang is a lecturer of Innovation Academy of the Tam Wing Fan Innovation Wing under the Faculty of Engineering, The University of Hong Kong. Before that, he worked as a Research Officer at Centre of Transformative Garment Production from 2021 to 2023 and as a postdoctoral fellow at Department of Computer Science, The University of Hong Kong from 2018 to 2021. Dr. Yang received his Bachelor's degree and Ph.D. degree from Dalian University of Technology in 2012 and 2018, respectively. Dr. Yang's research interest includes Computer-Aided Design, Computer-Aided Engineering, and Geometry Modeling and Multimedia.

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Abstract

This practice paper introduces a framework for preparing engineering students for industrial collaborations. Engaging engineering students in industrial projects provides them with valuable hands-on working experience in an authentic learning environment. However, industrial collaborations come with challenges among various stakeholders, including discrepancy in expected outcomes, limited support, and shortfall in contemporary technical knowledge and hands-on competency. To establish an effective industrial collaboration, the Faculty of Engineering at the University of Hong Kong has established the Tam Wing Fan Innovation Wing (a.k.a. the HKU Inno Wing) [1]. This center is designed to engage students in real-life projects, providing them with hands-on experience.

We propose and implement the Inspire-Equip-Showcase (IES) framework to prepare students for successful industrial collaboration. In the 2023/24 academic year, a cohort of students underwent pre-collaboration training activities under IES with a focus on the theme of AI and robotics. The training covered fundamental competencies such as Robot Operating System (ROS), localization, auto-piloting, computer vision, object recognition, LiDAR control, and GPS. Following this training, these students were then paired with a local railway company, collaborating with professional engineers on the exploration of robotic solutions to address various maintenance challenges in modern railway operation.

The practice paper analyzes students' written reflections collected during the pilot run of the IES framework in 2023/24, revealing the impact of the framework and its various learning components in preparing students for industrial collaboration. The insights from this study offer valuable lessons that can be applied to adapt to other technology domains in upcoming cohorts.

Keywords

Industrial collaboration, preparation program, robotics

Background

To foster industrial projects, collaboration among academia, industry partners, and students is essential. However, such collaborations present challenges, including disparate outcome expectations, limited support, and a common deficiency in contemporary technical knowledge and hands-on competency among students. In response to these challenges, the engineering faculty at the University of Hong Kong established the Tam Wing Fan Innovation Wing (also known as the HKU Inno Wing) [1]. The aim is to engage undergraduates in interdisciplinary experiential learning and tackle real-life technological challenges. Inno Wing first establishes a mutually beneficial collaboration plan, including clear objectives and commitments among various stakeholders. The center then provides comprehensive support to the participating industry professionals, academics, and students, such as workspaces, equipment, technical support, and preparation programs.

The Inno Wing is a 2,000-square-meter interdisciplinary workspace for undergraduates to explore and build technologies. It provides state-of-the-art prototyping equipment and hands-on training support. The educational aim of the Inno Wing is to entrust and empower undergraduate students - to unleash their creative potential by entrusting them to spearhead ambitious innovation and technology projects that will shape the future. Since its opening in December 2020, the user population has grown from 931 in 2020/21 to 2,800 in 2022/23. The community spans a diverse background in engineering, including students from mechanical engineering, electrical and electronic engineering, computer science, civil engineering, biomedical engineering, and industrial and manufacturing systems engineering. Starting from the 2022/23 academic year, the center actively encouraged students from other faculties to engage with engineering students in cross-disciplinary projects. As a result, about 11% of the user populations are from science, business, architecture, medicine, education, arts, social sciences, dentistry, and law; adding another layer of diversity to its talent pool. With such rich resources, diverse talents, ample workspaces, and well-equipped facilities, the center becomes an ideal platform to stimulate industry collaborations.

In the following sections, we first provide a literature review of various approaches to universities-industry collaborations (UIC). Then we present the Inspire-Equip-Showcase (IES) framework adopted at the Inno Wing, followed by a study of the effectiveness of the IES framework in our pilot launch on the theme of exploring technologies in “AI and robotics” with a local railway company in Hong Kong in the 2023/24 academic year.

Related works

The collaboration between universities and industries, known as Universities-Industry Collaboration (UIC), is a strategic partnership aimed at fostering knowledge and technology exchange [2]. This collaboration holds significant importance for various reasons. Firstly, it serves as a bridge between theoretical knowledge and practical application. While universities equip students with a robust theoretical foundation, industries contribute by providing hands-on experience and exposure to real-world problems and challenges [3]. Additionally, UIC enables industries to stay abreast of the latest research and developments in their respective fields. Universities, with their cutting-edge research initiatives and access to state-of-the-art technologies, offer valuable insights that can enhance industries' operations and product development [4]. Furthermore, UIC facilitates the creation of innovative solutions and products, ultimately boosting the competitiveness and productivity of the industry [5]. Lastly, this collaboration opens avenues for industries to attract and recruit talented graduates, offering students potential employment opportunities [6]. Acknowledging its numerous advantages, UIC is labeled as a strategic approach to enhance innovation efficiency and encourage the practical use of technological advancements in various tertiary education systems worldwide [7] [8].

As extensively studied in academic literature, universities employ a comprehensive range of strategies to prepare students for successful engagement in industrial collaboration. This approach includes curriculum design wherein universities intricately integrate industry-relevant courses and practical training into their curricula [9]. Study reveals that embedded and extra-curricular internships, as well as extra-curricular activities, are crucial for enhancing students' employability [10]. Regarding preparation programs, Hero suggests integrating collaborative projects that simulate real-world industrial collaborations [11], while Wats recommends enhancing students' soft skills, including communication, teamwork, leadership, and problem-solving, through workshops and training programs [12]. Additionally, Hu recommends enhancing students’ ability to apply theoretical knowledge to real-world problems via pre-collaboration research projects and pilot studies [13]. To enhance students’ exposure to industrial practices, Burns and Chopra advocate establishing internships and cooperative education programs with industry partners, a strategy shown to be effective in helping students develop industry-specific skills and understand the demands of industrial collaboration [14].

In this practice paper, an extra-curricular approach to providing industrial collaboration opportunities for students is adapted. Incorporating the findings of study, we seamlessly integrate a range of educational activities, including soft skills workshops, technical skill workshops, inspiring seminars, study trips, industrial visits, hands-on projects, and showcasing events, into a comprehensive three-stage Inspire-Equip-Showcase (IES) framework to prepare students for successful industrial collaboration [9] [11] [12] [13] [14]. We implement the IES framework within the Inno Wing established by the engineering faculty, which complements the study conducted by Wats's study [12] as their study focuses on supportive programs provided by career services departments or professional development centers within the university. This allows us to leverage ample resources such as workspace, equipment, facilities, technical guidance, and a wealth of student-initiated community support to create an immersive and dynamic environment for students to excel in industrial collaboration initiatives.

Preparing students for industrial collaborations: The IES framework

We propose and implement a three-stage progression framework to prepare students for industrial collaborations. The 'Inspiring' stage focuses on broadening students' horizons and enhancing their knowledge of contemporary developments within the collaborative technology theme, both in the industrial application and academic research arena. The 'Equipping' stage targets uplifting students' hands-on ability by providing the necessary technical competencies for prototyping innovative solutions to industrial problems. The 'Showcasing' stage emphasizes professional practices of students by engaging them in intensive partnerships and collaborative work with industrial partners. Additionally, it involves building a platform for students to disseminate their findings and innovations to industrial collaborators and other stakeholders through knowledge exchange activities.

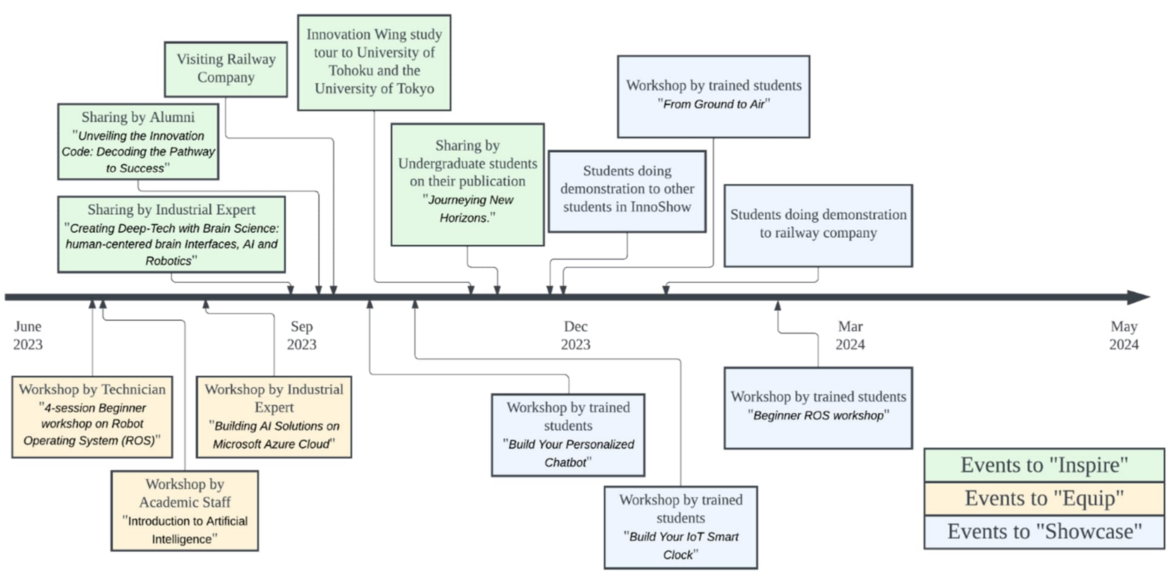

Figure 1 General timeline for implementation of the IES framework and the categories of related events during the 2023/24 academic year (work-in-progress).

The following section provides details on the student learning activities that were designed and implemented within the Inspire-Equip-Showcase (IES) framework. The framework underwent a pilot phase during the 2023/24 academic year in collaboration with a railway company, with a specific emphasis on the technology theme of "AI and Robotics", as listed in Figure 1.

Stage 1. Inspiring innovation through outreach explorations and invited sharings

As students are expected to work in an industrial environment, distinct from academic settings, we recognize the importance of expanding students' knowledge horizons, particularly their awareness of the latest operational processes and technology trends in the industry. This preparation is crucial for equipping students with the necessary technological background when collaborating with industrial partners. Therefore, engaging students in outreach explorations is necessary.

The outreach program first includes an in-depth on-site exploration of the operations of the industry partner. This allows students and academic mentors to delve into the actual industrial operational processes, understand the current solutions, and explore the potential for adopting innovative technologies. For example, we engaged students to access the maintenance center of the railway company in Hong Kong, where the actual daily maintenance work is conducted. Our team explored three important aspects of maintenance work that can potentially apply "AI and robotics" to optimize the process. First, as the maintenance work can only be done within the short mid-night time frame when the railway service was closed, inspections and autonomous detection of faults, such as potential cracks or worn nuts underneath the train compartment, would help facilitate the maintenance process. Second, learning that every train will undergo a complete disassembling and reinspection of every part regularly, the use of computer vision and robotic arms that could assist the sorting and counting of tool parts would be of great help. Finally, recognizing that the entire railway monitoring system is a huge information system with lots of real-time data, has the potential to apply big data and AI technologies for predictive analysis. These practical problem identification are done within the on-site exploration visits.

Figure 2. Outreach to research laboratory: The Human-Robot Informatics laboratory, which specializes in the latest robotics innovations addressing challenging terrain and situations.

Figure 3. Inspired by researcher: Insights into the next generation of robotics and inspire the possibilities of robotics during the seminar titled "Creating Deep-Tech with Brain Science: human-centered brain Interfaces, AI and Robotics" [16].

We acknowledge that the outreach program should go beyond simple industrial visits, instead it is necessary for students to draw inspiration from the latest technological advancements in the field. Therefore, our exploration trip extends to other pioneering academic research labs. In our pilot program, students participated in an overseas study trip to Japan, visiting major laboratories in AI and Robotics, including the Human-Robot Informatics Laboratory and Smart Robots Design Lab at the University of Sendai (Figure 2), as well as the Jouhou System Kougaku (JSK) Laboratory and the Laboratory Mitsuishi Harada Laboratory at the University of Tokyo. Throughout these visits, students delved into the latest developments in robotics, including humanoid robots, assistive robots, drone robots, search and rescue robots, medical robots, and their respective applications. Direct interactions with pioneering researchers in the field equipped students with a robust understanding of current and future development trends. This exposure aims to inspire students, encouraging the generation of new ideas to address prevailing industrial challenges. Student reflections from this pilot run, as analyzed and reported in the upcoming section, shows that these exploration visits have significant impact on their commitment and learning in the field.

In addition to outreach visits, the Inno Wing organizes a series of invited sharing seminars, featuring industry experts, academics, alumni, and senior students who discuss inspiring topics in AI and robotics. As a work-in-progress in the 2023/24 academic year, we welcomed an industry expert who successfully deployed big data analysis technologies for thermal camera image analysis in forest fire fighting [15] to showcase the capabilities of computer vision and big data analysis. For insights into the next generation of human-robot interactions, a world renowned robotics researcher was invited to share their expertise in a session titled "*Creating Deep-Tech with Brain Science: Human-Centered Brain Interfaces, AI, and Robotics*" [16] (Figure 3). Recognizing the critical importance of project management and team building in the success of industrial projects, we also invited alumni who have served as leaders in successful student projects at Inno Wing to share their experiences in a session titled "*Unveiling the Innovation Code: Decoding the Pathway to Success*" [17]. Furthermore, senior students with a track record of bringing their inventions to international academic publications shared their journey in a session titled "*Journeying New Horizons*" [18]. These sharing seminars aim to inspire students and provide them with professional insights into the potential achievements of their upcoming industrial collaborations.

Stage 2. Equipping core competencies through training programs and peer learning

The "Equipping" stage commences with the identification of technical prerequisites essential for students to qualify for the industrial projects. These core competencies are collaboratively defined by all stakeholders involved in industrial collaborations. In the 2023/24 period, the core competencies outlined for "AI and robotics" include:

- The ability to write firmware for microcontroller units (MCUs), demonstrating proficiency in controlling actuators and sensors efficiently [19].
- The ability to use the Robot Operating System (ROS) to design, implement, and manage robotic systems, incorporating tasks such as sensor integration, communication between robotic components, and navigation planning [20]
- The ability to conduct 3D modeling using software like SketchUp to design and fabricate intricate three-dimensional structures [20].
- The ability to apply Python programming language in implementing AI models, with basic understaindg in machine learning techniques [21].
- The ability to leverage application programming interfaces (APIs) offered by major cloud platforms for constructing generative AI applications, exemplified by the development and customization of a chatbot tailored to specific requirements [22].

Figure 4. Technical workshop by technicians: “2-day Beginner Workshop: Robot Control - Firmware” where students equip their knowledge on robotic control and firmware design [19].

Figure 5. Technical workshop by academic staff: “Introduction to Artificial Intelligence” to equip students on the field of machine learning and image recognition [21].

These technical competencies often demand a hands-on approach, a dimension not comprehensively covered by the traditional, theoretical-oriented engineering curriculum. Recognizing this gap, the Inno Wing seizes the opportunity to design training programs with a strong emphasis on hands-on learning. Despite ample support from academic and technical staff, along with contributions from industrial experts serving as initial trainers for these skill sets, the primary challenge lies in scaling up the learning experience to cater to the expanding undergraduate community within the center, which has grown to over 2,800 students in the 2022/23 academic year.

To meet the challenges of scalability and sustainability, we have embraced a train-the-trainers model. In this approach, the initial trainers, whether academic staff, technicians, or industrial experts, deliver an initial training session to our students. The objective is to nurture the first generation of knowledgeable student trainers capable of orchestrating subsequent training workshops for the next cohort of students through a peer learning approach. Figure and Figure 5 illustrate some initial training sessions conducted in 2022/23. Students engaged in industrial collaboration undergo training in these workshops and are entrusted with the responsibility of organizing additional product-design workshops for their peers in the final stage of the IES framework, constituting a mandatory commitment.

Stage 3. Showcasing professionalism through industrial partnerships and knowledge exchange

The “Showcasing” stage emphasizes the development of professional practices among students through immersive collaborations with industrial partners. This stage commences by translating industrial challenges into an academic study, facilitating the exploration of technology in a simulated environment within the Inno Wing. In the 2023/24 period, the Inno Wing and the railway company initiated a study on using robotic arms to enhance the sorting of tools and parts, exploring the potential adaptation of robotic automations in the train maintenance process. The scenario is initially transformed into an academic study that integrates computer vision, artificial intelligence, and robotic arm control for pick-and-sort challenges using research/educational-level robotics arms, set up within the academic environment of the center. Students delve into various vision AI libraries and control mechanisms, summarizing their study in a proof-of-concept report, followed by on-site

Figure 6. Showcase to industry partner: Students showcased outcomes of computer vision-enabled robotics arm pick and place application project to industry collaborators

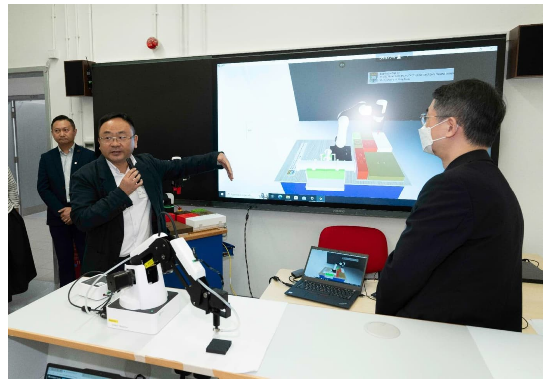

Figure 7. Showcase to industry partner: The team showcased digital twin technologies by integrating them with physical robotic arm control for a pick-and-place task to industry collaborators.

deployment and testing with the industrial collaborator. As a work-in-progress, Figure 6 and Figure 7 showcase the pilot team presenting preliminary outcomes during an on-site demonstration to the industrial partner. Subsequently, students collaborate with industrial engineers to explore opportunities for deploying the solutions at a working level and scale up the findings to incorporate the use of industrial-grade robotic arms in industrial operations.

In the pursuit of professional practices in industrial collaborations, students surpass mere hands-on knowledge application. These collaborations cultivate teamwork, effective communication, and project management skills, offering insights into industry dynamics, regulations, and ethical considerations. The experience encourages adaptability and innovation, fostering creative problem-solving. In addition to technical competence, students establish a professional network, contributing to comprehensive professional growth in their engineering careers. According to feedback from our collaborator, continuous collaboration with students allows them to monitor their professional practices, serving as a significant incentive for talent acquisition within their organization.

In terms of continuous growth, the IES framework aims to foster a cumulative effect within the community. The showcase component of the framework involves creating a platform for current students to share their findings and innovations with all stakeholders, including the next cohort of students, through two types of knowledge exchange activities. Firstly, students will present their discoveries in the Engineering InnoShow [23], a regular showcase carnival in the Inno Wing where they exhibit and demonstrate project achievements to stakeholders, receiving feedback for continuous improvement.

Secondly, current students will design and conduct a series of post-collaboration workshops, disseminating their knowledge and experience from their cohort of industrial projects to new students, ensuring continuity in both technical know-how and technology exploration with industrial collaborators. As a work-in-progress in 2023/24, Figure 8 and Figure 9 showcase the workshops hosted by students as the outcome of their learning in AI and robotics, including the workshops "*From Ground to Air*" [24] on drone robotics, "*Build your IoT Smart Clock*" [25] on smart technologies, and "*Build Your Personalized Chatbot*" [26] on generative AI technologies. The successful launch of these student-run workshops showcases that the IES framework has nurtured a cohort of technically strong students through industry collaborations, making a significant contribution to the overall growth of engineering students in the University of Hong Kong.

Figure 8. “Build Your Personalized Chatbot” workshop delivered by students to show their development on Chatbot and equip others to build a specialized chatbot of their own [26].

Figure 9. “Build Your IoT Smart Clock” workshop delivered by students to showcase their product and equip other students with knowledge on IoT [25].

Evaluation of the impact of the proposed IES framework

Methodology

We invited undergraduates engaged in the pilot run of the IES framework in the 2023/24 period to provide their written reflections on the impact of the framework and its various learning components in preparing students for industrial collaboration. Students who joined the activities were invited to provide a written reflection of the impact of the IES framework in preparing them for successful industrial project. Twelve undergraduate reflections were collected. In the analysis process, no predetermined themes were set and the final themes, uncovered and analyzed using a coding scheme [27], emerged from the data itself. The initial coding process was an open exploration, and the data were subsequently annotated. Words and sentences under each criterion were unitized and labeled as mutually exclusive categories [28]. Subsequent readings allowed for the emergence of themes. The uncovered themes cover problem-solving, technical proficiency, interdisciplinary teamwork, communication, and lifelong learning.

The findings presented in this analysis represent a work-in-progress, as the project is currently in the pilot run for a smaller group of undergraduates during the academic year 2023/24. Our primary focus aims to reveal the impact of the IES framework in preparing students for successful industrial collaboration through the study of students' reflections. The successful execution of the pilot run will pave the way for a scaled-up implementation scheduled for the academic year 2024/25. The initial stages, namely the “Inspire” and “Equip” stages, have been successfully completed. The last stage of the “Showcase” is underway, and initial feedback from industrial collaborators has been collected. A more comprehensive analysis of the last stage will be detailed in a subsequent study.

Results and discussions

On the aspect of “Inspiring” of the IES framework

Students reflected on the significant impact of the outreach explorations and invited sharing activities during the 2023/24 academic year, summarizing into four key impacts. Firstly, 67% of the participants expressed in their reflections the expansion of their horizons and the development of a global perception of the field. For instance, students shared sentiments such as "*a deeper appreciation for the potential of robotics in our daily lives,*" and "*a greater understanding of the importance of international collaboration in advancing this field,*" along with statements like "*broadened my horizons and made me realize the immense potential of technology to transform industries and improve our everyday lives.*" For most participants, the firsthand experience of witnessing the technology development "behind the scenes" and interacting with industry and research experts allowed them to perceive the application and development of the latest robotics technologies from an industrial perspective. This new viewpoint, in comparison to their daily user experiences, broadened the students' horizons. They gained an understanding of the ideation, engineering design, scientific approach, and development cycle of the technology before its actual deployment as a useful product in the market.

Secondly, 56% of the participants noted that the activities enhanced their technical understanding of robotics technologies. For instance, students expressed sentiments such as "*deepened our understanding of robotics-related research,*", "*get a look into serious research work,*" and "*discovered various cutting-edge technologies,*". The relatively lower percentage is understandable, considering that the focus of the activities in the inspiring stage does not emphasize intensive training in technical know-how in robotics. Nevertheless, immersing themselves in industry and research lab visits enabled participants to acquire an introductory level of technical understanding through detailed explanations and induction tours hosted by our collaborators.

Thirdly, an impressive 89% of the participants confirmed that they now have a better understanding of the potential and latest developments in the field. For instance, students shared experiences such as being "*exposed to groundbreaking research and innovation,*" realizing "*the immense potential of technology to transform industries and improve our everyday lives,*" and finding inspiration for new ideas that they applied to their projects. One student mentioned, "*I also got many ideas that I have already applied to my projects in various courses.*" Additionally, they became aware of the interdisciplinary nature of real-life engineering development projects; as one participant noted, "*I realized the importance of collaboration between different disciplines to better craft a product that can bring practical benefit to society.*"

Lastly, 89% of the participants expressed that the activities cultivated their motivation to learn, ignited curiosity, and contributed to advancements for social good. Students shared sentiments such as, "*It has awakened a sense of purpose and a thirst for knowledge as I seek to explore the limitless possibilities,*" and described it as "*a life-changing experience that deepened my passion for robotics and sparked my curiosity for further exploration in the field.*" These reflections demonstrate that the outreach explorations and invited sharing activities have not only stimulated their motivation but also inspired them to engage in future learning and project work within industrial projects. This positions them for entry into the "equipping" stage of the IES framework.

On the aspect of "Equipping" of the IES framework

Students' reflections provide insightful perspectives on their learning experiences in AI and robotics, collectively highlighting the transformative and interdisciplinary nature of their acquired skills. One common insight drawn from their reflections is the emphasis on the fusion of theoretical knowledge with practical ingenuity. A student describes the learning experience as a "*transformative journey,*" where tasked with creating autonomous robots, hands-on activities allowed for the development of technical skills, including coding and hardware assembly. Similarly, another student emphasizes the positive impact of actively participating in various projects and events during the learning experience. This exposure to real-world engineering scenarios facilitated the acquisition of essential technical skills, bridging the gap between theoretical learning and practical application. As student shared, "*The learning experience has been a transformative journey, blending theory with practical ingenuity. Tasked with creating autonomous robots, I developed a self-balancing, two-wheeled machine, and a navigation-enabled robot, powered by ROS, arduino, and jetson nano.*"

In addition to the common insights, there are special insights that offer unique perspectives on the challenges and personal growth experiences. Another student shares his struggles due to limited knowledge in electronics and programming. However, the ample support and guidance received from the Inno Wing and peers enabled a quick transition to proficiency in both areas. This experience highlights the resilience and adaptability required in the face of challenges, emphasizing not only technical proficiency but also the development of valuable time management and self-discipline skills. The student shared, "*During my learning experience … I had the opportunity to work on a spider robot project. As a student with limited knowledge in electronics and programming, I initially struggled to contribute effectively. However, with the support and guidance from the educational institution and my peers, I quickly gained the necessary skills and became proficient in both electronics and programming.*" Another special insight focuses on the enhancement of leadership and communication abilities. The student expressed, "*Additionally, the learning experience helped me enhance my leadership and communication abilities, which are vital for my career advancement.*"

In terms of measures learned to prepare for industrial collaboration, students acknowledge the significance of a supportive learning environment, exposure to real-world projects, and the development of interpersonal skills. As student shared, "*The supportive environment, paired with abundant facilities, accelerated my growth, pushing the boundaries of what I believed possible.*", and another student expressed, "*Moreover, I acquired essential technical skills and had the chance to establish meaningful connections within the industry.*"

On the aspect of "Showcasing" of the IES framework

Students' reflections are still in progress as they engage in ongoing industrial collaborations. The initial feedback from the industrial collaborator, however, provides insight into the positive reception of the students' efforts. The collaborator expressed, "*We are highly satisfied with the sharing session from your team provided in the Grand Opening Ceremony… They surpassed our expectations by showcasing exceptional expertise and professionalism. We truly appreciate their proactive approach and their contribution…*" The feedback suggests that the students, even in the early stages of their projects, have successfully showcased their skills and professionalism, exceeding the collaborator's expectations.

The positive initial feedback from the industrial collaborator is an encouraging sign of the IES framework's efficacy in preparing students for real-world projects, emphasizing both technical competence and professional practices. While the ongoing pedagogical examination of the framework's impact is in progress, the collaborator's satisfaction provides a positive indication of its meaningful influence in fostering excellence and professionalism among students involved in industrial projects.

Conclusion

The Inspire-Equip-Showcase (IES) framework, introduced and implemented in this practice paper, stands as a robust approach to preparing students for successful industrial collaborations. In a targeted exploration focusing on AI and robotics, a cohort of students engaged in pre-collaboration training activities under the IES framework. An analysis of their reflective writings reveals the profound impact of the framework. Students reported an expansion of their horizons, fostering a global perception of the field, an enhanced technical understanding, a deeper awareness of potential and the latest developments, heightened motivation to learn, ignited curiosity, and contributions to advancements for social good. The IES framework successfully facilitated the fusion of theoretical knowledge with practical ingenuity, fostering personal growth and professionalism.

As a work-in-progress in 2023/24, a quantitative analysis of the learning outcomes will be conducted after the completion of this cohort. The success of the pilot cohort demonstrates the IES framework's potential as a valuable resource for the next generation of students entering industrial collaboration. Comprehensive feedback received from stakeholders forms a dynamic guide, enabling iterative adjustments as the next cohort, with a focus on another technological area like generative AI, is currently underway.

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