Repurposing Student-initiated Workshops for Interdisciplinary Engineering Challenges

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Throughout his academic journey, Ryan has excelled in various engineering projects and research endeavors. He has been actively involved in designing workshops on cutting-edge technologies such as embedded systems, ROS and IoT. Additionally, Ryan has led a undergraduate student research team on robotics, developing various types of smart robots.

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 modeling and mechanical machining.

With a passion for creating a better learning environment for fellow engineers, Ryan is dedicated to enhancing his skills and contributing to the advancement of mechanical engineering.

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Ian Leong Ting Lo is a Computer Science graduate from The University of Hong Kong. Currently serving as a Technical Officer at the HKU Tam Wing Fan Innovation Wing, Ian is passionate about robotics, the Internet of Things (IoT), and STEM education. In his current role, Ian leads various student research projects, including the development of robotic arms, autonomous drones, quadruped robots, and an interactive tour guide robot focused on human-robot interaction. Previously, as a Student Research Assistant, he developed assistive teleoperation systems for robotic arms in collaboration with industrial partners and actively contributed to the open-source robotics community. He is dedicated to teaching and peer mentorship. Drawing on his experience as a Student Teaching Assistant for university programming courses, Ian frequently hosts hands-on workshops covering robotics control, electronics, and IoT development. He is eager to continue contributing to cutting-edge robotics software development while empowering fellow students in their engineering journeys.

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Prof. Chun Kit Chui, University of Hong Kong

Prof. 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, Prof. 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. Prof. 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).

[Work-in-progress] SMILE: Synthesizing Modular Workshops into Interdisciplinary Learning Environment

Abstract: This work-in-progress paper presents a bottom-up approach, SMILE, to synthesize student-led, modular workshops into engineering challenges and providing students with an interdisciplinary learning environment. We reviewed and discussed its connection to existing approaches as well as supporting background theories. We elaborate on our first implementation, a robot arm bin picking challenge, that combines two existing workshops in our makerspace and discusses the students' initial feedback. Finally, we present our key observations on the benefits and limitations of this modularized approach for designing experiential learning experiences in our makerspace and sharing our long-term vision on this practice.

Introduction

Tam Wing Fan Innovation Wing at the University of Hong Kong serves as an extracurricular student experiential learning center for undergraduate engineering students at a university. Like many other academic makerspaces [1-3], over the years, it has cultivated a diverse spectrum of extracurricular workshops (non-credit-bearing) developed by passionate students, with related skill sets organized as technical competencies. However, these workshops are typically standalone or confined within disciplinary silos, leaving the associated technical competencies unconnected. While student organizers and participants acquire valuable technical skills and experiences from these events, the interdisciplinary synthesis needed to tackle modern engineering challenges remains largely absent. This gap motivates the development of a pedagogical model that builds student initiatives to foster experiential learning and create a more intentionally interdisciplinary learning ecosystem.

This work-in-progress paper presents a bottom-up approach to enabling students to integrate skill sets across disciplines. We coin this pedagogical approach SMILE, which is short for Synthesizing Modular workshops into Integrated Learning Experience. Our approach repurposes domain-specific, standalone workshops, originally designed around students' technical enthusiasm, into training components for authentic engineering challenges. It scaffolds around student-initiated workshops in the makerspace and implicitly injects professional guidance from academic staff to support students' experiential learning [4]. Our approach is rooted in the experiential learning theory where a learner-centered environment was developed to coach students [5-7] and related to the zone of proximal development (ZPD) [8-10] in that the SMILE model starts with what students are interested (e.g., robotics or AI) and capable of and gradually direct toward more real-life challenges that requires expert support.

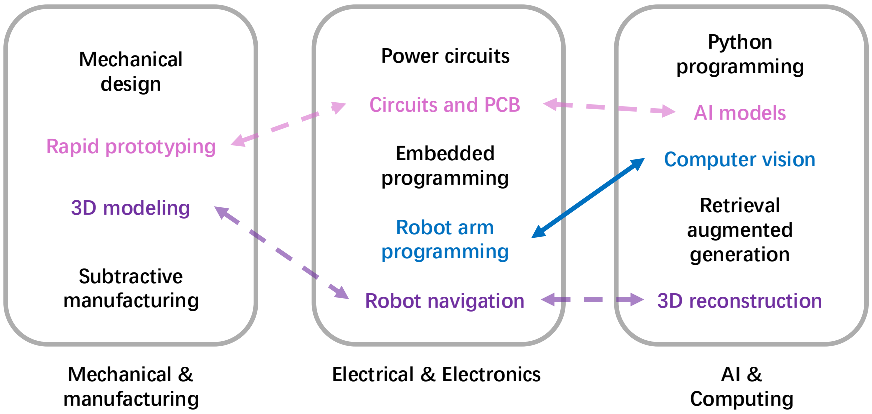

Figure 1. Some technical competencies developed over the past five years through student-led workshops. The solid line links two existing skill sets to develop the Robot Arm Challenge. Dashed lines indicate potential combinations for customized AIoT devices (pink) or digital twin technology (purple)

Compared to most project-based learning curriculum (e.g., [11-13]) or extracurricular competitions (e.g., Formula Student) that are driven primarily by instructors or organizers, our approach leverages student agency on rich content they generate in our makerspace and incorporate necessary modules to synthesize a coherent, interdisciplinary learning experience; see Figure 1. Unlike faculty-driven models where learning objectives and content are prescribed top-down, SMILE begins with what students are already passionate about and builds upward by introducing integrative elements to close disciplinary gaps. This bottom-up, modular structure allows reconfiguration of different workshop combinations for different real-world problems and is expected to be scalable through reusing existing resources and content in a makerspace. Next, we illustrate the SMILE model through an initial case and its preliminary results. We discuss the lessons learned from this initial case and how to generalize the SMILE model to deliver broader impact.

Case Study: Robot Arm Challenge for Automatic Bin Picking

Motivation and Objectives. This Robot Arm Challenge for automatic random bin-picking was motivated by an industrial collaborator seeking to automate the sorting and cleaning of bolts and nuts disassembled from heavy machinery. Random bin-picking is a fundamental problem in robotics research and in manufacturing and logistics industries [12]. We identified this challenge as an appropriate educational context for undergraduate students: it is grounded in a real industrial need, yet decomposable into subtasks manageable within a semester-long, extracurricular program.

The challenge, however, could not be addressed through the existing workshops alone. The robot arm programming (ROAP) workshop taught students how to command a manipulator using Python, while the AI-powered object detection (AIOD) workshop covered neural network training and inference for image-based object recognition. Missing was a crucial interconnecting component: the transformation from camera to robot workspace. This gap, reflected in many other student-generated workshops, highlights the need for targeted guidance from educators or domain experts. Therefore, a third workshop on hand-eye calibration (HECA) was co-developed by a group of experienced students and academic/technical staff at the makerspace. This integrative element "glues" the two existing workshops together, creating a coherent extension into a real-world engineering challenge. The teaching materials were vetted by academic and technical staff at the makerspace, and each workshop was delivered by student co-developers. Details of the challenge and workshops can be found at this link.[1]

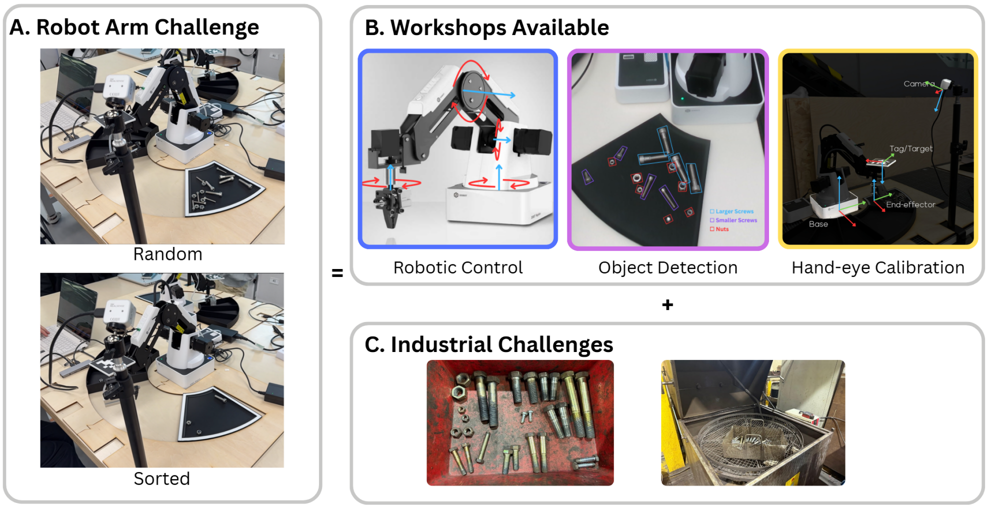

Figure 2: The final Robot Arm Challenge for automatic random bin picking (A) integrates interdisciplinary technical skills presented in modular workshops (B) to address real-world industrial scenarios (C).

Implementation and Iterative Design. We offered two sessions of the Robot Arm Challenge in Spring and Fall, 2025, with key design modifications based on the first iteration outcomes.

1) **Spring 2025 session:** Due to the time constraint, a single integrated workshop (approximately 2 hours) was delivered to cover all three components sequentially: robot arm programming, computer vision, and hand-eye calibration theory. Five attendees of this workshop were organized into groups. Three weekly help desk sessions (2 hours each, for three weeks) were offered by student co-developers, focused on answering questions about self-learning materials, software installation, and environment setup. No assistance with algorithmic decisions or reference implementations were provided to ensure fair

[1] Robot Arm Challenge Spring 2026. https://innoacademy.engg.hku.hk/robotarm2026/

competition. As discussed later, the initial outcomes were less satisfactory than anticipated.

2) **Fall 2025 session:** Based on Spring outcomes, we implemented three critical changes:

- ***Expanded workshop structure:*** To allow deeper focus on each component and emphasize more on the hands-on practices, the integrated workshop was split into three sequential workshops (2 hours each), i.e., ROAP, AIOD, and HECA. Each workshop was delivered the other week, spanning a six-week teaching period. Added hands-on practices include annotating images for training dataset and exploring coordinate transformations between a camera and a robot arm that previous integrated workshop did not provide.
- ***Intermediate assessment checkpoint:*** We introduced the "Click-and-Go" mini-challenge, in which participants had to program the robotic arm to reach 3D coordinates derived from clicking pixels in an RGB-Depth camera feed. This designated task verifies that students have correctly implemented hand-eye calibration before entering the final challenge.
- ***Flexible final challenge window:*** Instead of a single mandatory 3-hour time slot for multiple teams, the final challenge was offered over a full week with flexible booking of 30-minute execution slots. This arrangement reduced scheduling conflicts with courses and, by staggering team appearances, lowered the number of staff required on site while still ensuring consistent and fair competition conditions for all teams.

3) **Spring 2026 session:** We made three changes upon the Fall 2025 session. First, we provided an improved HECA workshop to help students understand better the coordinate transformation between different entities in the challenge. Second, we presented the HECA workshop before the AIOD workshop, so students have more time to digest the content taught in the HECA workshop. Third, we allowed students to select one of three challenge windows (each lasting one week) to avoid time clashes with their curriculum timetable.

Challenge Design and Supporting infrastructure. The final challenge requires teams to develop a computer program which commands a robot arm to autonomously sort 16 bolts and nuts (short M4 screws, long M6 screws, and M6 nuts) from a bin into their corresponding labeled bins without human intervention. Hardware provided includes a desktop-grade educational robotic arm with 4-degree-of-freedom (~US$1500), an RGB-Depth (RGB-D) camera (~US$200), and a NUC mini-computer (~US$1000). See Figure 2 for example. Teams are ranked by the number of successfully sorted items, with ties broken by execution time. Each team receives two attempts, and the best attempt counts toward the final ranking.

We prepared 5 sets of the listed hardware for simultaneous team practice and competition. Monetary incentives (US$150 per team member for the winner, plus sponsorship for an academic event up to US$600) and participation certificates were offered to motivate engagement. We also established a social media group facilitating team formation, question-asking, and peer support.

Student Participation and Demographics. Participation grew from 5 students in the Spring 2025 session to 67 in Fall 2025, before settling at 37 in Spring 2026. In both the Fall 2025 and Spring 2026 sessions, first- or second-year students accounted for a large proportion of participants: 67.7% in Fall 2025 and 86.5% in Spring 2026. All participants in Fall 2025 were engineering majors, while Spring 2026 also attracted a handful of science students.

Despite the considerable difference in total participation between the two sessions, the number of students who attended at least two workshops was similar across both. In the Fall 2025 session, 3 students attended all three workshops and 14 attended two; in Spring 2026, 5 students attended all three workshops and 12 attended two. Notably, the winning teams from both sessions had members who attended all three workshops. This pattern of high attendance may reflect strong intrinsic motivation and suggests a positive correlation between workshop engagement and challenge performance.

Challenge Outcomes and Feedback on Workshops. In the Spring 2025 session, five teams joined the final challenge, with only two teams managing to pick any screws or nuts. The winning team sorted 4 out of 16 items, while the runner-up sorted 3; the remaining teams encountered various technical issues, including failed camera calibration, accidental deletion of the coding environment, and rule violation for using an online object-detection API instead of training their own models. Notably, all teams struggled with inaccurate camera calibration, which motivated the subsequent introduction of “Click-and-Go” mini-challenge as checkpoint in the Fall 2025 session.

However, this requirement excluded approximately 80% of the registered teams, resulting in only two teams (totaling to 3 students) qualifying for the final challenge of the Fall 2025 session. This selective criterion is debatable; it should balance skill verification with broader participation. Yet it is worth noting that both finalist teams demonstrated markedly improved performance. Each team successfully deployed its algorithm to perform pick-and-place operations without the failures observed in Spring 2025, with the winning team sorting 11 out of 16 items within the 5-minute time limit and the runner-up achieving 9 successful sorts.

In the Spring 2026 session, we moved the hand-eye calibration (HECA) workshop earlier in the schedule and offered multiple timeslots for the "Click-and-Go" qualification. Eventually, six teams (totaling 16 students) were able to pass the qualification. Among them, one team never attended any of the workshops; instead, they made use of the online teaching materials and sample code we provided to build their autonomous bin-picking system. In this session, we observed a significant improvement in performance, with the champion team sorting 16 out of 16 items within 3.5 minutes and the first runner-up sorting 15 out of 16 items in under 2.5 minutes. From our interviews, we learned that all six teams leveraged AI coding assistants in preparing for the challenge.

Discussions

Lessons learned from the robot arm challenge. A focus group discussion with several workshop participants revealed two main reasons why students were attracted to the Robot Arm Challenge. First, the challenge is clearly tied to a real-world industrial problem, which students perceived as distinct from their usual coursework and more representative of authentic engineering practice. For instance, during the hand-eye calibration workshop in Fall 2025, a first-year student noted that although he was taking a linear algebra course, he had never connected linear algebra concepts to transformations and robotics before this experience. This observation was echoed by more participants in the Spring 2026 session, further confirming the gap between theoretical knowledge and practical application of linear algebra. It provides additional evidence supporting our proposed framework, which incorporates integrative elements that glue existing workshops together and extend what students can learn beyond their interest-driven workshops.

Second, students valued the opportunity to gain hands-on experience with real robot arms, along with exposure to computer vision and artificial intelligence, which many regarded as exciting and highly relevant technologies. Some students also mentioned that in course projects, they may struggle to find teammates who are equally passionate about the work. Moreover, course projects are typically designed to be less challenging than this one in order to accommodate students at all levels. Together, these comments suggest that careful synthesis of applied competitions by introducing integrative elements into student-initiated workshops can meaningfully increase motivation and participation among engineering students and provide an additional avenue for students with stronger interest in specific fields to distinguish themselves.

Meanwhile, several challenges emerged. Resource constraints also affected students' ability to fully engage with the challenge. Training AI models for object detection requires significant computational power, which many students' personal devices cannot reliably provide. Although the makerspace offers shared computing resources, access is restricted to daytime hours, and students must still configure their own training environments on those machines, which many participants with limited programming experience found time-consuming and frustrating. These findings suggest that pre-configured environments, containerized setups, or more flexible access to shared resources could substantially lower the technical barrier to participation.

In Fall 2025 session, some participants from Year 1 and Year 2 indicated that the final challenge was too difficult, given their limited prior exposure to diverse topics across programming, robotics, or AI. One student who joined as a one-person team reported finding it "difficult to do everything" alone. This difficulty was less apparent during our semi-structured interviews with each participating team (with their consent obtained) at the end of the Spring 2026 session. We found that all teams made use of AI coding assistants during their development. Two students studying mechanical engineering stated that they were able to describe what they wanted to implement to the AI coding assistant even without much programming experience and debugged their developed system using natural language instructions. This practice helped them boost development efficiency and meet the challenge deadline. We also note that most students were aware of the limitations of AI coding assistants, namely that they lack a proper understanding of the physical world. An interesting direction to investigate is how students make use of AI coding assistants in this and other similar challenges.

Overall, the current design emphasizes open-ended exploration, which aligns with the goals of the SMILE model but can be challenging for lower-division students. Several participants reported uncertainty about whether their object detection models were adequate for the task, or whether they were expected to use only the techniques demonstrated in the workshops to succeed in the competition. This highlights the importance of explicit scaffolding for solving open-ended problems, particularly for novice learners. In future iterations, we plan to introduce additional checkpoints, for example a keyboard-based teleoperation for robot arm and a taster for object detection, to provide a clearer roadmap for students' self-exploration and to support ongoing evaluation of their learning process. These checkpoints should be actively implemented to balance skill verification and broader participation.

In future iterations, we plan to develop assessment instruments more directly aligned with SMILE's interdisciplinary learning goals, including measures of cross-domain knowledge transfer and students' ability to synthesize competencies through the challenges. We plan to invite out industrial collaborator to co-design the evaluation criteria, ensuring the learning objectives were grounded in authentic industrial needs. This reciprocal relationship allowed students to work on a problem with real-world stakes, while providing the collaborator with exposure to student-developed solutions.

Generalization for Broader Impact. The initial case illustrates that the SMILE model has the potential to foster learner agency by encouraging the students to take an active role in designing modular, interest-driven workshops. As suggested in Figure 1, similar learning environments and experiences could be created by linking technical competencies from different streams. For example, our makerspace has been piloting an integrative learning activity between rapid prototyping, circuits and PCB, and AI models to develop AIoT devices. While rapid prototyping and PCB development are already closely integrated in many mechatronics' coursework, how to deploy an AI model on microcontrollers or development boards is less familiar to the students. Special model quantization technique (e.g., [15]) is required as shown by our prior experimentation. Another on-going effort is to connect workshops on robot navigation and indoor scene 3D reconstruction with a new 3D building information modeling workshop to link up these scattered topics and support more balanced participation among students from Civil Engineering and those from other engineering majors.

The SMILE model provides a lens to examine the existing student-initiated workshops, technical competencies they develop, and the competencies that remain missing. From an interdisciplinary viewpoint, it encourages connecting technical competencies from different streams to overcome disciplinary silos. Real-world applications play a dual role: they attract students to participate and ensure that the developed competencies are grounded in authentic practice and potentially impactful to society.

Achieving these integrations requires critical contributions of educators and makerspace managers, who must provide targeted guidance and carefully decide what supplementary content to introduce. Drawing on theories of scaffolding and the zone of proximal development, we plan to develop concrete practices and instruments for identifying potential “infill” content that supports interdisciplinary synthesis without overwhelming learners.

Looking ahead, rapid development in AI is likely to be disruptive to traditional curricula and many other industries. In response, we aim to further refine and extend the SMILE model, in concert with well-established learning theories, to offer educators new ways of leveraging student agency and professional expertise to design meaningful interdisciplinary learning experiences in this emerging era.

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