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Nurturing Student Innovation and Leadership through Student-Initiated Interest Groups

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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.

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Nurturing Student Innovation and Leadership through Student-Initiated Interest Groups

Abstract

To prepare students with strong technical skills and leadership abilities, the engineering faculty at the University of Hong Kong has established the Tam Wing Fan Innovation Wing (a.k.a. the HKU Inno Wing) and a program that supports student-initiated interest groups (SIGs) focused on technology and project-based learning. The SIG program engages students in hands-on projects, enhances their practical and project management skills, and gains valuable experiential learning experience. It also adapts the Students as Partners (SaP) method to cultivate students' sense of ownership and responsibility in their SIGs. Academic advisors and participating students collaborate in various decision-making processes, including planning, funding acquisition, recruitment, training, prototyping and deployment.

This practice paper offers an in-depth exploration of the SIG program hosted within the HKU Inno Wing, delving into governance aspects such as the management structure, funding model, resource allocation, and development support. It showcases two exemplary SIGs as case studies: one centered on bio-inspired robotics and the other on electric vehicle (EV) technologies. The bio-inspired robotics SIG achieved two Guinness World Records for "The Fastest 50m Swim by a Robotic Fish", while the EV technologies SIG designed and fabricated a fully functional electric vehicle from scratch, earning international recognition for their innovative efforts in overcoming financial and engineering challenges. Through case study interviews, we evaluate the SIG's impact on students' learning and development, revealing its effectiveness in cultivating profound technical skills and core leadership competencies. The paper concludes with an examination of identified challenges and opportunities, providing insights for similar initiatives in tertiary education.

Keywords

Student-initiated interest groups, engineering leadership, experiential learning, bio-inspired robotics, Guinness World Record, electric vehicle technologies, international award

Background

This practice paper introduces a program designed to cultivate the development of student-initiated interest groups (SIGs) with a focus on technological innovation and challenge-based learning within the engineering faculty of the University of Hong Kong. In December 2020, the faculty inaugurated a 2,000-square-meter Tam Wing Fan Innovation Wing [1] (a.k.a. the HKU Inno Wing) at a prominent location on campus. This center serves as the hub for the SIG program, equipped with cutting-edge prototyping facilities and extensive project spaces. Setting itself apart from curriculum-based course projects and capstone initiatives, which are typically instructor-led and driven by curriculum credits, the SIG program champions extracurricular projects fueled by student initiative and passion. Its core objective is to entrust and empower students to spearhead ambitious innovation and technology ventures that will shape the future. The program fosters an environment where students are encouraged to translate their innovative concepts into tangible solutions, collaborating with peers across various academic disciplines who share common interests.

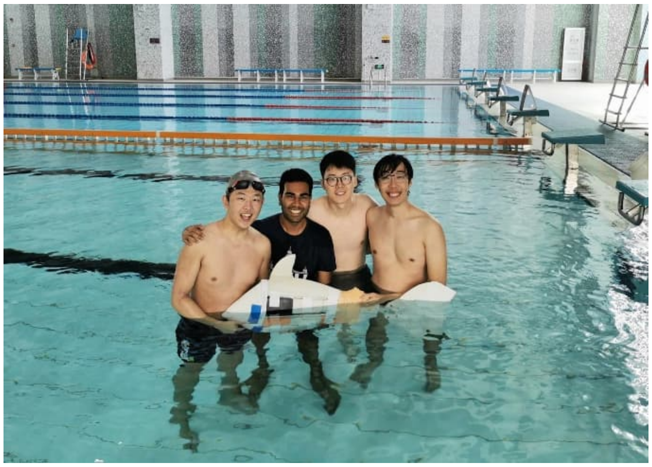

Figure 1. Bio-inspired robotics SIG: A robotic fish designed and built by students that set two Guinness World Records for “The Fastest 50m Swim by a Robotic Fish.” [2]

Figure 2. Electric Vehicle SIG: A fully functional electric vehicle designed and built by students.

Featuring the first robotics SIG case study in this practice paper, a group of students shared a common vision about the great potential for bio-inspired design in future robotics. Their goal is to create a fast-swimming robotic fish by studying the swimming patterns of tuna fish and incorporating these insights into their robotic engineering. Driven by enthusiasm for scientific exploration and technological advancement, they prioritize these aspects over simply achieving a high grade in a course. The SIG program offers a supportive environment for their team, leading to their dedicated efforts culminating in the successful creation of a robotic fish that breaks two Guinness World Records for “The Fastest 50m Swim by a Robotic Fish” [2], as depicted in Figure 1.

In another case study featuring the electric vehicle SIG, a group of students with a strong passion for electric automobile technologies collaborates to form an interdisciplinary team. This team comprises students from mechanical engineering, electrical and electronic engineering, and computer science, all sharing a common goal of designing and fabricating a fully functional electric racing car from scratch. Their commitment is twofold, aiming to contribute to a more sustainable and environmentally friendly future while immersing themselves in the learning of electric vehicle technologies, including power electronics, electric motors, battery technologies, vehicle dynamics, and more. Supporting such ambitious student initiatives demands substantial resources in terms of workspace, funding, and technical support. The team finds its home in the SIG program since 2020. As of June 2023, their efforts culminate in the successful construction of a fully functional electric vehicle as shown in Figure 2, earning them an international award that recognizes their resilience in overcoming financial and engineering challenges, highlighting the team's determination to succeed.

The above examples showcase the opportunity to support student-initiated projects that go beyond traditional curriculum studies. These endeavors not only enrich the educational experience for students but also yield mutual benefits for the faculty and the university, especially when these high-caliber projects find a home and visibility in the Inno Wing. As illustrated in Figure 3, at the beginning of the 2023/24 academic year, there are 24 established SIGs, exploring topics across a broad spectrum, including artificial intelligence, robotics, quantum computing, augmented and virtual reality, blockchain, synthetic biology, and more.

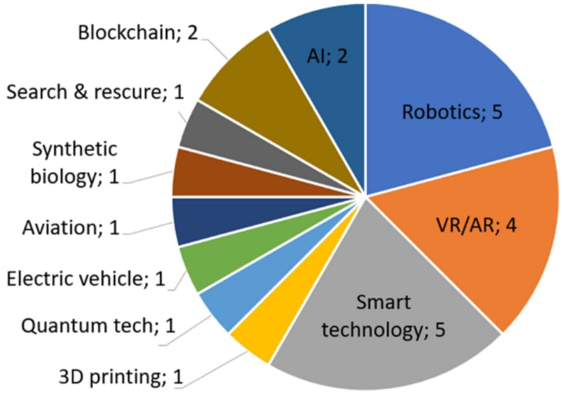

Figure 3. Technology topics of the 24 SIGs at the beginning of 2023/24

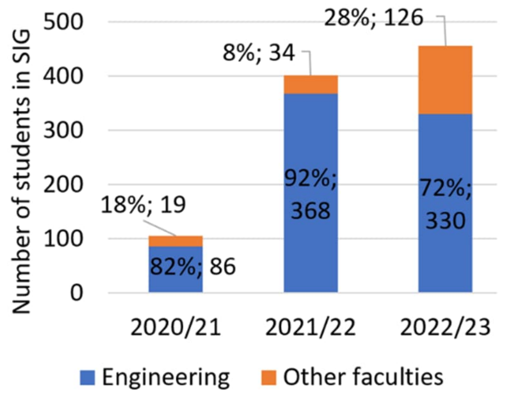

Figure 4. Number of students in SIGs (break down by engineering and other faculties)

These SIGs are also highly cross-disciplinary. Figure 4 further breaks down the number of students participating in SIGs, distinguishing between engineering and other faculties. As of the end of the 2022/23 academic year, there were 456 students who participated in the SIGs, with 72% of these contributors originating from engineering programs, highlighting a notable concentration of engineering expertise within these teams. The remaining 28% represent various faculties, contributing knowledge from diverse domains such as medical, social science, architecture, arts, business, law, and science. This diverse participation emphasizes the SIG's evolution into a cross-disciplinary learning platform, fostering collaboration and interaction among students from varied academic backgrounds.

This practice paper presents the design and implementation of the SIG program, covering the governance structure, finance principles, students-as-partners approach, and development support. Additionally, we conduct interview study on two exemplar SIGs to evaluate the impact of the SIG program on students' learning and development.

Related works

Supporting student-initiated projects has become a key focus for many institutions, as they recognize the importance of enhancing innovation competencies among students [4]. These initiatives not only equip students with valuable skills such as problem-solving, design thinking, creativity, project management, prototyping, teamwork, and leadership, but also foster a sense of ownership and empowerment. One particularly effective pedagogical approach that supports this goal is Challenge-Based Learning (CBL) [3]. CBL engages students in the process of identifying, analyzing, designing, and implementing solutions to open-ended sociotechnical problems [5]. By adopting a multidisciplinary approach and drawing on diverse perspectives and skills, CBL enables students to develop a holistic understanding of product development [6] and design thinking [7]. Unlike traditional engineering education, CBL places a strong emphasis on hands-on experiences, allowing students to gain a profound understanding of real-world challenges and encouraging them to think innovatively. By incorporating CBL into the curriculum, institutions can better prepare students for the complexities of the modern world and equip them with the skills needed to drive meaningful change [8].

Institutions establish supportive measures for student-initiated and challenge-based projects. Study reveals several key measures such as the provision of resources, guidance, training, and mentorship to students and staff in transforming ideas into tangible projects [9]. To effectively assist student initiatives, many institutes also establish dedicated infrastructures that specialize in aiding project planning, fundraising, and connecting students with relevant external networks [10] [11]. In terms of staffing, recognizing that existing staff and technicians may not possess the technical expertise required for the dynamic nature of student-initiated topics. Therefore, it is recommended to foster collaborative partnerships between students, academics, and existing staff throughout the entire planning and exploration process [12]. This Student as Partners (SaP) approach has revealed several critical pedagogical elements contribute to the success of student-initiated projects, including increased student engagement, motivation, and ownership of learning, as well as heightened student confidence and self-efficacy [13], [14].

While SaP is a promising model in supporting the SIGs, the survey study reminds that a successful SaP implementation values reciprocity of partnership, emphasizing equal support and benefit for the students and staff involved [13]. Research further points out that tensions and challenges in SaP that could potentially occur when different perspectives and motivations of stakeholders come into play, such as tensions between student and staff, as well as between policy and pedagogy [15]. In this practice paper, we incorporate the findings of studies [10] [11] [12] [13] [14] [15] into the careful design and implementation of the SIG program, which leverage the ample resources in the Inno Wing. We also adopt the SaP method in SIGs and establish clear governance structure, finance principles, and development programs.

The Student-initiated Interest Group (SIG) program

Governance structure

The SIG program adopts a Student as Partners (SaP) approach, which begins with consultation service aimed at assisting developing teams in uniting the commitment of five parties: student leader(s), student teammates, academic advisor(s), technical advisor(s), and host department(s). The careful selection of an academic advisor with expertise in the SIG's focus area is essential. This advisor, who are academic staff from departments, serves as a link between students and the program, ensuring access to essential resources for team growth, such as team finance, workspace, equipment, and tooling.

Considering the team's involvement in hands-on problem-solving, the program requires SIG to identify technical advisor(s) with project-specific knowledge. These advisors, technical staff from various departments, offer on-demand support and collaborate with the Inno Wing team to ensure safety in prototyping and deployment. Furthermore, due to the substantial staff resources required, particularly the involvement of academic and technical advisors, securing support from the heads of host departments is necessary. Notably, as of 2023/24, some departments recognize SIG works as part of their staff’s regular duties, fostering synergy between the departments and the SIG program. This establishes a robust support structure for these student-initiated, passion-driven projects that often span diverse academic domains.

Finance principle

Each SIG operates with its own financial structure; however, the SIG program advocates a shared financial principle involving five key sources: the institution, faculty, department, Inno Wing, and student contributions. Financial support from the first three sources typically involves experiential learning funding schemes for academic staff and students, covering expenses such as travel and accommodation associated with learning activities.

In addition to the experiential learning funds, the Innovation Academy hosted in the Inno Wing provides extra funding schemes aiming to support cross-disciplinary projects that target technology exploration beyond the curriculum. It supports two distinct categories of development costs: consumables and equipment. Consumable costs cover necessary items and materials for the prototyping needs of the SIG, which are expected to be consumed after the project ends. Regarding equipment requests, the Innovation Academy prioritizes leveraging existing resources in the Inno Wing. New equipment requests are considered only if they can significantly benefit a broader community, such as being used by multiple SIGs or other student members. This approach is grounded in the understanding that maintaining new equipment requires substantial technical resources and space, and the center aims to avoid the unnecessary duplication of equipment sets among various SIGs.

Requests for project-specific equipment involve careful planning with the academic advisor, technical advisor, and host departments. The procurement of such equipment is often supported by the host department, demonstrating a strategic commitment to fostering the growth of the SIG within the center. This approach ensures effective resource utilization and encourages collaboration across the SIG community.

Finally, we have observed that successful and sustainable SIGs often place significant emphasis on students' contributions to the expenses of the project. By involving students in the financial aspects of the team, there is a raised sense of responsibility in managing project expenses and seeking alternative funding sources. This not only ensures a more dedicated approach to handling the project's financial aspects but also secures a stronger commitment from the students to actively participate in SIG activities.

Assessment criteria

Once the governance structure and financial aspects of the SIG are established, the center initiates a comprehensive review of the SIG proposal. This detailed proposal includes information about the SIG's objectives, planned activities, deliverables, prototyping, and safety arrangement. A committee responsible for the evaluation consists of key members, including the faculty member and associate dean of engineering (student enrichment), along with the director of the Inno Wing. The evaluation focuses on the potential impact of the SIG, considering its innovation, uniqueness, scope, and overall potential influence. Additionally, the committee assesses the adequacy of academic and technical support allocated from the department.

The proposal is also scrutinized for the appropriateness of the proposed project-specific equipment/tools and the requested minimal storage space, emphasizing safety arrangements. Furthermore, the committee evaluates the adequacy of the planned Teaching and Learning (T&L), Research and Development (R&D), and Knowledge Exchange (KE) activities. This thorough evaluation ensures that the proposed SIG aligns with the center's objectives and contributes meaningfully to the academic and innovative landscape.

Student as partners pedagogical strategy

The Students as Partners (SaP) pedagogical strategy is implemented in SIG supervision, embodying a collaborative approach to learning and teaching. In this model, academic and technical advisors join forces with participating students to collectively plan, fund, recruit, train, prototype, deploy, and make decisions about strategy implementation.

The SIG program assists students in identifying academic advisors, often academic staff with research expertise aligned with team topics, and technical advisors, often technicians with the required technical expertise. Advisors play a critical role in providing guidance, support, and expertise during the planning and execution of the strategy, while students contribute their unique perspectives, ideas, and experiences. Together, they engage in meaningful dialogue, negotiate roles and responsibilities, co-design the learning experience, and evaluate the strategy's impact on student learning outcomes.

During the planning phase, the SIG program empowers its advisors by providing funding schemes, project workspace, and recruitment venues for the teams' utilization under their advisors' endorsements. Advisors guide and support students, ensuring alignment of ideas with the project's objectives. Collaboratively, they develop a detailed roadmap outlining project goals, timelines, and required resources. Advisors assist students in identifying potential funding sources and provide guidance on writing grant proposals or seeking sponsorships. Recruitment is another area where advisors play a crucial role, helping students reach out to potential team members and ensuring the formation of a diverse and inclusive group. In the training phase, advisors provide mentorship and knowledge-sharing opportunities, equipping students with the necessary skills for successful project execution. Peer-to-peer training offers senior team members a chance to share acquired knowledge and experience from participating in the SIG with junior team members. In the prototyping and deployment stages, advisors collaborate with students to provide technical expertise, ensuring the project meets required standards. Regular decision-making processes involve advisors and students discussing and evaluating options, collectively making informed decisions for the project.

By adapting and empowering students as partners in the pedagogical process, the SIG program creates a more inclusive, engaging, and student-centered learning environment in the Inno Wing that fosters active participation, critical thinking, and authentic learning. As exemplified and analyzed in the later section of this paper, the SaP approach ensures that the project benefits from diverse perspectives and expertise, leading to a more successful and impactful outcome.

Development support

Figure 5. SIG promotion weeks: SIGs hosting recruitment talks and demonstrating their technologies to recruit like-minded talents in the Inno Wing.

The Innovation Academy of the Inno Wing provides support for the growth of student projects through four dedicated programs. To begin with, the *SIG Promotion Weeks* program [16] is organized during the initial weeks of the academic year. This initiative allows SIGs to actively promote and recruit like-minded talents to join their teams. As shown in Figure 5, the center facilitates this by offering ample exhibition booth space strategically located at a prominent location of the campus. SIGs take turns utilizing these spaces to showcase their team missions and demonstrate their current achievements. Additionally, the center schedules student-run recruitment talks and taster workshops for SIGs in its social and activity spaces. These events are designed to welcome newcomers, providing them with the opportunity to visit and experience firsthand the creativity and vibrant working environment fostered by the SIGs within the center.

Figure 6. Student-initiated course: *Introduction to Robotics: Mechanical* taught by senior undergraduate students in SIG.

Following the recruitment of new members, fostering active peer learning is essential to enhance the hands-on abilities of students, preparing them for technology exploration within their respective SIGs. To achieve this objective, the Innovation Academy introduces the *Student-Initiated Course* program [17], enabling senior students from SIGs to design and teach semester-long technical courses. As depicted in Figure 6, the center extends its support by providing access to its makerspace for these courses. Recognizing the value of this initiative, the university acknowledges both the student instructors and learners in the program with out-of-classroom learning credits. These credits, listed on students' transcripts, go beyond the university's degree requirements, acknowledging the additional academic merit gained through this unique learning experience.

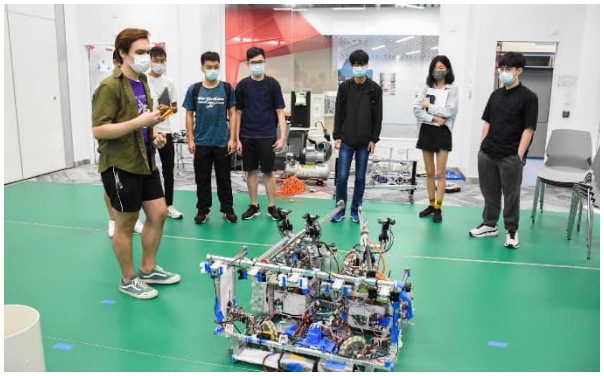

Figure 7. Hands-on workshop: Senior students sharing their knowledge of robotics, acquired through international robot design competitions, to other students in the Inno Wing

Figure 8. Sharing seminar: "*Unveiling the Innovation Code: Decoding the Pathway to Success*" led by the leader of SIG, who broke the Guinness World Record for the fastest robotic fish in the world.

Upon achieving technological breakthroughs, SIGs actively participate in *Sharing Seminars and Workshops* [18], [19] to disseminate their findings and achievements to the wider public (Figure 7). This practice facilitates an environment of active exchange, allowing students to interact and learn from each other's experiences. As the community expands, SIG alumni frequently take on the role of invited speakers in these seminars (Figure 8). They share valuable insights and stories, focusing on their personal journeys to career success and offering perspectives on future opportunities for current students. Since the inception of the SIG program, a diverse range of workshops covering topics such as robotics, artificial intelligence (including generative AI), virtual and augmented reality, web3.0, quantum computing, electric vehicles, and various technical depths have been delivered by students.

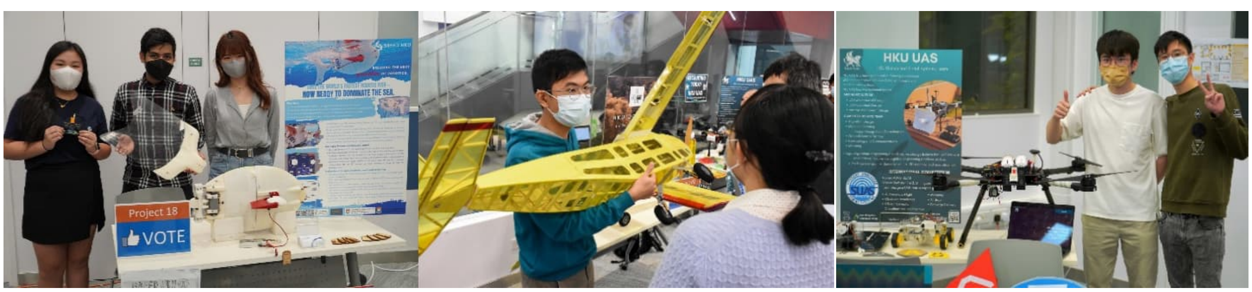

Figure 9. Engineering InnoShow: Showcasing carnivals with SIG projects presenting their achievements in the semester and gathering feedback for improvement.

The grand finale event, known as the *Showcase Carnival* [20], is organized at the end of semester to celebrate and demonstrate the outcomes of students' learning and creations (Figure 9). This carnival serves as a platform for SIGs to gather constructive feedback from peers, teachers, industry experts, and the public through knowledge exchange. It provides opportunities for SIGs to transform ideas into innovative (re)inventions, fostering a dynamic and collaborative atmosphere within the community.

Feedback mechanism

A Staff-Student Consultative Meeting (SSCM) committee has been established, comprising student representatives from each SIG, along with the director of the Inno Wing and its managing staff. The primary goal of the SSCM is to enhance transparent communication and collaboration between the center and its SIGs, creating a platform for students to express any concerns or suggestions related to the support provided by the center. The SSCM actively collects feedback from students through SIG representatives and holds regular meetings to formulate responses and take actions on various support measures for SIGs. This includes considerations such as the provision of equipment and operational support tailored to the specific needs of the SIGs. The committee acts as a bridge, ensuring that the perspectives and requirements of the student community are effectively communicated and addressed within the center's initiatives and support framework.

Impact of the SIG program on student learning and development

Methodology

To examine the impact of the SIG program on nurturing students' innovation and leadership, we conducted case study interviews with two student teams, (1) bio-inspired robotics SIG and (2) Electric Vehicle SIG. These two teams exemplify successful SIGs, demonstrating technological breakthroughs achieved by students within the center. Their projects, entirely extracurricular, originated from the shared interest of engineering students exploring underwater technology and electric automobile technology. Initially conceptualized as exploratory projects, these teams found their place within the center, evolving into cross-disciplinary units with students from diverse academic backgrounds.

Following the completion of their initial objectives, the two teams took on different paths. The bio-inspired robotics SIG concluded its journey within the SIG program. One leader embarked on a PhD research journey in robotics, while another assumed the role of CEO in a startup specializing in AI and robotics. Conversely, the EV SIG continues to refine the design of their racing car and impart knowledge to successive cohorts of students.

The two SIG teams were interviewed separately, with each interview group comprising the team leader, partners, and core members of the SIG. Both interviews utilized the identical set of questions outlined in Table 1, and all interviewee were given opportunity to answer the listed questions. Subsequently, the interview data underwent analysis following the steps and coding scheme delineated in [21]. No predetermined themes were established; rather, the final themes emerged organically from the data itself. The initial coding process entailed open exploration, followed by the systematic coding of the data. Words and sentences falling under each criterion were unitized and categorized as mutually exclusive entities [22]. Subsequent readings facilitated the identification of themes, which are summarized as findings presented in following sections.

Table 1. Questions of the interview.

Background
• Can you briefly introduce your team, including members' academic backgrounds, and their roles in the SIG? • How did you first become interested in bio-inspired robotics / EV technology, and what motivated you to join the bio-inspired robotics SIG / EV SIG?
Student's innovation
• [Ideation/inspiration] Describe the impact of Students-as-Partners (SaP) in the SIG development, what is your experience of SaP in the ideation, inspiration, of the innovation process of the SIG? • [Execution] Can you list out some of the technical challenges you face when you participate in the SIG? and how do you address them? • [Overall] How did the incorporation of SaP elements contribute to the overall success of the SIG?
Student's leadership
• [General aspect] Do you encounter any leadership challenges when you manage the SIG? How do you navigate them? • [Financial aspect] Did you encounter any financial challenges (including but not limited to, accounting, budget planning, funding seeking, reimbursement, sponsorship) when running the SIG? and how do you address them?
Impact to learning and personal growth
• How has your experience in the SIG impact your learning and personal growth? • Do you see a direct connection between your involvement in the SIG and your professional path or future goals?

Case study interview – (1) Bio-inspired robotics SIG

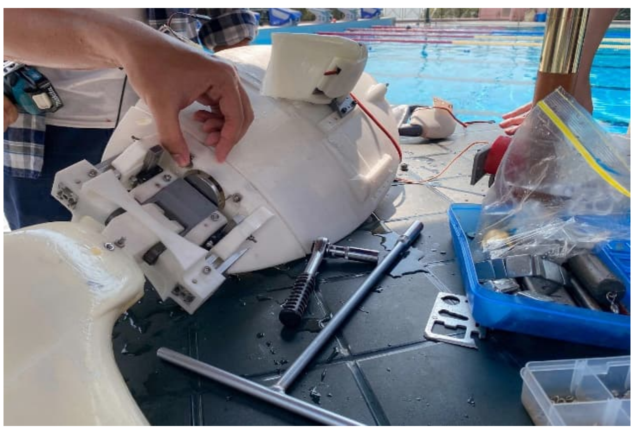

Figure 10. On technical feasibility aspect of the team: 3D printing is employed for the fish body design, and waterproofing is addressed when assembling parts.

Figure 11. The team transitions from primarily mechanical-focused to a diverse mix of engineering, science, and business backgrounds.

According to the interview with the bio-inspired robotics SIG, the team focuses on two primary aspects in its project development: *technical innovation* and *technical feasibility*. The technical innovation aspect involves the ideation and scientific exploration process to address the various theoretical and research challenges of building the world's fastest robotic fish. In this regard, the SaP model places a strong emphasis on partnering with research professors whose expertise lies in the field of soft robotics.

The team has established a recurring two-week iteration cycle that identifies various engineering designs aligned with the research professors' expertise. Subsequently, the team undergoes extensive literature study on soft robotics design, follows the provided direction, and compiles the findings into an initial engineering design within a two-week timeframe. This process involves close collaboration with the professor's research lab, which provides academic guidance for every encountered failure. The students in the SIG conduct scientific studies addressing these failures by taking academic insights seriously. It is this proactive approach from the students that ensures the success and continuity of the SaP model, as students shared, "*We learned to systematically address engineering problems, involving cycles of data collection, analysis, reengineering designs, and continuously improving until we achieved success. We are the one who drive the process, while the professor provides advice that helps us stay on the right track.*"

Concerning technical feasibility, the team focuses on the hands-on work essential for prototyping and implementing the robotic fish designs. Proficiency in prototyping skills is particularly essential at this stage. In this context, the SaP approach prioritizes collaboration with technical experts at the Inno Wing, utilizing available equipment to address various technical challenges. As an example in Figure 10, 3D printing is employed for the fish body design, and waterproofing is addressed when assembling various parts. According to the team leaders, significant implementation challenges arose due to a lack of technical know-how among undergraduates. Cycles of failures and retries were evident in various aspects of the building process, including the selection of motors, waterproof design, circuit design, and battery design. The team learned that proficient maker skills are necessary to eliminate prototyping defects that could impact the scientific measurement of data - a critical factor in enhancing the robotic fish design.

In terms of its impact on student leadership development, the team encountered two significant challenges: one related to the commitment of team members and the other concerning the management of cash flow. Regarding commitment, the founding leader emphasized that the SIG offers real-life training in leadership. Given that students who take the initiative to start a SIG are typically highly motivated and engaged, challenges arise during the recruitment of teammates, who may be drawn to the team solely because of their interest in underwater robotics. The leader highlighted that managing expectations and instilling discipline within the team constitutes the primary challenge he faced and learned from. Unlike curriculum projects, which can motivate students through grades, a SIG is purely passion-driven and initiated by students. Thus, establishing team dynamics and identifying individual contributions become essential skills to develop. The leader discovered that every student can contribute their talent and expertise to the project if the leader can recognize their potential and assign suitable tasks. As he shared "*I really believe that every student has something special to offer. It's all about the team recognizing what each person is good at and giving them a chance to shine.*"

In addition to individual contributions, the team emphasized the importance of building a diverse team, highlighting the significance of communication. When encountering any problem in the project, it is important to have someone from a specific field in the right position to solve the problem. As the leader shared, "*We actively look for talents with specific skills we need. For example, we teamed up with mathematic students to study fluid dynamics and got business students on board for finance and PR works.*" They also emphasize that effective communication skills are necessary to reach out to these individuals. Consequently, the team as shown in Figure 11 evolved from a pure mechanical engineering team to a team with diverse engineering backgrounds, including computer science, electrical and electronic engineering, industrial management, civil engineering, as well as cross-disciplinary members from the business school specializing in finance and marketing to manage the team effectively.

Regarding the challenge of cash flow, the team conveyed that they consistently grapple with funding issues. However, they discovered that this challenge may not always be detrimental to SIG development. The team learned to proactively explore funding opportunities and adapt to various constraints. Some funding sources may support only consumables and not equipment procurement, while others may assist with transportation but not cover the rent for testing venues, among other considerations. Moreover, the approval and granting of funding typically take time, compelling the team to engage in early planning and budgeting for any development and experimental work to be undertaken. These learning opportunities would not occur in curriculum projects, which are typically pre-designed with fixed timeframes and pre-assigned budgets.

The SIG team further articulated their perspective on the potential impact of the SIG program on student development. The team highlights a general lack of hands-on competencies among engineering undergraduates and expresses their aspiration for the Inno Wing and its SIG program to persist as the platform for enhancing these technical skills. They expressed, "*An idea without execution is just a concept. I believe the center will continue to uplift the technical competencies of future students, which the majority of them are still lacking at the current stage.*".

According to the team, the valuable learning opportunities and benefits offered by the SIG would be significantly overlooked if an engineering student lacks the hands-on ability to build technologies. They assert that engineering challenges become apparent through rounds of exploration and prototyping, emphasizing that insights are not immediately evident at the outset. In their project, the found that new members often oversimplify the challenges of creating an underwater robotic fish, initially perceiving it as a mere toy challenge. However, continuous prototyping and confronting failures lead them to acknowledge the necessity of engineering knowledge in fluid dynamics, control systems, energy systems, underwater communication systems, computer vision, and more. Engaging with these authentic challenges heightens their awareness of the importance of hands-on learning.

In addition, the team stressed the importance of trainings in the SIG program to instill an innovative mindset among students. Recognizing that students consistently encounter diverse challenges during SIG projects, there is a need for an enhanced sense of ownership and advanced problem-solving skills, extending beyond mere passion and dreams. As one of the leaders shared, "*A dream becomes a goal when written, and a plan when timelined. I envision the center excelling in nurturing students' innovative mindsets and cultivating their sense of urgency, direction, and responsibility.*"

Case study interview – (2) Electric Vehicle SIG

Figure 12. The team achieved the Race Tech William Kimberley Award, recognizing their resilience in overcoming adversities such as a lack of funds and significant engineering obstacles.

Figure 13. Students create a fully functional EV in a constrained environment using manual labor, without industrial-grade machinery.

In the interview with the electrical vehicle SIG, the team's introduction revealed its origin in 2018 with a cohort of undergraduates majoring in mechanical engineering who shared a passion for electric vehicle technologies. The team's primary objective, as defined by this group of enthusiastic students, was to design and fabricate the institution's first student-built formula-style electric racing car. Moreover, throughout this ambitious process, the team expressed its commitment to promoting the learning of electric vehicle technologies and anticipating participation in international competitions.

The team's inception involved organizing a group of undergraduates with specialized focuses in five distinct subdivisions: powertrain, driving input, chassis, aerodynamics and suspension. The interdisciplinary nature of the SIG was evident from the beginning, necessitating collaboration across mechanical engineering, electrical and electronic engineering, and computing disciplines. This collaborative approach reflects the team's dedication to merging diverse skill sets for the successful realization of their electric vehicle project. As students mentioned, *"Our team is composed of students from various departments across HKU, each contributing their expertise to the project. We have ME students dedicated to the mechanical design of our race car, EE students focused on the electrical aspects, and CS and EE students working on the control system. Additionally, our team also includes Medical and Engineering students who form our Sim Racing Team, while Art, Science, and Business students handle sponsorship and public relation matters."*

Recognizing the fact that fabricating a fully functional racing car is beyond the scope and ability of undergraduates, the SaP model comes into play. The project began with multiple academic staff from various engineering backgrounds serving as advisors to the team. According to the students, their academic advisors adopted a solution-oriented approach when tackling problems arising from various stages of the design and fabrication of the electric vehicle. This approach provided an authentic scenario to uplift their problem-solving and leadership abilities. As the student expressed, "*My SIG requires extensive automotive-related knowledge beyond the syllabus, including areas such as suspension engineering, electric vehicle system design, and more. Accumulating this knowledge requires a dedicated study of research and discussions with* *our advisors. Numerous comprehensive case studies involving failures in previous designs entail a challenging solving process and fine-tuning by teammates and advisors. This valuable knowledge and experience will be passed on to the next generation of teammates through internal peer to peer training courses developed by senior teammates."*

Delving into the team's operation, students described it as a lengthy two-stage journey, including the design stage and the fabrication stage. In the design stage, academic advisors guided students to commence with a comprehensive study, referencing vehicle designs from various cohorts, and drawing insights from successful examples at other institutes. Recognizing the importance of gaining insights and assessments from domain experts for their design, the team actively reached out to academics, industry professionals, and teams in other institutions with related experience for advice. Professional advice on suspension system engineering for optimal handling and high-voltage system knowledge for designing a high-performing and safe powertrain and electrical system were acquired in the process. In this context, SaP refers to the combined effort between students and academic staff in identifying and inviting these domain experts for a rich knowledge exchange. A student shared, *"Our advisor connected us with a local battery research and development company, providing us with the opportunity to consult on the design and fabrication of the high-voltage battery for our electric race car. Through this collaboration, we gained valuable professional and industry knowledge that extended beyond what we learned in the classroom. The insights and expertise we acquired from the company equipped us with the necessary safety awareness and electrical knowledge to successfully develop a high-voltage battery for our race car."*

The team proudly presented their achievement, proof of the success of SaP model in the first stage. As depicted in Figure 12, they brought the design of their electric vehicle to the Formula Student UK Concept Class competition, secured the 4th place in 2022 in the cost and manufacturing event. Additionally, they were honored with the Race Tech William Kimberley Award, recognizing the team's resilience in overcoming adversities such as a lack of funds and significant engineering obstacles. A student shared, *"Participating in the Formula Student UK Competition brought us a sense of frustration. While observing other teams who efficiently manufactured 80% of their car parts in-house, we found ourselves limited to only 20% in-house manufacturing capacity on our car parts due to the limitation from departments and university. The remaining 80% had to be outsourced, leading to significant challenges of long lead time, ranging from 4 weeks onwards. Considering our tight project timeline, it was not feasible to produce a second improved version of the vehicle within a single race year. Thus, we focused on developing a single, well-designed, and conservative vehicle. Frequent consultations with our advisor provided valuable guidance and feedback, enabling us to achieve the best possible outcome under our circumstances."*

The second stage of the journey focuses on fabrication, encountering various resource constraints and limitations such as funding, space, techniques, and machinery. In this phase, the SaP approach places emphasis on nurturing leadership abilities among the team. While students initially expected an ideal scenario where resources are readily available upon request, challenges and discouragement hit the team when various resource requests are either rejected or partially fulfilled due to inadequate funding sources and a lack of professional-grade fabrication machinery. The academic advisor plays a critical role as a mature coach, motivating the students by guiding them to think critically and explore alternative solutions. For example, in the absence of industrial-grade CNC machinery in the Inno Wing, the students turned to utilizing available medium-grade semi-digital CNC machines, smaller water jet cutting machines, as well as a manual lathe machine to fabricate most of the components of the vehicle (Figure 13). This involved multiple rounds of practices and re-engineering to adapt to the available resources and overcome constraints. Although painful and tedious, students harvested valuable outcomes from this process and shared, *"We faced challenges in manufacturing composite material parts at school due to the lack of resources such as an Autoclave and a suitable vacuum pump for curing wet carbon fiber cloths. Our team members took the initiative to assess available resources and came up with a creative solution. They developed a powerful pneumatic system that repurposed an industrial-grade air pump into a functional vacuum pump. Throughout the refinement project, the team members leading this initiative sought continuous guidance and consultation from our advisor. This development not only allowed us to overcome the limitations but also presented us with a valuable opportunity to enhance our leadership skills."*

The interview reveals that developing leadership abilities, described by the students as the core of the success of this project, is again the most significant learning outcome of the SIG program. A student leader echoed this aspect by recalling his experience in conflict management and team motivation; he shared, *"During the Formula Student UK 2023 competition, a conflict arose between an impatient teammate and two-thirds of the team. The situation created a tense atmosphere within the team. Drawing upon the knowledge and experience gained from regular discussions on leadership and project management with my advisor, I took the initiative to resolve the conflict. Through patient communication and mediation between the parties involved, I successfully diffuse the tension and restored a positive working environment within the team."*. The partnership with the academic advisors offered students valuable mentorship and guidance, empowering them to take leadership roles in the project. He concluded, *"My partnership with my academic advisor has been a valuable opportunity for personal and professional growth. It has allowed me to actively participate in project management within my SIG, enhancing my leadership, interpersonal, and project management skills. I feel privileged to be a part of this partnership and hope that my successor will also recognize and cherish this opportunity. This partnership not only benefits us as individuals but also to the entire team."*.

Challenges and opportunities

Lack of technical competency

The interviews conducted with the SIGs have highlighted several significant challenges in implementing the SIG program. Firstly, since most SIGs involve the development of technologies, we have observed a general lack of technical competency among students, hindering their ability to translate engineering designs into practical implementation. Recognizing that bad prototyping can result in significant implementation errors, which in turn hampers the evaluation of an engineering design, there is a pressing need to enhance the hands-on technical competencies of undergraduates.

To address this issue, the Inno Wing collaborates closely with academic advisors to identify essential technical competencies. Subsequently, we develop training workshops tailored for SIG participants. For instance, acknowledging the increasing demand for AI adoption across various SIG topics, the center has established several generative AI training workshops in collaboration with industry partners. An example includes the "*Building AI Solutions on Microsoft Azure Cloud*" workshop, which instructs participants on using the Open AI API service. We have successfully trained an initial group of undergraduate trainers and further organized peer-learning training sessions among students, such as the "*Build Your Personalized Chatbot*" workshop hosted by student instructors. This proactive approach ensures that students acquire the necessary skills to successfully navigate the challenges posed by the SIG program.

Limited design-thinking skills

The second challenge concerns the limited design-thinking skills. While a majority of students are familiar with the definition of design thinking, the actual application reveals a tendency to assume a well-designed problem with a preconceived solution, resembling typical coursework settings. Both SIG leaders emphasize the necessity of enhancing students' innovation mindset, specifically cultivating sensitivity and empathy to understand the needs, feelings, and perspectives of end-users. This involves not only clearly defining and expressing engineering problems but also exploring a variety of ideas from a broad perspective, implementing, testing, evaluating, and re-identifying problems for improvement. These skills are considered fundamental for all engineering students.

To address this challenge, the SIG program conducts active exchange workshops among SIGs to facilitate the sharing and convergence of best practices. This collaborative approach aims to instill and reinforce the practical elements of design thinking among students.

Discipline matters

The third challenge involves the discipline management of SIG teams. While each SIG develops its own mechanisms for promoting, recruiting, and training team members, a commonality among mature SIGs that consistently deliver results is the presence of an internal peer-support network. This network not only provides technical assistance but also fosters a culture of mutual help and encouragement, facilitating progress on individual tasks and ultimately contributing to the achievement of the SIG's overarching objectives. SIGs that have cultivated these peer-support networks exhibit a stronger sense of ownership among team members and demonstrate better resilience to conflicts.

Furthermore, these SIGs incorporate various teamwork-building activities to nurture team spirit, ensuring the cohesion of the team over successive cohorts of students. This holistic approach to discipline management contributes to the sustained success and effectiveness of SIGs in navigating the challenges they encounter.

The importance of implementing a sunseting plan for a SIG

In the first three years of operation of the Inno Wing, we observed the rise and fall of some SIGs over time. The SIG program plays a leading role in preventing a SIG from continuously repeating the same projects without expanding into new directions or achieving further milestones.

For instance, consider the bio-inspired robotic fish SIG, which achieved the remarkable feat of setting two Guinness World Records for "The Fastest 50m Swim by a Robotic Fish." Following these achievements, the team was directed to pursue new initiatives. Funding requests for rerunning the same project without a significant justification for new innovation were rejected. Subsequently, a leader of the team embarked on a Ph.D. study in robotics, while another leader took the technology on a startup journey. Eventually, the SIG gracefully transitioned out of the Inno Wing, freeing up resources for the development and growth of other emerging SIGs. This strategic approach ensures that the SIG program remains dynamic and responsive, fostering continuous innovation and progress.

Conclusion and future works

In this practice paper, we outlined the design and implementation of the SIG program hosted within the Tam Wing Fan Innovation Wing, emphasizing its robust governance and supportive structure. We demonstrated the effectiveness of a challenge-based learning model and the student-as-partner approach in nurturing student innovation and leadership. Drawing from case studies, we identified several significant challenges encountered during the program, including students' weaknesses in technical skills, limited design-thinking abilities, disciplinary issues, and the absence of a sunseting plan. These areas represented key focal points for future development and improvement within the SIG program. By addressing these challenges head-on, we aimed to enhance the program's effectiveness and sustainability, ensuring that it continued to provide valuable opportunities for student engagement and growth in the realm of innovation and leadership.

As the SIG program progresses, it aims to enhance its pedagogical impact by leveraging the expertise of alumni who have undergone the entire SIG experience. During interviews, leaders expressed their commitment to contributing to the continued growth and development of the center on the global stage, stating, "*I am committed to contributing to the continued growth and development of the center on the global stage,*" and "*I envision the center to excel in nurturing students' innovative mindsets and cultivating their sense of urgency, direction, and responsibility. I am happy to come back and contribute anytime.*" We envision the SIG program scaling up in terms of alumni and industrial "partners" in the SaP model, thereby enhancing the diversity of support and advice available to students in the Inno Wing. This collaborative effort with alumni and industrial experts not only enriches the overall educational experience but also provides students with valuable insights and guidance from those who have successfully navigated the SIG journey.

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Ethical approval

Ethical approval for this study was obtained from the University of Hong Kong, with HREC reference number EA230632.

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