Application of Robotics Education through the Collaborative Class between the Robot SIer Company and National Institute of Technology, Kushiro College

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This paper presents the application of education on robotics through collaborative courses jointly conducted by a robotics company and the National Institute of Technology, Kushiro College. The increasing demand for robotics engineers, driven by recent societal changes, highlights the urgent need for specialized training of robot system integrator (SIer) professionals.

Robotics is playing an increasingly vital role in addressing societal challenges, such as shortages of laborers, owing to population decline. Society needs to foster robot SIers who can apply engineering skills with a focus on robotics. Higher education institutions are actively implementing education on robotics. However, few educators possess sufficient experience with industrial robotics to deliver practical instruction. Therefore, our institution has adopted social-implementation-based education through joint classes with a local robotics company. This is unique in that it emphasizes hands-on experience in teaching tasks utilizing cooperative robots. In addition, this educational initiative stands out owing to its collaboration with a robotics SIer company. The course centers on the use of a cooperative robot. Students design robotic hands using 3D CAD software. The designed hand is manufactured using a 3D printer and can handle materials. The design concept and operation are evaluated by engineers from the local company, and students are advised on effective learning. These corporate engineers conduct evaluations and provide advice for improvement accordingly. In this paper, we discuss the details of the practical application. Our research identifies areas for improvement in current pedagogical approaches and directions for future developments.

Keywords: *education on robotics, PBL education, industrial robot, collaborative robot*

Introduction

1. Social Necessity and Situation of Industrial Robots

Japan is a well-known "robot powerhouse." According to a report titled "Trade and Industry"[1)] by the Ministry of Economy, Japan accounted for approximately 90% of the global sales volume until the 1990s. Japan was among the first countries to introduce and utilize industrial robots in factory automation, contributing significantly to the global dominance of its electronics and automobile sectors during the 1980s. China has since become the largest producer of robots globally; however, as of 2019, over 60% of its robots were manufactured by Japanese firms. The robotics industry of Japan still holds the second largest share of the global market in terms of robot shipments.

However, Japan faces a declining birth rate and an increasing shortage of production laborers owing to the substantial retirement of postwar baby boomers. Wider deployment of industrial robots is anticipated to address this labor gap. In addition, robotics is an effective means of addressing problems in industries as well as in an aging society[2)].

Although several world-class robot manufacturers exist in Japan, the diffusion of robots into small- and medium-sized manufacturing enterprises has been limited.

A significant barrier is the shortage of system integrators (SIers) who can effectively implement this technology, as also noted in the aforementioned "Trade and Industry"[1)] report.

2. Research Trends and Objectives

Several studies have addressed education on robotics. For instance, Toyama et al.[3)] implemented robotics education across academic departments. The content focused on the practice of problem-based learning (PBL) education through student group works. Sato et al.[4)] recently developed training programs for skills related to smart industrial robots, assigning students the task of autonomous robot teaching. However, to the best of our knowledge, no prior studies have reported practical applications using the equipment provided by local companies.

Therefore, we initiated robot SIer education for social implementation in FY2021 to foster robot SIer professionals[5)]. The program involved collaboration with local companies and joint classes using the robotics education facilities of these companies. In this paper, based on the experience of implementing this program, we propose a novel educational model through industry academia collaboration. In addition, we identify areas for improvement in current pedagogical methods and discuss directions for future developments.

COMPASS5.0 (Robotics Field) and Kushiro College Robot SIer Education

The Cabinet Office launched the 5th Science and Technology Basic Plan and proposed Society 5.0[6] as an ideal future society. In response, the National Institute of Technology launched COMPASS5.0[7] (Curriculum Development of Next-Generation Fundamental Technology Education) as a nationwide project for the National Institute of Technology in 2020. COMPASS5.0 comprises five fields, one of which is robotics. The Kitakyushu and Tokyo colleges are the core colleges pursuing this field. Eighteen participating colleges, including ours, are implementing this educational model.

This initiative involves the development of an educational package that combines the following five elements: (1) goal formulation, (2) curriculum, (3) syllabus, (4) material development, and (5) educational practices. This includes original initiatives that exploit the strengths of each technology college. A distinctive feature of the efforts of our institution is the robot SIer education that is provided through joint classes with a local robotics company.

Robot Education Facility and Education Schedule

1. Robot Education Facility

The local company, which supports education on robotics, leveraged its track record to open Hokkaido Robot Laboratory[8] (HRL), which is the first corporate-integrated industrial education on robotics facility in Hokkaido, in April 2022, as a solution for human resource development.

This facility was established to develop human resources for robot SIer, which is in high demand within the industrial sector, and one of the services that it offers is "classes for students using industrial robots." A distinctive feature of this initiative is that, among the various types of equipment owned, industrial parallel-link and SCARA robots are used in student classes. Figure 1 shows a student class at this facility.

2. Robotics-Related Subjects

This article describes our institution's curriculum regarding the main devices used in industrial robots.

Figure 1 Student class at
the Hokkaido Robot Laboratory facility

"System control devices" are studied in the first semester of the fifth-year undergraduate course in control engineering. "End effectors" and "safety education" are studied in the second semester of the fifth year in the "Digital Design Competition" subject (a compulsory subject with 15 lectures). This subject is introduced to fifth-year students in the field of mechanical engineering.

Other robotics-related subjects are listed in Table 1. First-year students learn the basic operation of a computer in the "Information Literacy" subject. Second-year students learn how to operate a robotic car using interactive programming in the "Basic Creative Engineering Exercises" subject. Third-year students learn how to program and run line-trace cars using PIC in the "Mechanical Engineering Experiments and

Table 1 Robotics-related subjects in the field of mechanical engineering

Grade	Subject	Contents	Classes
1	Information Literacy	Computers	6
2	Basic Creative Engineering Exercises	How to operate a robotic car using interactive programming	6
3	Mechanical Engineering Experiments and Training	How to operate line-trace cars using PIC	12
4	Composite Fusion Exercises	How to operate a robotic car using Arduino and how to handle various sensors	8
5	Control Engineering	Fundamentals of control engineering	30
5	**Digital Design Competition**	Joint classes with local companies	30

Training" subject. Fourth-year students learn how to operate a robotic car using Arduino and manage various sensors as one of the themes of the "Composite Fusion Exercises" subject. Fifth-year students learn robotics in the aforementioned "Control Engineering" and "Digital Design Competition" subjects.

Robotics Education Contents in "Digital Design Competition" Subjects

1. Schedule

The Digital Design Competition course comprised 15 classes (two school hours each). Eight of these were joint classes with a local company. The class schedules are presented in Table 2.

The first and second classes were overviews presented by the local company. They explained the environment surrounding robots, types of robots, and key points for designing end effectors. The end effector in this project is a robotic hand for transporting cups. From the third to sixth classes, students were introduced to the robotics laboratory of the local company, "HAL," for an overview of industrial robots and to gain experience in operating a robot. In addition, they formulated specifications for a robotic hand.

From the 7th to 9th classes, each student created a concept sheet for a robotic hand and designed it employing CAD. During the 10th class, each student presented a robotic hand concept. Subsequently, they selected the robotic hand to be used in machining and formed teams. During the 11th class, an engineer from the local company with expertise in designing robotic hands evaluated the robotic hands that were created by the students. This practical approach is a distinctive feature of this educational program.

During the 12th–14th classes, the created robotic hands were mounted to the collaborative robot of the institution. The students performed teaching tasks on the robot. During this process, the students acquired the relevant knowledge necessary for robot teaching, including programming. In the 15th class, a robot operation competition was organized for the teams using the robotic hand created by the students.

Table 2 Digital design competition course schedule

Class	Contents	Remarks
1st–2nd	Overview explaining key points for designing robotic hands	Joint classes
3rd–6th	Experience in operating an industrial robot	Joint classes
7th–9th	Creating a concept sheet for a robotic hand and designing it using CAD	Our institution
10th	Presenting the robotic hand concept and dividing into groups	Our institution
11th	An engineer from a local company evaluates the robotic hands created by the students	Joint classes
12th–14th	The robotic hands created will be attached to the collaborative robot, followed by robot teaching	Our institution
15th	A robot operation competition will be organized in teams using the robotic hand created by the students	Joint classes

2. Collaborative Robots

As shown in Figure 1, industrial robots must be enclosed within safety fences or other devices to separate them from the worker space completely. Therefore, small- and medium-sized enterprises with small factory floor spaces cannot easily introduce robots. However, in recent years, collaborative robots have been included as a new category of industrial robots. This is owing to the incorporation of safety functions based on the technical specifications for collaborative robots published by ISO/TS15066. Furthermore, with the issuance of a notice (Kihatu-1224 No. 2, dated December 24, 2013) and the revision of the Industrial Safety and Health Act, workers and robots can currently coexist in the same space. Thus, collaborative robots are becoming increasingly widespread in industry.

This positive impact also extends to the educational field. Academic faculties are still required to undergo a special training course of approximately three days, as stipulated in Article 36 of the Industrial Safety and Health Regulations. However, as opposed to conventional industrial robots, collaborative robots are equipped with a function that detects overload and stops the servomotor. Therefore, fences and partitions are not required (Figure 2). This facilitates the installation of collaborative robots. Collaborative robots do not require safety measures and can be operated efficiently. For this reason, cooperative robots are suitable for use in educational settings.

Figure 2 Collaborative robot installed at our institution

3. Robotic Hand Production Project for 2023

In 2023, a project was launched to create a robotic hand that can transport paper cups. The robotic hand is operated by an actuator using air pressure. Details of the project are shown in Table 2. Company engineers directly presented an overview and discussed issues surrounding industrial robots with the students. Subsequently, students were trained on how to operate industrial robots in the robotics laboratory of the company (Figure 1).

Thereafter, each student designed a robotic hand using CAD (Figure 3). During the design process, company engineers provided online support to students to update their progress and address any questions regarding assignments.

The deliverables were a concept document and CAD model, which were evaluated using the evaluation criteria presented in Table 3 that were prepared by company engineers.

After selecting four or five robotic hands from the completed CAD models for production, the robotic hands were modeled using a 3D printer. We actively selected new structures that did not exist in previous years.

The created hand was attached to an industrial robot, and a performance test was conducted (Figure 4). At this point, the obtained results could be predetermined when the created hand moved an object. Changing the picking speed of an object could result in it being missed or the robotic hand breaking. Students were surprised when they witnessed this. Thus, we could infer the possibility of achieving educational benefits from a student perspective.

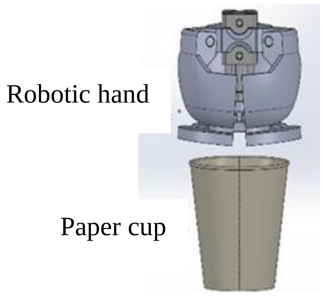

Figure 3 End effector (robotic hand) and transported object (paper cup)

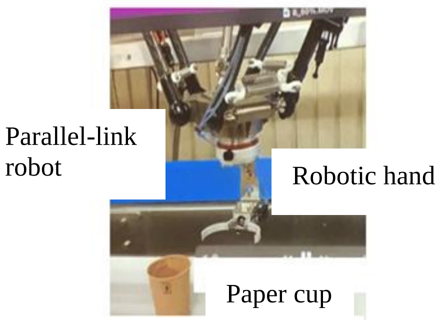

Figure 4 Robotic hand created by a student using a printer attached to a parallel-link-type industrial robot

Table 3 Robotic hand evaluation criteria

Items	**Points**		**Evaluation contents**
Restrictive	30		Gripping strength is the most important factor
Concept	20		Emphasis on thought process
Submission deadline	20		Delivery dates are important to companies
Others	30		“Others” are as follows:
-Accuracy		5	No interference during operation
-Strength		5	Durability after repeated operations
-Practicality		5	Realism
-Versatility		5	No restrictions on grip
-Design		5	Good appearance, functionality, and creativity
-Challenging		5	Proactive and open to new challenges
Total	**100**		

4. Robotic Hand Production Project for 2024

Nikko Co., Ltd., a local company with which we have been conducting joint classes, is primarily involved in the manufacturing of robots for transporting food such as seafood and vegetables. By 2024, chicken wings were transported instead of paper cups. Because handling raw meat in class was not realistic, we used models made from paper clay (Figure 5). However, as opposed to paper cups, each food item has different dimensions. To retain the characteristics that rendered transportation challenging, models with variations of several millimeters were used. Therefore, a hand that can accommodate variations in the shape of a target object should be developed.

Students could choose between swing- or piston-type pneumatic actuators to move the robotic hand. The flow of the assignment was the same as that in 2023, in that the design was created using CAD, evaluated by company engineers, manufactured using a 3D printer (Figure 6), and attached to an industrial robot for testing. The difference was in the type of robot used. Unlike the previous year, the introduction of a collaborative robot (Figure 2) allowed students to assist easily with robot-teaching tasks. As a result, students could safely conduct direct robot teaching (Figure 7). This made learning about robotic operations more in-depth than that in the previous year. The robot program is illustrated in Figure 8.

Figure 5 Chicken wing model made from paper clay

Figure 6 Creating a robotic hand for transporting chicken wings

Figure 7 Direct robot teaching

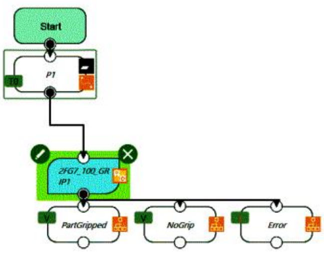

Figure 8 Example of robot teaching data

Issues and Future Prospects

Areas for improvement become noticeable when implementing robot SIer education in collaboration with local companies. A major challenge associated with robotic hand design is insufficient time. Even if company engineers identify flaws in students' work from a professional perspective, they cannot take measures to improve the robotic hand. Consequently, students may not feel a sense of accomplishment. The suggestions of the company engineers are reflected in the design and improvements are made to reproduce the product. This will hopefully further improve the ability of the company to render the product usable. One means of achieving this would be to task students with assignments related to design modifications outside of class time.

Through the initiative described in this paper, the teaching materials were almost completed. Awareness of robotics technology can be further enhanced by utilizing them in events of the institution (such as experience classes in College Festival and Open-College).

As a future effort, we will conduct a survey on the types of skills (e.g., technical, practical, and problem-solving skills and attitude changes) acquired by the students obtained. This should validate the effectiveness of the education.

It is important to attempt to visualize the education by quantitatively evaluating the satisfaction of students and corporate engineers. Therefore, after the survey, we will review the evaluation criteria for the robotic hands.

Improved teaching materials, as well as revised evaluation criteria, will be subject to an additional questionnaire survey. This will allow for further revision and improvement of the teaching materials in the following year. Thus, longitudinal tracking of educational effectiveness is important.

Conclusions

The current labor shortage has increased the demand for the widespread operation of robots. Therefore, training robot SIer engineers who can implement system integration in industrial contexts is imperative. The presented initiative is unique in that education on robotics is held in collaboration with a local food processing machinery company.

Social implementation has gained significance recently, and engineers with expertise in production systems that incorporate robots evaluate the student-designed robotic hands. Furthermore, these robotic hands are mounted to industrial robots and tested in realistic conditions, rendering this course highly practical. As opposed to evaluations that are conducted solely by an academic faculty, assessments conducted by experienced engineers provide students with more credible and application-oriented feedback. This collaboration significantly enhances the educational experience and introduces professional rigor that is rarely found in traditional classrooms. The course is structured as a PBL-style exercise, in which students are assigned engineering tasks that are subsequently examined from multiple perspectives to address a specific problem. Through this experience, students gain exposure to both the technological competencies and business operations of the partner company. We aim to continue to leverage this collaborative environment and improve our educational materials further.

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