Affordable robotics toolkits for equitable and interdisciplinary education, transformable to searching nodes for disaster onsite investigations

Mr. Hiroyuki Ishizaki, Shibaura Institute of Technology

Hiroyuki Ishizaki is a Visiting Professor at Shibaura Institute of Technology (SIT), a leading Japanese engineering school. His research interests include multidisciplinary teaching and learning, cross-cultural competence, collaborative online international (COIL), technopreneurship, and project/problem-based learning methods. As a Director of the Malaysia Office, he has been expatriated in Malaysia since 2014 and leading the internationalization of SIT and its partner universities throughout the Southeast Asian region. Under his initiatives, various short-term mobility programs and student exchanges have been started. He is also Chair of the Mobility Special Interest Group of Asia Technological University Network (ATU-Net) and initiated a COIL program called Virtual Asia Exploration (VAx) by orchestrating the collaboration of six Asian universities. He is also an entrepreneur through his consulting company established in 2004, and has been rendering management consultation services to both small-medium size companies and multi-national enterprises such as global strategy planning, cross-border business entry, middle manager training, and partner development. These business achievements are reflected in his academic activities through the designing of lectures and mobility programs with practical implementation perspectives. Ishizaki has been actively presenting and publishing his academic achievements at international conferences in the Asia Pacific region and North America such as APAIE, WERA, and NAFSA. He earned a Master of Business Administration majoring in international business at the University of Southern California in the United States of America, and a Bachelor in Law at Hitotsubashi University in Japan.

Dr. Sumito Nagasawa, Shibaura Institute of Technology

Dr. Sumito Nagasawa received Ph.D. in Engineering from the University of Tokyo in 2001. He is a Professor in Department of Engineering Science and Mechanics at SIT. His research interests include miniaturized robots using Micro-Electro-Mechanical Systems technologies and robot education for STEM.

Prof. Hatsuko Yoshikubo, Shibaura Institute of Technology

Dr. Hatsuko Yoshikubo is currently an Associate Professor and a deputy director of the Innovative Global Program, a research-based full English degree engineering program at the College of Engineering at Shibaura Institute of Technology (SIT), Tokyo, Japan. She is a Principal Investigator of the Japan Society for the Promotion of Science Research Grants 20K02943 and the AY 2022 SIT Grants for Educational Reform and Research Activity. She obtained a Ph.D. in English Literature from Chiba University in 2002. Her current main research interests are: 1) how including humanities courses in an engineering education curriculum can help students to gain flexibility, and an appreciation of equity, and a greater richness of ideas; 2) finding and solving the systematic issues impacting the effectiveness of engineering education, specifically in the context of project-based learnings; and 3) assessing the impact of interdisciplinary engineering project-based learnings. Below are her recent presentations at international conferences: WERA 2022, APAIE 2022, IIAI DSIR 2021, IIAI DSIR 2020, WERA 2019. She obtained the Outstanding Paper Award in DSIR 2021.

Dr. Hitoshi Nakamura, Shibaura Institute of Technology

Dr. Hitoshi Nakamura received Ph.D. in Urban Engineering from the University of Tokyo, Japan in 2006. He is a Professor of Urban and Regional Planning in the Department of Planning, Architecture and Environmental Systems at Shibaura Institute of Technology, Japan. His research interests include Planning for Urban and Regional Resilience focusing on multidisciplinary studies across architecture, civil engineering, environmental studies, and social sciences.

Affordable robotics toolkits for equitable and interdisciplinary education, transformable to searching nodes for disaster onsite rescue

Hiroyuki Ishizaki*, Dr. Sumito Nagasawa, Dr. Hitoshi Nakamura, Dr. Hatsuko Yoshikubo

Malaysia Office
Shibaura Institute of Technology
*ishizaki.hiroyuki.n3@sic.shibaura-it.ac.jp

Abstract:

A cross-department research team at Shibaura Institute of Technology (SIT), a Japanese leading engineering institute, has initiated an ambitious project to develop and implement multi-dimensional robotics toolkits which are effective for facilitating engineering education for all generations – from K-12 with no programming knowledge to working professionals – by combining technopreneurship for commercializing robotics learning tools with below US 100 dollar affordability enabled by rapid technological advancement and interdisciplinary engineering education methodology theming robotics as knowledge integration of various engineering aspects. Moreover, these robot tools are equipped with practical functions to be deployed for earthquake survivor search and rescue by taking advantage of swarm technologies utilizing mesh-net mutual data communication among multiple nodes.

Through this project and related research activities, the project team aims to promote solutions for each country's natural disaster profile by interconnecting the above-mentioned factors, pragmatic social issues, and the global project/problem-based learning (GPBL) method, which the authors are also passionately working to develop. This article also discusses the benefit of starting interdisciplinary robot education in early age, the necessity of an entrepreneurial mind amongst teachers, and the Robotics Learning Roadmap as a whole picture of lifelong learning.

Keywords: robotics, robot education, search and rescue, technopreneurship, interdisciplinary education, Robot Operating System (ROS), ROS2, Cooperative Distribution System (CDS)

1. Background, problem statement, and objectives

1) Project philosophy of robotics toolkits for practical and interdisciplinary learning journeys

Robotics is an excellent subject for interdisciplinary learning as a combination of hardware (HW) knowledge such as mechanics, electric and electronics, materials, and software (SW), which includes programming design, logical structure, algorithm, control, coding, etc. [1] In interdisciplinary education, closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills with a higher level of integration. Such an approach is effective not only for the students in undergraduate and higher levels with engineering majors but also for K-12 students with STEM (science, technology, engineering, and mathematics) subjects[2]. Nowadays it is also called STEAM (science, technology, engineering, art, and mathematics), which is an inclusion of the "Robotics" discipline in the content of training of future teachers of physics, mathematics, technology, visual arts, and others [3]. Meanwhile, robots and robotics are an interesting topic for children, teenagers, adults, and even professionals. People are familiar with robot stories from childhood through fairy tales, science fictions, movies, cartoons, and animations. In Japan, cartoon and TV animation characters have been playing important roles in raising children's curiosity for many decades. Even adults are attracted by *anime* content. Typical examples are Astro Boy from 1952, Doraemon since 1969, and Mobile Suit Gundam started in 1979. Through these stories, all generations are developing awareness and attachment to robots.

Robot technologies are already embedded in our daily life including electric appliances, vending machines, Factory Automation/Office Automation (FA/OA), and even accelerating application fields such as Unmanned Aerial Vehicles (UAV) and auto delivery systems. Because of the growing demand for future engineers, kids, and their parents are both keen on learning robotics and control software from younger ages. Many schools are addressing their focus on STEAM subjects. Most importantly, educational robotics provides fun and exciting learning experiences because of its hands-on nature and the integration of technology[4]. Thanks to the opensource, it is getting easy for educators to develop own tools to fill the gap in K-12 education that doesn't address the importance of imparting technology literacy, project-based learning and transdisciplinary educational activities, and causing a deficiency of skill sets necessary for university students [5]. Robotics education can be started from elementary school or even kindergartens [6] for providing students with learning-by-doing approach based on the constructionism theory by Seymour Papert of the Massachusetts Institute of Technology's Media Laboratory [7].

However, most existing robotics tools are essentially toys with limited or no practical usage. After completing parts assembly, they are mostly displayed inside the child's room. Some, not many, are associated with coding, though largely still at a rudimentary level, which may not lead to comprehensive programming studies. Such products can also be quite expensively priced, with a minimum price tag of a couple of hundred US dollars, which is mostly for wealthy households. A typical product was the LEGO® MINDSTORMS® [8]. It is already used as an educational tool and assessed how it impacts students' interests in STEAM related subjects [9]. As a commercial product, its series is frequently discontinued and unavailable for new purchase. There are some other educational tools such as WaterBotics ® [10]. RoboCupJunior is also wonderful program with project-oriented approach with a focus on hands-on and scaffolded learning experiences for students up through age 19, which include Rescue, Soccer, and Onstage [11]. Normally these products or learning programs are quite expensive, mainly for fun learning experiences like toys, and not for practical use.

Thus, this project aims at newly introducing robotics study toolkits and teaching programs, which can be adjustable to engineering knowledge for any learner's level. Expected learning outcomes include soft skills for creating solutions to societal issues with practical applications in addition to HW and SW. To meet potential educational demands, the target price is set at less than US 100 dollars for offering affordability to the general public. After commercializing the toolkits, our next goal is to establish a university-originated venture company for offering them all over the world. These entrepreneurial efforts will be reflected to SIT's engineering education content so that it becomes more practical.

2) Disaster preparation as expected social issues

There is an inconvenient fact that Japan has encountered many natural disasters throughout its 2,600 years history. In particular, there are many earthquakes because of geological features given Japan's location at the marginal point of 4 major continental plates. There are 111 active volcanoes in the Japan islands area, which is nearly 7.4% of the total for the entire planet. In January 2020, the Japanese Ministry of Land, Infrastructure, Transport and Tourism disclosed a 70-80% probability of magnitude 8-9 class earthquake(s) within 30 years. Even smaller scale but still impactful earthquakes are happening every year and causing deadly damage. Considering the worldwide data that earthquakes accounted for more deaths than all other natural hazards combined, causing nearly 56% of total global disaster mortality between 1996 and 2015 [12], it is the primary priority to develop a way to mitigate earthquake-related fatalities.

As a prospective solution, automated robots could be effective to search for survivors trapped in debris. Small-sized unmanned robots with thermal and human voice sensors are viable measures on behalf of rescuers for avoiding the risk of losing their own lives.

2. Major 3 categories, respondent 5 action items, and progress to date

While our future goal for rescue missions is to establish a social system that enables the deployment of survivor search robot swarms to disaster sites within 72 hours, this will become achievable when this robotics education method is adopted by many educators and learners in the community in ordinary life. This approach could be extended around the world where disasters would happen. As the beginning of this wide-ranging project, the first phase is focusing on the speedy launch of these robotics toolkits, the establishment of an engineering education methodology, and the quick implementation of these methods through technopreneurship. The objective of this article is to demonstrate the insights of interdisciplinary robot education methods both in undergraduate and K-12 level through the planning and commercialization of new toolkits. Another expectation is to attract advocates to this project such as collaborating researchers, adopters of this education methodology, trial users of these robotics tools, business co-founders, and investors.

Figure 1: 3 Major Action Categories and Outcomes to Date

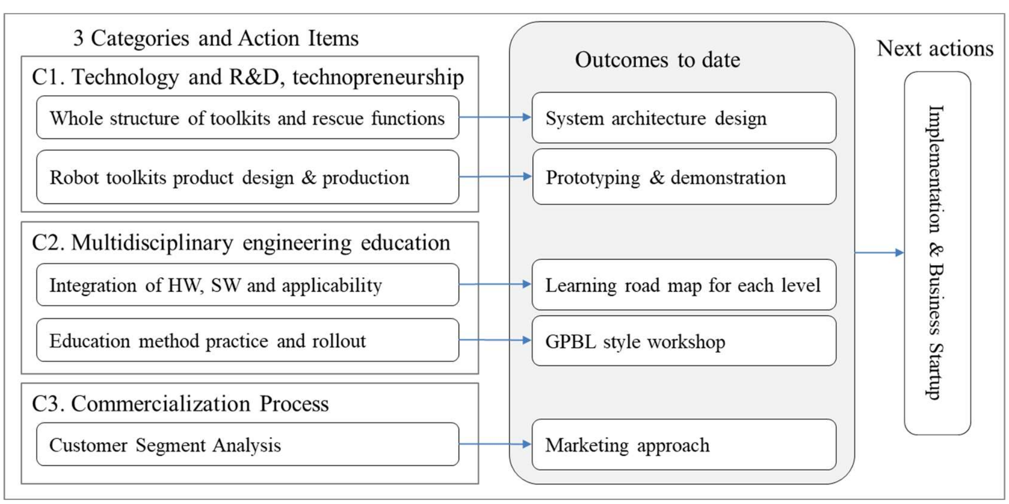
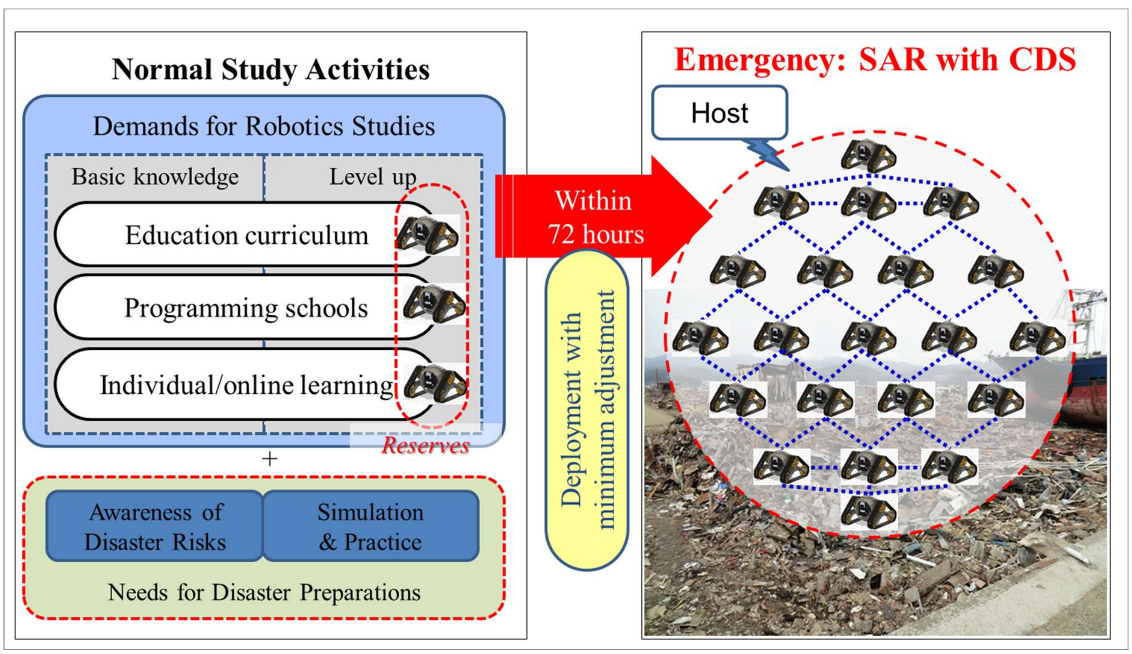


Figure 1 shows the outlook of 3 major action categories, C1. Technology and Product R&D based on technopreneurship, C2. Interdisciplinary engineering education, and C3. Commercialization Process, and the outcomes to date.

1) Whole structure of toolkits & rescue functions, and system architecture design

Technological breakthroughs in recent years have led to a revolution such as Machine Vision and Search and Rescue (SAR) Robotics, to be used in post-disaster environments with rustic conditions (low luminosity, suspended particles, obstructive materials) [13]. These technological advancements have enabled to invent this robotics toolkits with reducing production costs. The whole structure of this robotics system is depicted in Figure 2, as an overview for mesh-net based survivor search missions. While a single robot is equipped only with minimal capabilities, the Cooperative Distribution System (CDS) will enable multiple nodes' synchronized performance for swarm sensing coverage and extended SAR areas. For real rescue missions, it is important to implement minimum and sufficient functions to achieve the capability of deploying to the disaster site within 72 hours after the occurrence of the incident. Another important feature is the networking and collaboration function. At the very beginning of learning with this robotics toolkit, students are instructed to understand this whole outlook and each node could contribute to the entire system. Additionally, such a structure is related to the achievement of the learning objectives [14].

Figure 2: Overview of System Architecture SAR with CDS



2) Robotics toolkit product design & production, prototyping & demonstration

The main concept of this product consists of learning flexibility with minimum engineering expertise in each level; affordability, flexibility of functional enhancement; and practical usefulness. Figure 3 is an outlook for the prototype, and Table 1 is a list of major specifications, respectively.

Figure 3. Rescue Search Robot Prototype

Table 1: Robot Specification

Size (L x W x H)	10cm x 10cm x 10 cm (tentative)
Weight	100g (tentative)
Operating System (OS)	Robot OS (ROS) 2
Programming method	Tinkercad
Communication	Wi-Fi
Camera system	Web camera
Sensors	Thermal sensor, Human voice sensor
Wireless control	Smartphone and PC
Actuator	Gear Mode (pololu)
Battery	3.7V 220mAh X 2
Driving system	2 motors and caterpillar
Remote control	Via global network using Blynk
Uptime	Nearly 21 minutes

First and foremost, the principal concept is a simple and minimal structure based on the intention that even primary-level students should be able to easily understand. This is also related to the minimization of the parts so that the selling price would be within US100 dollars. Still, the functionality should be enough for SAR with human thermal and sound sensors. The node is also equipped with GPS and a wireless communication system to transmit the location information when a survivor is identified.

This has become possible with the advent of the XRCE (eXtremely Resource Constrained Environment)-DDS (Data Distribution Service) -Client "micro–Robot Operating System (ROS) 1 and ROS2, which are a low-cost and open-source mobile robot platform [9]." It also enables users to establish reliable communications with a host PC that carries high power and functionality. ROS is also capable of carrying out the robot's automatic data processing and control. The simple structure is available for functional upgrade in accordance with the learners' skill enhancement. This will be an analysis and thinking process for everyone to develop their own ideas and create unique solutions based on each user's specific conditions. The main advantages of ROS 2 are modularity and platform independence. Several ROS 2 packages are available for swarm robotics that provides a library of ready-to-use swarm behavioral primitives [9]. If advanced searching capabilities are needed, it is also possible to add high-end devices such as modern optical cameras, thermal sensors, and lasers for capturing data in post-disaster environments with rustic conditions with low luminosity, suspended particles, and obstructive materials [15].

Demonstrations are to be done on several occasions. The first one is the Japan Rescue Robot Contest, which is held every year for the purpose of facilitating enhancement of SAR technologies and simultaneously improving preparedness for natural disasters. This prototype is already qualified to attend the primary round in June 2023. This type of event is suitable for attracting public attention and obtaining feedback from experts in this field. The other demonstrations are at academic societies, starting from the ASEE 2023 Annual Conference. This is also an important process to attract interest among educators and researchers, and fine-tune this approach from the aspect of both technopreneurship and engineering education.

3) Initial marketing and demand analysis

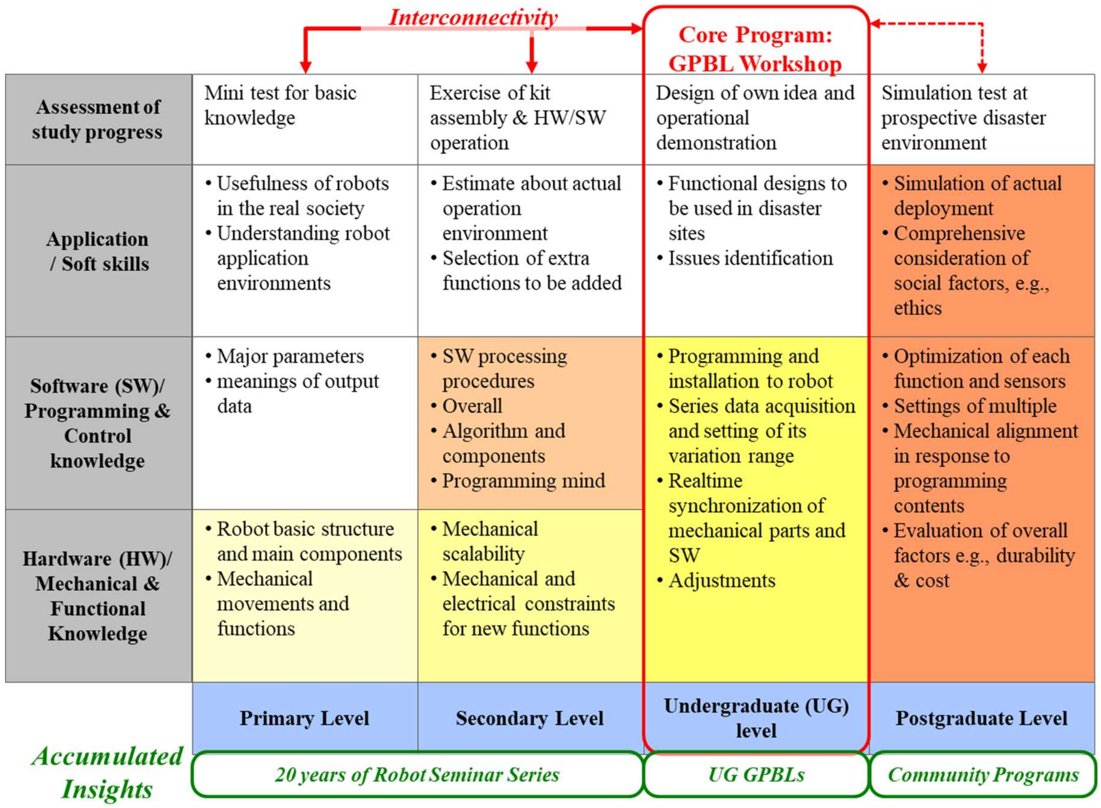
In order to identify customers' potential demands and unmet needs for robotics education, SIT's group subsidiary SI Tech Co., Ltd. provides summaries of questionnaire results collected through "Boys & Girls Robot Workshop" series, which are to be elaborated later. As there are many similar existing products, it is quite important to balance the learning effectiveness and pricing, which is a very first screening factor. While individual households and private primary/secondary schools are price elastic, US 80-100 dollar is the highest limit from the viewpoint of public school teachers and administrative staff. Therefore, the final product should be within this price range, with the balance of enough SAR functions achieved by ROS/ROS2, CDS, and XRCE-DDS. Meanwhile, the product carries scalability to add optional gadgets such as high specification sensors.

Another discussion is with a prospective manufacturer with lots of experiences for prototyping and marketing. It is a tech startup with 45 years activities in R&D and new business development with frequent collaborations with SIT. They can give critical and objective feedbacks from the end-users' viewpoint referring to their previous cases. This project will also their chance for creating a new business lineup as another revenue source.

4) Integrated education based on technical skill level, and learning roadmap for each level

Table 2 describes a robotics learning roadmap for each level, based on our accumulated insights.

Table 2: Robotics Learning Roadmap for Each Level



This derives from the accumulation of teaching experiences from SIT's GPBL workshops for undergraduate students using Arduino and Tinkercad, and also SIT's "Boys & Girls Robot Workshop" for primary/secondary students using mechanical toolkits, which are discussed afterward. In summary, following lessons learned are addressed.

(1) Grade 4 or year 10 is already good timing to start engineering education through the lens of the robot practice since it would fascinate children's interest.
(2) Robotics should be taught through interdisciplinary approach especially during young age by addressing the importance of teamwork and multiple knowledge. It is important for teachers to deliver the message that one robot could be only through collaboration of multiple experts.
(3) It is highly suitable for K-12/primary/secondary school teachers to explain the outline of undergraduate engineering education so that their students will become able to grasp the interconnectivity between what they are presently doing and the future applicability.
(4) It is also meaningful to mention the possibility to become robot-based entrepreneurs in the future, based on several cases that past robot seminar participants have created their own startup venture or became robot researchers.

The core program is designed mainly for undergraduate-level students. Meanwhile, this teaching method is adjustable to the learners' level from primary school to postgraduate students. For instance, through a GPBL style 5-day workshop, undergraduate-level participants will become able to understand the combination of HW mechanical structure and its synchronization with SW. They are also instructed to analyze the condition of possible disaster sites and discuss possible issues and hurdles to be overcome for real use. For those who already know about programming, they can elaborate on the SW part by utilizing other existing ROS-based open tools [16]. If the students are coming from other fields with little or no SW knowledge, they can still learn the basics using Tinkercad.

On the other hand, the focus on instructing at the primary level will be simplified to the acquisition of a basic understanding of the HW mechanical structure and parts components because the main learning objective is to raise curiosity about robotics engineering. For the SW part, they will simply memorize major parameters and the meaning of output data. No programming knowledge is necessary. An essential point is to be aware of the application to real disaster sites and ponder the SAR environmental condition where the robots will deploy.

For the secondary level, the principal point is shifting to the SW side using Graphic User Interface (GUI)-based Tinkercad coding. The participants will recognize the algorithm and programming mindset, which will lead to a foundation for undergraduate study. The HW part will also be upgraded to meet the details of mechanical movement and electrical constraints when the ancillary functions are added. As for potential applications, the participants are encouraged to consider the types of disasters that may possibly occur in their own country and imagine the application of these robots to SAR missions. Instructors will articulate the perspective of an interdisciplinary approach, as comprehensive knowledge and collaborative ideas are essential even for operating such small robots with simplified designs.

For the level of postgraduate students or advanced engineers, learning objectives gear up to the integration of all factors, for swarm sensing coverage with CDS and simulation of actual deployment. As this is about network-based collective movement, the synchronization of multiple nodes is essential. During the workshop, leadership and collaboration among the team members are also inevitable, and therefore this is suitable for group competition and assessment. Instructors will lead participants' learning experiences with logical analysis, causal relations, and critical thinking skills. Additionally, when the participants have completed this level, they will be encouraged to become an instructor.

The focal educational context from engineering and interdisciplinary perspectives is to develop participants' interactive thinking skills so that their learning outcomes are put to practical use. It is important to have real-time interaction with an actual environment in which the robots have to constantly react, such as adjusting the motor power to a slippery ground surface, moving to a specified position within certain seconds, and recovering to a flat angle in the case of accidental overturn. Through the process of estimating actual operating conditions, learners are required to take multiple factors into consideration such as mechanical movement, software control, and realistic solutions to overcome unavoidable constraints. This is also facilitated through group discussions to show how others may have different opinions based on their own observations.

5) Education method practice & rollout, and GPBL style workshop

(1) Global Project/Problem-Based Learning (GPBL) Program

The teaching methodology of this robotics toolkit is initially designed for a 5-7 day workshop for undergraduate students in English. GPBL is an excellent option for persuading students to apply what they have learned to the analysis of real social issues/problems and idea creation of solutions. Educational robotics is an effective learning tool for project-based learning where STEM, coding, computer thinking and engineering skills are all integrated in one project. Robotics provides opportunities for students to explore how technology works in real life [17].

The authors' team has been conducting GPBLs for several years, the format of which includes in-person, online, and hybrid modes, and accumulated know-how together with foreign partner universities. Figure 4 is pictures from a hybrid mode GPBL in Japan and Malaysia.

Figure 4: Hybrid Mode GPBL in AY2020

In the Japanese Academic Year (AY) 2023, the team will host GPBLs together with Southeast Asia university partners as Proof-of-Concept (POC), share the outcomes with them, and transfer the instruction expertise to them so that they can conduct the same workshop by themselves with the purchase of this toolkit.

(2) Robotics workshop for primary/secondary youngsters

This project aims at the provision of robotics learning opportunities to youngsters for stimulating their curiosity about engineering from an early age. SIT provided robot seminar series beyond university curriculum as a part of community activities from 2000 until 2019. Core target participants are from age 10/grade 4 students up to age 15/grade10. The seminars were also provided to adults as a lifelong education. As shown in Figure 5-1 and 5-2, this mainly aims to become familiar with mechanical engineering by assembling metal parts and motors, and no SW programing. These toolkits were designed and supervised by SIT professors, and produced by group company SI Tech, Co., Ltd.

Figure 5-1: Toolkits before assembly

Figure 5-2: Assembled 6 legs boxer robot

Its pedagogical philosophy was started initially to nurture engineering mind from childhood as grass root education. In addition, it is enhanced as societal collaboration and lifelong learning. Thus, this series is organized with following 4 levels.

- Primary/secondary level: "Boys & Girls Robot Workshop" which consists of parts assembly, design, and competition
- Highschool level: Line tracing robot seminar, including basic programming and control
- Undergraduate/postgraduate level: technological lecture, R&D, and GPBL
- Adult level: assembly of self-reliant robot embedded with micro computer and SW

These design philosophy and accumulated insights through 20 years has eventually organized a foundation of above-mentioned Table 2.

Figure 6 illustrates the assembly session and competition part. The total number of participants is 31,043 children with 747 events at major cities throughout Japan, New York, Singapore, and Malaysia. 8 types of robot assembly kits were developed and produced by SI Tech, and sold to the participants in USD 50-80 price range, subject to product features. The contents consisted of a lecture about the basic structure of robots, the mechanical assembly of the robot package, exterior decoration, and the competition. As it was mainly focused on mechanical assembly, SW control or program coding was not included. It was also a genuine study material and there was no practical application.

Figure 6: Boys & Girls Robot Workshop Series 2000-2019

Through the course of this instruction process, we have been adopting interdisciplinary approach for encouraging students to become interested in everything. For instance, language study is correlated with effective communication for optimizing the group performance to complete one robot. Observing issues in the surrounding environment will provide ideas for creating solution robots.

Here are several insights extracted from questionnaire analysis. In one case in New York City, 60 participants consisted of 22 or 36.7% grade 4, 16 or 26.7% grade 5, 11 or 18.3% grade 6, and 11 or 18.3% secondary. When they were asked about easiness/difficulty of the workshop, 10.0% responded "easy", 53.3% "proper", and 36.7% "difficult". Table 3 shows the participants' impression about the contents. More than half of the grade 4 participants expressed that this robot assembly was easy or proper.

Table 3: Degree of contents difficulty by grade

Grade	Easy	Proper	Difficult	Total
4	1	12	9	22
5	1	10	5	16
6	2	4	5	11
7	1	4	1	6
8	1	2	2	5
Total	6	32	22	60

6) Commercialization process of newly invented toolkits

The upcoming robot toolkits would provide all the segment level with the lifelong learning opportunities. Table 4 is based on the Organizational Buying Behavior[18] and Marketing Management[19] for clarifying who are users and payers in each segment level.

Table 4: Customer Analysis by Target Segment Level

Segment Level	Learning method	Learner (user)	Payer (customer)	Influencer	Sales channel
Primary/ Secondary	Seminar	Participat	Parent/Guardian	Teachers	Seminar host
	School curriculum	Class student	School	Teachers	School
	Extra-curricular lesson	Participat	Lesson organizer	Media PR	Direct
Undergraduate	PBL program	Student	School (or own)	Academia	School
Adult	Seminar/Training	Participat	Organizer	NA	Organizer
Individual learner	Self-learning program	Individuals	Own	Media PR	Mainly online

Initial targets are (1) undergraduate students and (2) primary/secondary students in consistent with the above-mentioned Table 2. Based on this priority, the marketing approach is defined.

(1) Undergraduate students through GPBL programs

GPBL is always a suitable testbed for POC, and fine-tuning with the findings. The robotics GPBL for examining the applicability of this tool kit is already scheduled in the 1st quarter of 2024 together with the Thai university in Bangkok. Through this process, product details, teaching method, and instructing materials are elaborated so that this toolkit and education methodology could be replicated to other universities. As a marketing activity, interviews with participating students and their instructor would be conducted before and after the event.

(2) Primary/secondary school students through seminars or school curriculum

In the case of Boys & Girls Robot Workshop series, while leaners and users of the toolkit are participating students, the payers of the fee and eventually customers are their parents and guardians. The survey result of the 29 workshops has revealed parents/guardians' average satisfaction is 98.0%, which is even higher than that of participating students with 95.2%. Most of the cases, they initially introduced this robotics workshop to their children and suggested to attend, based on the information from teachers or parents/guardians' associations. Thus, toolkit design and customer marketing strategy will be separately considered. When the prototype is completed, preliminary marketing research will be conducted to the institutes which hosted the previous workshop series.

7) Business start-up as a technopreneurship

After completing product R&D with the manufacturing cost for US100 dollar retail price, design of business models for several revenue sources such as toolkit sales and provision of group workshops, and POC through GPBLs, a university-originated startup venture is going to be established. In addition to the initial investment from founding members, possible financial sources are SIT's internal fund and Japanese government startup support programs. In the case of the decision not to establish a new legal entity, other options are to manage this project as SIT's new revenue-generating business lineup. Otherwise, the usage of this intellectual property will be offered to other educational material producers for loyalty payment. While there are multiple choices, our initial mission is to provide as many students as possible with affordable learning opportunities which leads to the SAR solutions for natural disasters around the world.

3. Assessment of students' learning outcomes and the measurement of this project

1) Assessment of students' learning outcomes (LOs)

This project aims at interdisciplinary learning step by step, and therefore LOs are assessed to confirm that a student has reached a certain level of knowledge and thinking skills, and is ready to shift up to the next level. For the primary level, requirements are to memorize major components of HW and basic knowledge about SW together with key engineering terms and possible application methods, and therefore the assessment method is a mini test to confirm knowledge memorization.

For the secondary level, exercise assignments will be given for confirming learners' understanding how SW and HW collaboratively work.

Regarding the undergraduate level, since it is mostly team activities such as GPBLs, the assessment will also become more group-centric. In addition, participants are requested to show their own ideas about practical applications. The requirement is to design solutions for the issues they have selected and demonstrate robots they have customized. Wireless network collaboration is another checkpoint for achieving swarm sensing coverage.

As for postgraduates, since the expected level is to become able to prepare for the prospective deployment to real disaster sites, students are expected to demonstrate that their customized robots will be able to clear the simulated disaster models they have designed with their own analysis about possible incidents.

At the completion of every level, a certificate will be issued. In addition, instructors will also be certified when they conduct a workshop.

2) Reflection of technopreneurship practices to engineering education

At SIT, authors team are seeking interdisciplinary approach to its engineering education. Among 14 classes for the Micro Electro Mechanical System (MEMS) subject, 1 is allocated to the special lecture about entrepreneurship. Its learning objective is to nurture awareness about applying MEMS technical knowledges to the products and solutions in the daily human life. While most of the students will work for companies, research institutes, or any organizations as employees rather than becoming founder of new business, entrepreneurial thinking is extremely critical because of the need of skills for solving unprecedent issues. This project progress will be included in this special lecture for enhancing the contents more practical and convincing.

4. Conclusion and next actions

The final goal of this project is "to develop and commercialize robotics toolkits, which are usually effective for engineering education for any level of learner and in an emergency deployable to disaster SAR missions, and to implement them for practical application throughout the world." This article is to clarify initial actions of the first phase as the introductory part of the entire project scope to sell these toolkits into the world market and educational scene, and present the progress and outcomes for public attention.

Outline of the ROS2-based robot toolkit and application to rescue mission are designed. Robotics Learning Roadmap is developed to show the interconnectivity between the K12, undergraduate, and postgraduate/adult levels for the purpose of streamlining lifelong learning journeys. The Japanese robot seminar series for K-12 youngsters has proved that the grade 4 students are ready to start robotics learnings regardless of preliminary knowledge. Teaching contents should be interdisciplinary including the development of entrepreneurial mind. To apply university R&D activities to disaster SAR solution, this project is going to offer practical robotics learning methods to all age levels with affordable price. When the prototype becomes ready for the pilot project and marking, test trial will be done through GPBL in the 1st quarter of 2024. Meanwhile, potential customer research will be conducted to students' parents/guardians and their teachers by leveraging customer segment analysis which derives from the questionnaire result of 20 years seminar series.

To achieve the goal for creating sustainable and scalable business, this project will be turned into a startup venture, SIT's new business lineup, or provision of intellectual properties to educational material vendors with loyalty payment. Additionally, this technopreneurship activities will be reflected to SIT's engineering education lecture.

In the course of these endeavors, collaboration will emerge with learners, educators, researchers, product developers, manufacturers, investors and other partners. For instance, we can imagine a case in which an educational institution would be welcomed to co-host GPBLs together with the authors using this robotics tool. Such efforts can also be published as international collaborative papers.

Acknowledgements:

The authors gratefully wish to thank all of SIT professors and staff who contributed the design of previous robot toolkits, as well as the participants and their parents/guardians of the seminar series. We also appreciate supports by SI Tech Co., Ltd. and Hamano Products Co., Ltd. Last but not least, we thank Dr. Ron Watson, Associate Professor of Beloit College, for adding insights for fine-tuning this article.

Reference:

[1] A. M. Dochshanov and M. Lapina, "Robotics in STEM education: A multiperspective strategy case study," *CEUR Workshop Proc.*, vol. 2494, no. May, pp. 20–23, 2019.

[2] 37–41. http://doi.org/10.1037/a0022390 Tuma, J. M., & Pratt, J. M. (1982). Clinical child psychology practice and training: A survey. \ldots of Clinical Child & Adolescent Psychology, 137(August 2012) *et al.*, "Innovations in Education and Teaching International Rethinking PhD learning incorporating communities of practice Rethinking PhD learning incorporating communities of practice," *Innov. Educ. Teach. Int.*, 2009, doi: 10.1080/14703290903069019.

[3] T. I. Anisimova, F. M. Sabirova, and O. V. Shatunova, "Formation of design and research competencies in future teachers in the framework of STEAM education," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 2, pp. 204–217, 2020, doi: 10.3991/ijet.v15i02.11537.

[4] A. Eguchi, "Educational robotics as a learning tool for promoting rich environments for active learning (REALs)," *Handb. Res. Educ. Technol. Integr. Act. Learn.*, pp. 19–47, 2015, doi: 10.4018/978-1-4666-8363-1.ch002.

[5] M. Nabeel *et al.*, "Robotics education methodology for K-12 students for enhancing skill sets prior to entering university," *2017 IEEE Int. Conf. Robot. Biomimetics, ROBIO 2017*, vol. 2018-Janua, pp. 1702–1707, 2018, doi: 10.1109/ROBIO.2017.8324663.

[6] E. Cejka, C. Rogers, and M. Portsmore, "Kindergarten robotics: Using robotics to motivate math, science, and engineering literacy in elementary school," *Int. J. Eng. Educ.*, vol. 22, no. 4, p. 711, 2006.

[7] S. Papert and I. Harel, "Situating constructionism," *constructionism*, vol. 36, no. 2, pp. 1–11, 1991.

[8] "LEGO® MINDSTORMS® | Invent a Robot | Official LEGO® Shop US." https://www.lego.com/en-us/themes/mindstorms (accessed Feb. 28, 2023).

[9] T. K. Kaiser, M. J. Begemann, T. Plattenteich, L. Schilling, G. Schildbach, and H. Hamann, "ROS2SWARM - A ROS 2 Package for Swarm Robot Behaviors," *Proc. - IEEE Int. Conf. Robot. Autom.*, pp. 6875–6881, 2022, doi: 10.1109/ICRA46639.2022.9812417.

[10] "WaterBotics." https://waterbotics.org/ (accessed Feb. 26, 2023).

[11] "RoboCupJunior – Creating a learning environment for today, fostering technological advancement for tomorrow." https://junior.robocup.org/ (accessed Feb. 26, 2023).

[12] J. Brier and lia dwi jayanti, "Poverty & Death: Disaster mortality 1996-2015 | UNDRR," vol. 21, no. 1, pp. 1–9, 2020, [Online]. Available: http://journal.um-surabaya.ac.id/index.php/JKM/article/view/2203.

[13] D. Flannery and K. Deiglmeier, "Managing the Social Social Enterprise," pp. 12–18, 2000, [Online]. Available: http://www.juma.org/content/newsAndEvents/pdf/article2.pdf.

[14] W. Jo, J. Kim, R. Wang, J. Pan, R. K. Senthilkumaran, and B.-C. Min, "SMARTmBOT: A ROS2-based Low-cost and Open-source Mobile Robot Platform," 2022, [Online]. Available: http://arxiv.org/abs/2203.08903.

[15] C. Cruz Ulloa, G. Prieto Sánchez, A. Barrientos, and J. Del Cerro, "Autonomous thermal vision robotic system for victims recognition in search and rescue missions," *Sensors*, vol. 21, no. 21, 2021, doi: 10.3390/s21217346.

[16] J. M. Cañas, E. Perdices, L. García-Pérez, and J. Fernández-Conde, "A ROS-based open tool for intelligent robotics education," *Appl. Sci.*, vol. 10, no. 21, pp. 1–20, 2020, doi: 10.3390/app10217419.

[17] A. Eguchi, "Robotics as a Learning Tool for Educational Transformation," pp. 27–34, 2014.

[18] F. E. Webster Jr and Y. Wind, "A general model for understanding organizational buying behavior," *J. Mark.*, vol. 36, no. 2, pp. 12–19, 1972.

[19] P. Kotler, K. L. Keller, P. MarkKotler, and K. L. Keller, "Marketing Management. Global Edition (Vol. 15E)." 2016.