An Experiential Learning Framework to Harvest Synergy from College and Industry Partnership

Dr. LEI YANG, University of Hong Kong

Dr. 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 interests include Computer-Aided Design, Computer-Aided Engineering, and Geometry Modeling and Multimedia.

Chun Kit Chan, The University of Hong Kong

Ryan Chan Chun Kit is a Technical Officer with a title of Student Project Development Officer of Tam Wing Fan Innovation Wing in the Faculty of Engineering, the University of Hong Kong. During his experience working in Tam Wing Fan Innovation Wing, Ryan has been involving in numerous teaching, development and outreach programmes. Throughout his academic journey, Ryan has excelled in various engineering projects and research endeavours. He has been actively involved in designing workshops on cutting-edge technologies such as embedded systems, ROS and IoT. Additionally, Ryan has led an undergraduate student research team on robotics, developing various types of AI robotics for teaching and industrial use. Moreover, Ryan has been contributing to the community of Robotics through volunteer means. He has served as an Adviser for BREED and Nestspace at HKU, where he offers consultation and guidance on various projects. Ryan's technical proficiency includes 3D Printing, robotics, 3D modelling and mechanical machining.

Dr. Kin Sun Lam, MTR Corporation

Dr. LAM Kin Sun, Martin is the Senior Technical Training Manager at the Operations Training Department of the MTR Corporation. Dr. Lam has made significant contributions to the field of technical training and management. In his current role, Dr. Lam manages a team of over 50 staff members who provides technical training to nearly 18,000 employees in MTR. He also oversees more than 400 Railway Technical Trainee and nearly 100 Graduate Engineer training schemes. Previously, Dr. Lam was the Programme Manager at MTR Academy, where he developed HKCAAVQ accredited programmes and collaborated with various institutions to promote railway studies.

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). The Innovation Wing aims to unleash students' creativity by entrusting them to spearhead ambitious innovation and technology projects that will shape the future. This iconic facility is situated 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.

In addition to his role as Director, Dr. Chui holds the position of Assistant Dean (Teaching and Learning) in the Faculty of Engineering at HKU, responsible for driving curriculum reform and active learning activities. His research interests include database and data mining, as well as pedagogical research in engineering education.

Dr. Chui has been the recipient of several prestigious awards, including the University Distinguished Teaching Award (Individual Award) at the University of Hong Kong for the 2024-25 academic year, 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 2023-24 and 2012-13 academic years. Additionally, he has been honoured 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).

An Experiential Co-Training Framework to Harvest Synergy from College and Industry Partnership

Abstract: The rapid advancement of artificial intelligence (AI) and robotics presents substantial opportunities for innovation across diverse sectors. Industrial enterprises are actively seeking partnership with universities to develop effective testbed scenarios for integrating these emerging technologies into their operations and talent development. On the other hand, college students studying computer science, engineering or relevant fields possess fundamental knowledge of AI and robotics but often lack practical experience and exposure to real-world applications.

This paper reports on an on-going collaborative initiative between the Tam Wing Fan Innovation Wing at The University of Hong Kong (or HKU InnoWing) and the Operations Training Department (or OTD) of MTR Corporation (or MTR), a public transport company in Hong Kong. The study identifies the challenges and opportunities in bridging this gap and proposes an experiential learning framework designed to empower college students with practical experience, while simultaneously equipping the staff from the industrial enterprise with insights necessary for successful technology adoption, knowledge transfer, and staff competency development required in workplace. Evaluation based on the self-reflections collected from the first cohort of three HKU InnoWing students and five MTR staff indicates positive outcomes from the experiential learning framework. Additionally, teaching materials as well as the programming codes for robots underscore the achievements of this collaborative initiative. The paper concludes with a discussion and future work to further advance this initiative.

The proposed experiential learning framework consists of several key components designed to foster synergistic collaboration between HKU InnoWing students and MTR staff. On the one hand, HKU InnoWing students organized three progressive workshops to equip MTR staff on how to program a robotic arm serving as the foundations for the testbed scenarios. This hands-on teaching approach not only reinforced the students' understanding of robotic operations programming and improved their interpersonal skills, but also demystify the robot arms for the staff and empowered them with the ability to program robots. In parallel, MTR staff arranged technical visits to familiarize HKU InnoWing students with the industrial work environment in depots, training centers, and frontlines, and outlining potential tasks that the robotic arms could fulfill within their operational framework. A collaborative project was conducted in a scenario-based learning approach, where a robotic system for cleaning CNC machines was developed to evaluate the outcomes of the previous hands-on workshops.

We observed that this collaboration allowed students to gain insights into real-world applications and operational challenges faced by the public transportation industry while boosting the industrial partner's confidence in exploring the development of testbed scenarios and equipping the frontline staff with the applications of the technologies. The synergistic partnership between the university and the industrial enterprise enhances both parties' understanding and capabilities in technology integration and deployment, ultimately benefiting students from the educational institution and talents within the industry partner. We also note that this co-training model can be generalized to other industries.

Introduction

Emerging digital technologies offer viable solutions to a range of global challenges. For instance, digital twins enhance efficient and lifelong building information management; Internet of Things (IoT) technologies are crucial to promote sustainability; robotic and automation technologies address labor shortages; and generative artificial intelligence (AI) improves work productivity. Consequently, the shift toward a digitalized world is an inevitable trend across the industrial sector.

With the advancement of various emerging technologies, MTR established a mission to deploy smart maintenance strategies in the workplace through adopting identified new technologies. However, only a small portion of employees possess the necessary digital skills. Many, including technicians, supervisors, maintenance engineers, and managerial personnel, may not be ready for this transformation. A sudden shift could disrupt the current workforce, adversely affecting both company culture and their competency development. Therefore, it is crucial to identify ways to gradually equip the workforce with essential skills needed for digital transformation.

On the other hand, higher education institutions have developed curricula to prepare students for this transformation, equipping them with essential skills such as programming, computational thinking, and more recently, AI literacy. However, a lack of practical training hampers their ability to effectively translate learned knowledge into viable solutions for industrial needs. Consequently, comments from employers about this deficiency among graduates are not uncommon [1] [2]. While capstone projects have been implemented among universities to improve the students' ability in problem-solving and systematic design, the participation of industrial partners is limited. Recent works have suggested close collaboration between the university and the enterprise in capstone projects can benefit the students' employability skills [3] [4].

We identified a common problem faced by both higher education institutions and enterprises: universities find it challenging to remove established components from their well-developed curriculum architecture, while enterprises struggle to allocate additional training hours to equip employees with new digital skills alongside traditional training modules. In this paper, we present a joint innovative effort between Innovating Wing at The University of Hong Kong (HKU InnoWing) and the Operations Training Department of MTR Corporation to address this challenge. Specifically, we explore how extracurricular activities can be transformed into experiential learning opportunities for students and industry employees, enhancing their practical and digital skills through the synergy of university-enterprise collaboration.

The mission of the Innovating Wing at The University of Hong Kong, established in 2020, is to explore innovative teaching and learning methodologies with a strong emphasis on experiential learning. Being a student-centric and extracurricular makerspace, HKU InnoWing provides its student members with semi-structured and comprehensive experiential learning opportunities aimed at enhancing their critical thinking, problem-solving skills, and self-learning abilities. The Operations Training Department of

MTR Corporation has been established since 1978 to equip, upskill, and reskill employees for maintenance tasks within the transportation sector. MTR targets to equip staff with technical competence to tackle different types of maintenance tasks that come across in the workplace efficiently and effectively by adopting various tech-based testbed scenarios.

There is a long history of collaborations between HKU and MTR, but these partnerships primarily focused on technology transfer between research labs at HKU and different departments within MTR. Although personnel involved in these collaborations can learn from one another, deep knowledge exchange is often a byproduct, with the information being scattered and unconnected. This fragmentation is unlikely to initiate an upskilling process that empowers employees to enhance their skills, which are vital for contributing to the organization's long-term development [5]. The fast turnaround times and deliverables in practical applications characterize the many University-Industry collaborations, leaving few opportunities for authentic workplace training for undergraduate students, such capstone projects [6] [7] [8] [9]. Li and Griffin propose a skill set for championing and improving the university-industry collaboration [10]. On the other hand, many upskilling programs are specifically designed for the industrial workforces [11] [12] [13].

In response to the digital transformation, we present a *synergistic* initiative between HKU and MTR -- a tailored co-training model to address the need for contextual learning environments for undergraduate students and the industrial workforce. Given the demand for automation in the routine operations of MTR, we selected robot programming as a focal point. The collaborative training initiative comprises an *equipping* curriculum and a series of *inspiring* tours, involving a cohort of three undergraduate students and five MTR staff. The *equipping* curriculum consists of three sequential hands-on workshops, two of which are implemented through a peer-learning approach, where university students act as instructors and industrial apprentices participate as attendees. This design aims to enhance the university students' understanding of robot programming while imparting this knowledge to MTR staff.

To contextualize the training and enhance university students' understanding of real-world challenges in the MTR's operational frontlines, we have arranged various activities, including a site visit to the data center of MTR for discussions with industry experts in digitalization, a site visit to a maintenance depot to explore current applications of robotics in a real-world industrial setting, and an enterprise annual report session to showcase the intermediate collaborative results.

We evaluated the outcomes of this collaborative training initiative across two dimensions. First, participants were tasked with developing a remote-controlled robotic system for cleaning CNC machinery in the metal workshops. The results from the intermediate outcomes of the cleaning robotic system demonstrate the overall benefits of the collaborative program for the participants. Second, we conducted a questionnaire survey to assess how the participants' confidence, knowledge, and perspectives on robotic technologies changed following the program. We also discussed several limitations identified through our close observations and the feedback collected from the participants.

An Experiential Co-training Model

The co-training model adopts an experiential learning approach that aligns with Kolb's theory of experiencing, reflecting, thinking, and acting [14]. Our model includes: 1) a series of hands-on workshops led by university students for industrial personnel, 2) on-site visits related to industrial digitalization organized for university students by the industrial partner, 3) a collaborative scenario-based project assigned to the cohort of students and trainees, and 4) real-world challenges. The model is shown in Figure 1. For the university, the model is designed as an *extracurricular* activity for the three students, complementing the current curriculum. For the enterprise, the model is structured in a mixed format, with the hands-on workshops integrated into the training curriculum for MTR staff and the collaborative project in a scenario-based learning approach serving as a co-curricular component and assessment of their training.

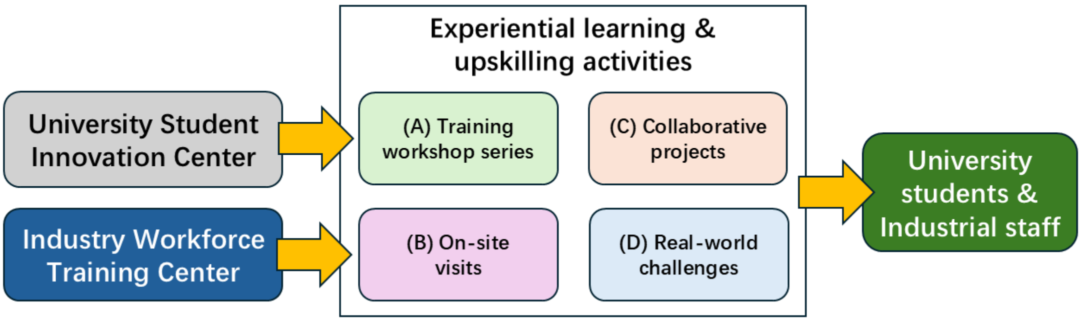

Figure 1. Co-training program framework. HKU InnoWing and Operations Training Department of MTR Corporation synergistically contribute to the experiential learning and upskilling activities designed for improving students' problem-solving skills in real-world scenarios (e.g., developing a telerobotics solution for MTR applications) and equipping MTR staff with essential skills in digital transformation (e.g., programming robot arms).

The first cohort of this co-training program consists of undergraduate students majoring in Engineering at the University of Hong Kong and industrial practitioners from MTR. Given the need for automation in the routine operations of MTR, robot programming and control is identified as the focal point for this cohort. None of the participants have prior experience in robot programming, and all three industrial apprentices are novices in coding. Detailed background information of the cohort and the selection criteria are summarized in Table 1.

Existing Curriculum for Digital Transformation. The current university syllabus is well developed to cover a diverse range of fundamental knowledge, practical training, and communication skills. Digital technology has advanced rapidly in the recent decade, leading to a diverse array of useful tools. For example, this includes robot programming for Industry 4.0 and video storytelling for more efficient communication. However, this array of tools may not be able to replace any well-developed syllabus in the curriculum. Therefore, it entails an extracurricular venue which provides flexibility for students to explore novel technologies or popular topics at their time beyond their core engineering curriculum, in response to the dynamic developments of the digital era. On the other hand, MTR equips maintenance staff with the necessary technical knowledge and skills through a comprehensive training program focused on junior supervisors, ranging from foundational to intermediate levels. While advanced digital technologies may be available in research labs or on the market, the operational knowledge of these technical tools may not be readily accessible to train the frontline staff. This creates gaps in trainers' technical competency and effective knowledge transfer for smart maintenance in the digital era. Testbed training scenarios are thus essential to enhance staff competency in achieving this mission.

Table 1: Background of the cohort and the selection requirements

	HKU InnoWing students	**MTR Staff**
Background	Three undergraduate students in their final year. Two are from Department of Computer Science and One from Department of Electrical and Electronic Engineering	Three apprentices in their second/third year and two trainers with one graduated with BEng in Mechanical Engineering and the other graduated from BEng in Electrical Engineering
Selection requirements	Proficient in programming Foundational knowledge in robotics No experience in robot programming	Some knowledge in programming Foundational knowledge in robotics No experience in robot programming

Hands-on Workshops. The hands-on workshops were organized by university students who organized the teaching materials, designed the exercises, and delivered the sessions. Since the MTR staff have elementary knowledge of computer programming, the first workshop helped them review fundamental concepts of programming and provided exercises to program a robotic arm. To address the question of why computer programs are necessary for controlling a robotic arm instead of using a control panel, the second workshop demonstrated how a robotic system composed of a robot arm and a camera sensor is built, highlighting the importance of a customized robotic system and thus the need for programming. The final workshop showcased how computer programs communicate with the robot arm. Next, we will detail the content of the workshops and illustrate how they complement the university curriculum while extending the training of MTR staff.

Workshop 1: Basic Robot Programming (2 days). The goal of the first workshop was to enable participants to program specified control operations on a 4 degrees-of-freedom (DOF) robotic arm using Python. The university students were led by a technical instructor from HKU InnoWing in preparing the teaching materials and exercises. The first day focused on the basics of computer programming and the structure of robotic arms, divided into several progressive parts. Each part began with a brief description delivered by an instructor from HKU InnoWing, followed by hands-on practice to help participants familiarize themselves with the concepts by executing and reproducing similar robot movements. Since computer programming was not previously included in the training of MTR apprentices (and for many trainers), this workshop, along with the subsequent ones, effectively broadens the training scope at OTD, preparing MTR staff with entry-level digital skills for the transformation. For the university students, this experience provided novel learning opportunities, distinct from their usual university environment where the audience shares similar backgrounds and speaks the same language. They also encountered a ‘challenge’ that they addressed in the next workshop; they were asked by an MTR apprentice why it is necessary to learn programming for controlling a robotic arm instead of using a control panel or the manufacturer’s software.

Workshop 2: Robot Operating System for System Integration (2 days). In this workshop, the students prepared teaching materials to explain basic concepts of the Robot Operating System (ROS) [15] and demonstrated its application in integrating the robot arm with a depth camera. To foster effective communication, they replaced technical jargon with layperson-friendly terms and used analogies to clarify the concepts. They also created several interactive demonstrations to showcase the capabilities of the integrated robotic system. While the MTR staff may not have mastered every detail presented given the limited time, they became familiar with the robotic arms and began to contemplate how these technologies could be applied in their daily routines. Furthermore, through these hands-on practices, the students addressed the earlier question about the necessity of learning computer programming. We believe that through these two workshops, both the students and the MTR staff gained a deeper understanding of robotic concepts and knowledge in using ROS for development.

Workshop 3: Apply the Learned to New Scenarios (1 day). Unlike the previous two workshops, this session utilized a different 6DoF robot arm that lacks a publicly available control package. This distinction offered the cohort a valuable opportunity to apply their previous learning to a new application scenario. The university students were tasked to develop a Python package that translates Python programs specifying various robotic movements (such as joint or end-effector movements) into official TCP/IP control commands (provided by the robot arm manufacturers) for executing these low-level actions. This approach deepened their understanding of how Python programs communicate with hardware for execution. Additionally, this novel test case evaluated the MTR staff’s learning outcomes by applying their knowledge in practice. There are two main differences: first, the use of a new robot arm with a different configuration—characterized by six degrees of freedom, mechanical limits, and varying lengths of each link—affects reachability and requires adaptations in the movement programs. Second, the software package created by the university students necessitated that the cohort modify their existing code to utilize the functions provided by this new package. Despite these challenges, the cohort successfully completed the tasks in just one morning, demonstrating their ability to apply the learned knowledge in novel applications.

In summary, the three hands-on workshops were conducted using a peer-to-peer learning model, with university students serving as instructors (except for the first workshop, where they acted as tutors) and MTR staff as attendees. The curriculum of these hands-on workshops began with basic programming, progressed to advanced system-level concepts and practice, and ultimately focused on applying the knowledge in a new scenario. The positive results indicate that this co-training model can reinforce the university students' understanding in programming and robotics and equip the MTR staff with knowledge about robot programming while enhancing their confidence.

Table 2: Learning outcomes of the serial hands-on workshop

Workshop	Students	MTR Staff
1 & 2	Explain fundamental concepts in robotics Organize teaching materials Design a course to teach relevant concepts with exercise Assemble components to integrated systems	Repeat the codes Select appropriate codes and translate them to achieve different goals Program and operate a robot arm to achieve basic robotic arm movements
3	Understand how software programs communicate with robot hardware Develop a software package	Adapt the existing codes for different scenarios Program and operate a robot arm to achieve customized robotic arm movements

On-site Visit. We start by showing the participants the need for and importance of the relevant technologies in robotics, before delivering technological details and hard skills to the participants. Specifically, HKU InnoWing students should understand industrial perspectives and practices on problem solving and addressing their daily challenges; MTR staff should be more exposed to recent advancements in digitalization and HKU InnoWing's strengths. Through a series of designed tours for both sides, we expect to inspire all participants to think of how technology can facilitate the MTR daily routine work or even address the challenges they faced with.

We have organized tours of MTR facilities, showing students the current workflow on daily operation, maintenance, and the latest technical advancement at MTR. We have invited MTR staff to HKU InnoWing to learn about on-going student projects there. MTR staff have participated in several introductory workshops on ROS, artificial intelligence and machine learning, hosted at HKU InnoWing students. Through this process, MTR staff gained a better understanding of HKU InnoWing and its students.

Outcomes and Evaluation

We evaluate the proposed framework through the performance of the cohort in a collaborative scenario-based project and their subjective feedback.

Collaborative Project and Outcomes. After the previous visits to MTR, the authors (including both HKU InnoWing teaching staff and MTR senior trainers) defined the collaborative task for the cohort: Developing a robot arm to clean CNC machines in the metal workshop in a scenario-based learning approach. This task was selected because the cleaning task is familiar to the MTR staff and provides the HKU InnoWing students with a real-world task to address. Instead of aiming at a fully autonomous robotic system within a short period of training time, we expect the cohort to apply what they have learned from the serial hands-on workshops to this real-world scenario.

Therefore, the HKU InnoWing students were tasked to develop a teleoperation system that allows end users (e.g., MTR frontline workers who have no experience with robot arm programming) to remotely and intuitively program the robot arm to perform the cleaning task. They underwent the following process. **1) Building a control interface.** The students are expected to possess the skill sets necessary to develop a control interface for the robot arm after organizing the serial workshops. As the first result of this scenario-based project, the students successfully developed a prototype interface for controlling the robot arm using a 6DoF joystick (HTC Vive) based on [16], showing their ability to create such an interface. **2) Identifying real-world challenges.** The students first identified the issue that the robot arm might not be able to precisely trace a pre-specified path due to kinematic singularity. With a solution proposed in [17] (provided by the instructor), they successfully incorporated this method into their control interface. After allowing the robot arm to move along a prescribed path with tolerance using [17], the students tested their developed control interface on a simplified groove model, which is a common feature in CNC machines. They then realized that remote control of the robot arm can be both mentally and physically demanding, as the free-hand controller trajectory often leads to collisions between the robot arm's end-effector and the groove model. As a result, they proposed imposing constraints on the mapping from the free-hand controller trajectory to the robot trajectory, limiting the robot's movements in accordance with the geometry of the groove. These two observations demonstrate that the scenario-based project may be beneficial to the students by providing them with the learning opportunity to identify real-world challenges and adopt existing solutions or propose their own to address these challenges. **3) Ethical practices in user studies.** Ethical practices are crucial for future engineers and designers of artificial intelligence and robotic systems. The students were advised to conduct a user study to validate their system design. Before conducting any study involving human participants, it is essential to secure approval from the Human Research Ethics Committee (HREC) of the University. This step introduces the important concept of ethical research practices as they prepare the necessary materials, including the user consent form and protocols for handling collected data, to apply for HREC approval.

On the other hand, MTR staff were tasked to study the cleaning process and then develop an end-effector for this purpose. They underwent the following process. **1) Cleaning process survey.** The MTR staff surveyed and compared various methods for cleaning a CNC machine and identified three options for collecting metal debris: sweeping with a brush, using a heavy-duty vacuum cleaner, or employing a magnetic bar. They ultimately selected the sweeping method, as the robot arm's payload might be insufficient for a heavy-duty vacuum cleaner, and aluminum, a non-ferrous metal commonly used in their workshop, cannot be picked by magnet. **2) Brainstorming the cleaning tools.** With the sweeping approach selected, the MTR staff proposed designing a customized dustpan to collect debris.

They noted that a void at the end of the grooves is common across various CNC machines, leading to their suggestion of a dustpan that can easily fit into this void for efficient debris collection. **3) A compliant holder for the brush.** We organized several face-to-face meetings between the two teams who physically worked in different places. The HKU InnoWing students introduced to the MTR staff a problem they encountered: Accidental collisions between the sweeping end-effector and the machine could occur, potentially generating significant impact forces that might halt the control algorithm or damage the physical connector. Consequently, a compliant holder for the sweeping brush became essential. Despite having only three days for development, the MTR apprentices adopted a spring-based damper and transformed it into a compliant holder of the sweeping brush for the cleaning robot arm. This demonstrates their confidence and basic knowledge in robotic systems, as well as the skills they acquired through their daily training.

Finally, the cohort equipped the robot arm with the compliant sweeping end-effector and commanded it to clean a CNC machine using the developed control interface. The system is shown in Figure 2. They observed that, under the imposed geometric constraints, the robot arm moved with fewer collisions with the grooves of the CNC machine. Even when collisions did occur, the use of the compliant sweeping end-effector prevented failures in the robot's control system or damage to the end-effector. This marks the success of the collaborative project among the first cohort and highlights the achievement of intended learning outcomes. Now the student team is aiming to address this real-world challenge by developing a more intuitive control system for end-user programming. Their preliminary result has been accepted to the Student Design Challenge in the HRI'25 Conference [18]. The cohort is working on deploying this system in the MTR's metal workshop for their daily training.

Discussion on the Participants' Feedback. We have designed a questionnaire for our cohort to gather feedback on the proposed experiential learning framework. Consents have been gathered and the feedback gathered is anonymized. The questionnaire is attached to the Appendix.

The questionnaire consists of five questions for each participant. The first three questions (each in the form of a statement) assess subjective feelings regarding: 1) the increase in robotics-related knowledge, 2) the acquisition or enhancement of programming and communication skills, and 3) confidence in programming a robotic arm. A 5-point Likert-scale score is used. These first three statements are slightly different for the groups of three HKU InnoWing students and of three MTR apprentices to adapt to their roles in the hands-on workshops. We receive five out of six responding "Strongly Agree" to the first three questions, while the remaining saying "Agree" to all three questions. The participants agreed that the workshop has enhanced their knowledge, skills, and confidence regarding the technology (i.e., the robot arm). This evidences that the workshops help lower the boundary for industry workers to learn/use technology.

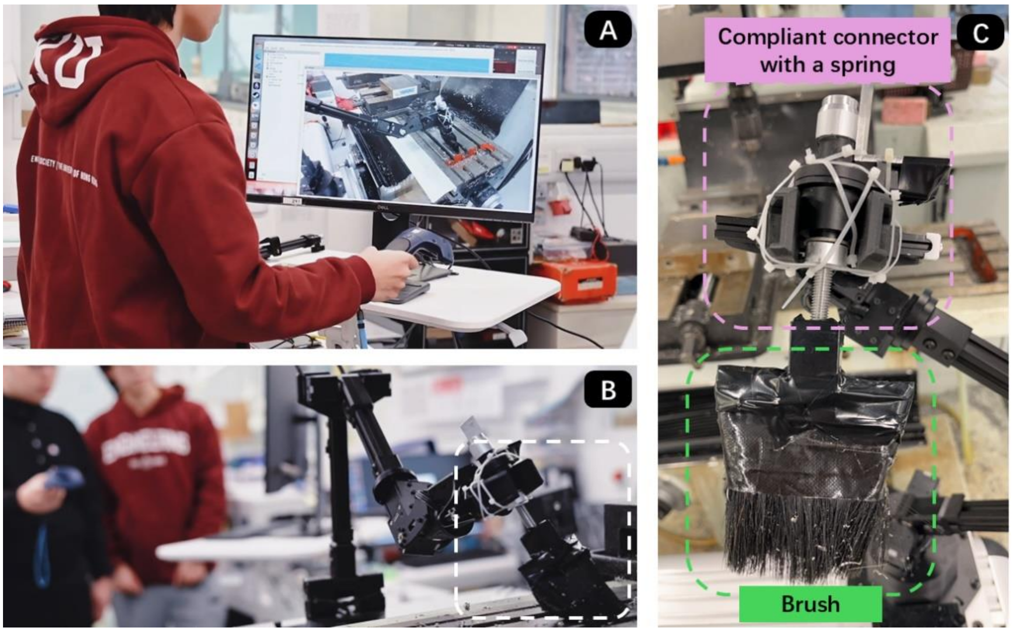

Figure 2. Collaborative project as an assessment. (A) One member testing the developed telerobotics system. (B) Members exchanging ideas and feedback on the telerobotics system. (C) The compliant brushing end-effector prototype.

The fourth question ("You have identified some possible applications in your working environment that robot arms can help.") aims to explore how participants can transfer their learning to other relevant contexts. All of the respondents answered "Yes" to the question and furnished some potential applications including "Assistance to moving objects", "Deport Maintenance", or "Operating some dangerous machine that might injure human body". Among these replies, we highlighted a potential application suggested by a MTR apprentice, that is "Deploying the robot arm to an electronic workshop for maintenance of the PCB boards". The reason behind this is that cleaning PCB boards requires operators to wear goggles, along with other personal protective equipment, to protect their eyes and skin from being hurt by electronic waste inside the board. He further explained "teleoperated robot arms can separate operators from dangerous working environments, making them particularly suitable for this application". This example demonstrates the value of this co-training program, transforming the MTR apprentices who had little exposure to robotic arms into someone with a deeper understanding on how robotic arms can be applied in their working environment.

For the last question on suggestion for improving the workshop, participants suggested "Have more offline/out-of-class practice" and "Wish to have more time to learn". It reflects that the participants were motivated and enthusiastic about the co-training program. The overall feedback for the co-training program is positive, showing the synergy gained between the university and the enterprise. It created an opportunity for college students and enterprise staff to learn from each other and think creatively and practically for enhancing productivity.

Despite these fruitful results, we also highlighted some limitations of the current co-training program reflected from the survey as well through our close observations. Firstly, the future program can provide participants with more time and opportunities to practice the knowledge they have learnt from the workshops. While assignments were designed in the current program, future program can consider how to seamlessly integrate the assignments into MTR apprentices' daily training, taking the PCB board cleaning task as an example. Secondly, while starting in June 2024, the co-training initiative could only be conducted when both the HKU InnoWing students and the MTR apprentices were available from their courses and their duties. A more paced curriculum should be developed for both parties to collaborate. For the HKU InnoWing students, hiring them as student interns can effectively ensure their commitment during term time. For MTR, seamless integration of the practices into the apprentices' everyday duties may alleviate this problem. We believe these experiences are valuable for others who wish to establish or enhance their university-industry partnership on experiential learning.

4. Conclusion

We presented a co-training program supported by Innovation Wing of HKU and Operations Training Department of MTR Corporation. The program consists of three hands-on workshops to teach or enhance understanding, practical skills, and confidence of the cohort in programming and controlling robotic arms. While the size of the first cohort is small, six participants involved with three undergraduate students from the University of Hong Kong and three apprentices from MTR, the post-workshop outcomes were promising – the participants successfully developed a teleoperated robotic system prototype to clean CNC machines widely seen in metal workshops of the University of Hong Kong makerspaces and MTR depots and further enhanced the ease-to-use of this system by exerting their expertise. The subjective survey results indicate the co-training program provides a favorable learning experience to them. We believe this co-training program can serve as a model for other educational institutions and their industrial partners. This model is generalizable to university-industry collaboration in promoting other digital technologies like artificial intelligence, internet-of-things, or digital twins.

Reference

[1]. Portela, C. S., Vasconcelos, A. M., & Oliveira, S. R. (2015). How to Develop Competencies and Abilities Professional in Software Engineering in Undergraduate Students?. In *Int'l Conf. Frontiers in Education: CS and CE-FECS* (Vol. 15, pp. 91-94).

[2]. Ramadi, E., Ramadi, S., & Nasr, K. (2016). Engineering graduates' skill sets in the MENA region: a gap analysis of industry expectations and satisfaction. *European Journal of Engineering Education*, *41*(1), 34-52.

[3]. Baker, S. D., Peach, N., & Cathcart, M. (2017). Work-based learning: A learning strategy in support of the Australian Qualifications Framework. *Journal of Work-Applied Management*, *9*(1), 70-82.

[4]. Edinbarough, I., Santiago, A. R., & Gonzalez-Rodriguez, J. (2019, June). Development of a Senior Design and Internship Integrated University-Industry Collaborative Program to Address the Skills Gap in Advanced Manufacturing. In *2019 ASEE Annual Conference & Exposition*.

[5]. Ivaldi, S., Scaratti, G., & Fregnan, E. (2022). Dwelling within the fourth industrial revolution: organizational learning for new competences, processes and work cultures. *Journal of Workplace Learning*, *34*(1), 1-26.

[6]. Ray, J. L. (2003, November). Industry-academic partnerships for successful capstone projects. In *33rd Annual Frontiers in Education, 2003. FIE 2003.* (Vol. 3, pp. S2B-24). IEEE.

[7]. Aktan, H. M., Polasek, J. S., & Phillips, K. J. (2011, June). Industry University Partnership in Senior Capstone Design Course. In *2011 ASEE Annual Conference & Exposition* (pp. 22-867).

[8]. Venson, E., Figueiredo, R., Silva, W., & Ribeiro, L. C. (2016, October). Academy-industry collaboration and the effects of the involvement of undergraduate students in real world activities. In *2016 IEEE Frontiers in Education Conference (FIE)* (pp. 1-8). IEEE.

[9]. Berthoud, L., & Gliddon, J. (2018). Using wikis to investigate communication, collaboration and engagement in Capstone engineering design projects. *European Journal of Engineering Education*, *43*(2), 247-263.

[10]. Li, K. E., & Griffin, M. (2021). Nurturing Collaboration? A Skill Set for University-Industry Collaboration Champions. In *Academic and Practitioner Proceedings of the 2021 University-Industry Interaction Conference Series*.

[11]. Simões, A. C., Ferreira, F., Almeida, A., Zimmermann, R., Castro, H., & Azevedo, A. (2021). Innovative learning scheme to up-skilling and re-skilling–designing a collaborative training program between industry and academia towards digital transformation. In *Smart and Sustainable Collaborative Networks 4.0: 22nd IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2021, Saint-Étienne, France, November 22–24, 2021, Proceedings 22* (pp. 729-737). Springer International Publishing.

[12]. Pors, A. L. K., Bennyson, R., Laursen, E. S., Geraldes, C. A., Leitão, P., Sheridan, I., & Christiansen, L. (2022, September). Co-design of technical upskilling training program through early stakeholder involvement. In *International Conference on Cooperative Design, Visualization and Engineering* (pp. 175-186). Cham: Springer International Publishing.

[13]. Lang, J. (2023). Workforce upskilling: can universities meet the challenges of lifelong learning?. *The International Journal of Information and Learning Technology*, *40*(5), 388-400.

[14]. Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

[15]. S. Macenski, T. Foote, B. Gerkey, C. Lalancette, W. Woodall, “Robot Operating System 2: Design, architecture, and uses in the wild,” *Science Robotics vol. 7*, May 2022.

[16]. Jia, Ruixing, Lei Yang, Ying Cao, Calvin Kalun Or, Wenping Wang, and Jia Pan. "Learning Autonomous Viewpoint Adjustment from Human Demonstrations for Telemanipulation." *ACM Transactions on Human-Robot Interaction* 13, no. 3 (2024): 1-23.

[17]. Wang, Yeping, Pragathi Praveena, Daniel Rakita, and Michael Gleicher. "RangedIK: An optimization-based robot motion generation method for ranged-goal tasks." In *2023 IEEE International Conference on Robotics and Automation (ICRA)*, pp. 9700-9706. IEEE, 2023.

[18]. Lo, Ian Leong Ting, Bao Guo, and Shaoyu Zeng. "An End-user Programming Interface for Robotic Arm Cleaning CNC Machines." *Proceedings of the 2025 ACM/IEEE International Conference on Human-Robot Interaction*. 2025.