ELEMENTS OF CDIO IN GRADUATION RESEARCH PROJECT UNDER UNIVERSITY-INDUSTRY COLLABORATION

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ABSTRACT

Most Japanese students in Engineering College collect class credits before junior year ends and intensively focus only on the graduation research project in senior year. Each student researches an independent project theme while being aided by a professor. The volume and level of a graduation thesis is less than those of a master's or doctoral thesis. However, it is sure to originally include the essential elements of "conceive", "design", and "implement." This paper records students' and working professionals' (company employees') participation in a university-industry collaboration system as graduation research project. The observations were made when the authors of the paper worked in the laboratory of one such participating university. In particular, our observations showed that such participation had a positive effect on the skills and basic knowledge of working professionals attending university lectures as part of their company's project participation, allowing them to learn alongside students in university. The several-time classes aided them in improving their skills and basic knowledge and enabled them to keep up with scientific and technological advancements. Moreover, this paper applies a CDIO based perspective to university-industry collaboration projects to demonstrate how the element of "operate" plays an important role in such projects by allowing participants to consider the practical and applicatory aspects of the research results.

KEYWORDS

CDIO, university-industry collaboration, graduation research project, credited auditor, co-educated working professional, Standards: 1, 2, 3, 5, 6, 7, 8

INTRODUCTION

The usual period of study at a Japanese university is about four years. During senior year of university, all students are typically engaged in the graduation research project. In particular, most students in Engineering College collect class credits before junior year ends and intensively focus only on the graduation research project in senior year. That is, the place of their main activity changes from the classroom to the laboratory. This project based learning is a culmination of undergraduate education. Each student researches an independent project theme while being aided by a professor. For example, about ten students are assigned to each laboratory at our university, the Kanazawa Institute of Technology (KIT).

A rough schedule detailing the graduation research project activities is shown in Table 1. The process begins in April, when a professor proposes some potential research topics to the students. Each student selects an interesting theme from among the options provided. After understanding the purpose of his/her own research, the student plans the research scheme from May to June. In order to learn more about the background of the topic of research, the students survey past literature related to the subject. Next, the students conduct investigations, experiments, or analyses from July to December. Thereafter, the acquired data are compared in the period spanning from November to December, and a conclusion is reached. Students then prepare an abstract for their research in January. A presentation, which is open to all university members and other persons as public, is conducted, and the report is finalized in February. The volume and level of a graduation thesis is less than those of a master's or doctoral thesis. However, it is sure to originally include the essential elements of conceive, design, and implement.

Table 1. Graduation research project schedule

Month	Student Activity	Element of CDIO
April	Student is officially assigned to a laboratory.	-
	Project themes are introduced by a professor.	Conceive
	Each student selects a project theme based on his or her own interest.	
May ~ June	The purpose of the project is recognized.	
	A schedule is drafted.	Design
	Related literature is surveyed, and elementary knowledge is reviewed to form an understanding of the problem.	
July ~ Dec.	Research activities are promoted. (investigation, experimentation, analysis, discussion, evaluation, verification, etc.)	Implement
	The experiments and research of other students are supported, and students use them to contribute to their own research.	
	The student, professor, and any other project participants gather to discuss about results.	
Jan. ~ Feb.	The research is reported, and the findings are presented to everybody in university.	
March	The students graduate.	-

This paper explains how the element of "operation" also plays a major role in graduation research projects executed under the university-industry collaboration system. Moreover, such projects introduce a new system where a working professional or company worker learns alongside students in a classroom, thus providing professionals from different industries with a chance to participate in graduation research projects. A description of this paper is promoted about not a special examination by each department but a whole university. Therefore, a case in Civil and Environmental Engineering Department to which one of authors belongs is shown in first half. On the other hand, a case in Robotics Department to which another author belongs is shown in latter half.

UNIVERSITY-INDUSTRY COLLABORATION AND GRADUATION RESEARCH PROJECTS

Various university-industry collaboration research projects have been conducted in Japan as well as other countries [1]. There has been a case where the company engineer conducted experiments by himself, without any student participation, while consulting a professor and using the university's equipment. On the other hand, there has also been a case where there was partial university-industry collaboration, which advanced the graduation research of a student [2]. In the Miyazato laboratory (one of the authors of this paper), the graduation research projects were executed through various university-industry collaborations, as shown in Table 2.

Table 2. Graduation research projects at Miyazato Laboratory in 2017

Student	Title	Type of cooperation
F. R.	Evaluation of corrosion of galvanized rebar in concrete	Research group of engineering society
G. Y.	Influence of curing humidity and aggregate kind on concrete shrinkage	Cooperation with private company
K. S.	Evaluation of mechanical performance of pre-stressed concrete beam with composite deterioration	National project (SIP) [4]
N. Y.	Development of an inspection method for corrosion cracks in concrete	Cooperation with some universities under JST foundation
O. R.	Proposal of a new measurement method for chloride ingress in concrete	Research group of engineering society
T. Y.	Clarification of chloride penetration phenomenon in concrete under changing environmental actions	National project (SIP) [4]
T. T.	Feasibility study for application of thermoplastic FRP rod in infrastructure	National project (COI) [3]
Y. K.	Prediction of repair effect on reinforced concrete after patch repair	Cooperation with private company

The Center of Innovation program (COI) has been promoted as a national project for nine years since 2013 [3]. In addition, Cross-ministerial Strategic Innovation Promotion Program (SIP) has been promoted for five years from 2014 onward [4]. As part of these research projects, teams consisting of two or more universities propose a project plan for the public and advertise it in order to gain the government's support and funding. On the other hand, in the case of Grant-in-Aid for Scientific Research, the individual or some professors propose a plan that contributes to scientific and technological development, and the subvention is provided from government funds. In either case, after adoption, the plans are studied as part of graduation research projects.

Additionally, research that the company originally developed can also be executed through university-industry collaboration. Table 3 shows the ranking of trust research costs in 2016 at Japanese universities that employed this system of graduation research projects.

This type of research usually commences with a company engineer requesting the cooperation of a professor. The course of research proceeds smoothly if the engineer knows the professor. In addition, this is studied as part of a graduation research project.

Table 3. Example of trust research costs taken on by university-company partnerships [5]

Rank	University	Cost（thousand yen / professor）
1	Nagoya Institute of Technology	1,506
2	Toyota Technological Institute	1,413
3	Nagaoka University of Technology	1,092
4	Tokyo Institute of Technology	1,087
5	Gifu Pharmaceutical University	1,042
6	Toyohashi University of Technology	1,004
7	Kyoto University	880
8	Tohoku University	825
9	Yamagata University	807
10	St. Luke's International University	783
11	The University of Tokyo	772
12	Tokyo University of Agriculture and Technology	768
13	Kyushu Institute of Technology	766
14	Osaka University	744
15	Keio University	716
16	Chiba Institute of Technology	703
17	Kanazawa Institute of Technology	655

However, if the company engineer does not know a specialist with a lot of knowhow, which relates to the technology that the company wants to develop, the project cannot begin. In such cases, a coordinator plays an active role in matching the company to an appropriate university. When the company requests our university’s participation, the coordinator, who belongs to the research development division, introduces the company representative to a suitable professor. However, the coordinator responds to any inquires or requests by the engineer for recommendations of other potential universities. This usually happens when the specialty or professor with the technology which the company is interested in is not a part of our university. On the other hand, the start of a collaboration research project might be difficult for the company even if the specialist or professor is a member of our university. This can happen, for example, in cases where the coordinator presents the results to the company after obtaining detailed research plans from the selected professor, but an employee without the required knowledge and skills is in charge of development and so cannot grasp the information provided by the coordinator. As a result, the university-industry collaboration research does not succeed. The research is likely to be defeated at global competitions if the relevant technological development cannot advance because of such circumstances, especially in the present age when innovation is necessary.

NEW SYSTEM FOR WORKING PROFESSIONAL PARTICIPATION IN SEVERAL-TIME CLASSES

Young people aged 18-20 years old form 98% of students entering college after finishing high school [6]. Very few Japanese college entrants are over 25 years old compared with other countries as shown in Figure 1. That is, Japan lacks an educational culture that encourages people who are over 20 years of age to enter or return to university. Therefore, for a working professional attempting to learn a new skill or supplementing an insufficient skill, there are very few opportunities to study to university and update their skills until now, there were no sufficient opportunities to study at university for corporate workers interested in updating their knowledge and skills; however, under the university-industry collaboration research project, situations such as the one described in previous Section of this paper are becoming more common. Therefore, up until recently, the company worker had to study by him/herself, while reading textbooks and participating in seminars. As a result, many people were not able to gain the confidence required for acquiring knowledge or failed in their attempts to do so.

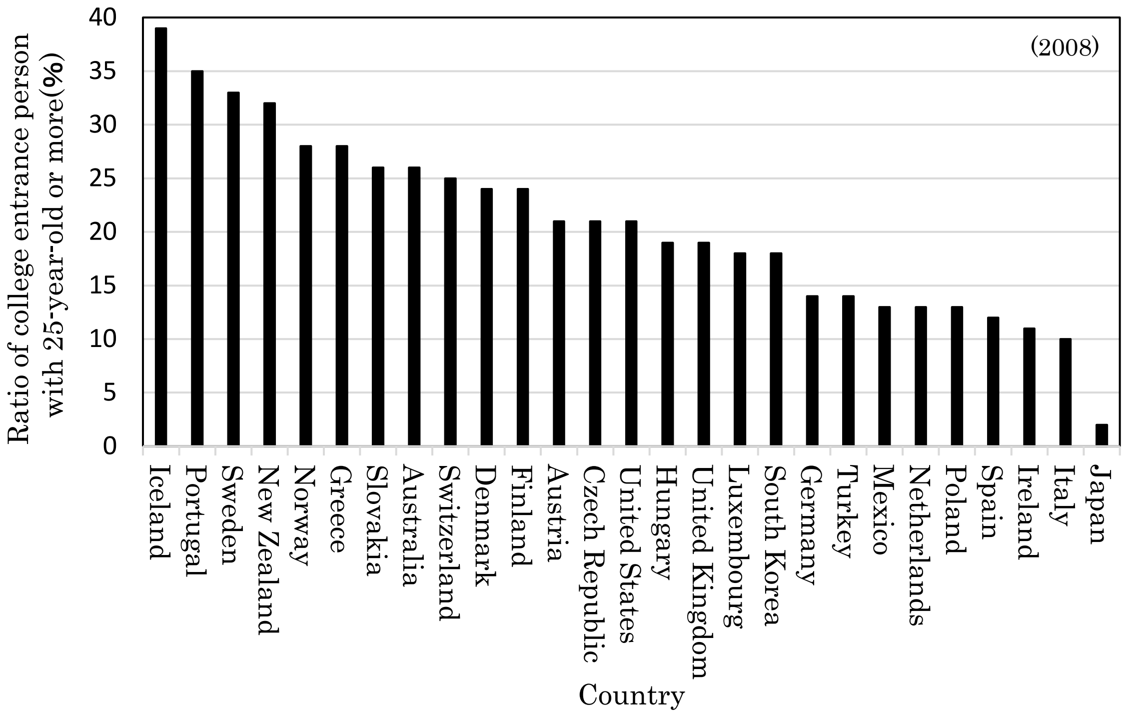

Figure 1. Ratio of college entrants aged 25 years old or more [reference to 7]

To improve the above-mentioned bad situation, it is desirable that the working professional with a clear learning objective need attend university only for necessary lectures in the relevant subject. In this context, working professionals from the company are expected to acquire basic knowledge and skills not only for the purpose of promotion of the university-industry collaboration but also the acquisition of qualifications and the expansion of business content for the company. As shown in Table 4, KIT established a new system that enabled working professionals to participate in only several-time classes after 2016, in addition to a past system of credited auditors. In the current system, 16 lectures and practices are composed for the subject intended for such university students each semester. Those who participate in all the classes and pass the required examination can gain all the required credits. Working professionals who apply for this course may participate in the selected course out of interest in all the modules of the relevant subject. However, with regard to the above mentioned university-industry collaboration, working professionals are usually only interested in classes that will help them supplement their lack of basic knowledge. In 2016, 96 working professionals participated in the 32 subject using this new system. The attendance of such persons at relevant subject lectures was excellent even though their original level of basic knowledge were low. In addition, as shown in Figure 2, working professionals who participated in several-time classes acquired the basic knowledge necessary for keeping up with technological advancements. Additionally, a mentoring relationship (trust relation) was built between working professionals and professors.

Table 4 Type of class participation among working professionals in KIT

System	Type	Content
Current	Credited auditors	If the student passes an examination and produces a report they pass. Additionally, they receive the same credits as normal students after participation in all classes. In such cases, the credited auditor students can gain all the required credits.
New	Co-educated working professional	These students have little interaction with fellow students and very little participation in the classroom. Even if they pass the examination and submit the report, they cannot gain a credit.

Primitively, the credited auditors are suitable. The participant might have been perplexed because the system was new. However, when various generations acted in the group, the discussion offered students a good educative effect.

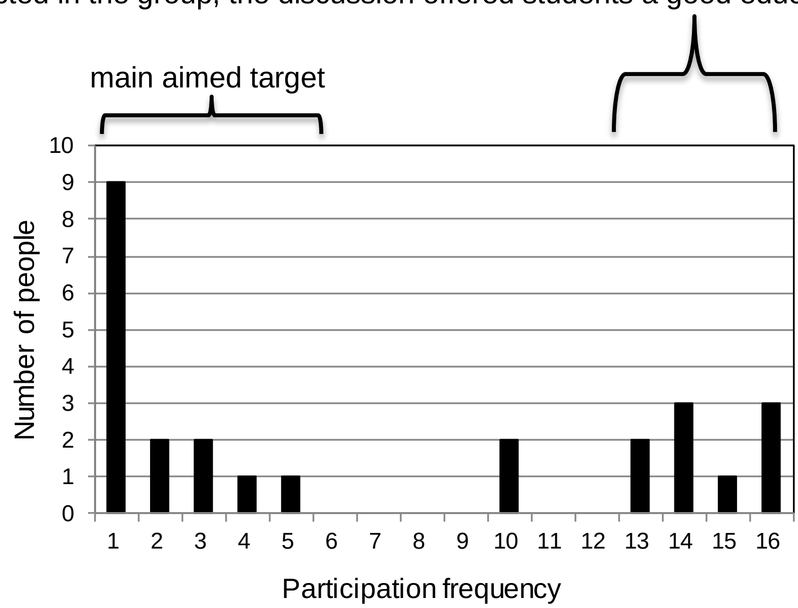

Figure 2. Number of times classes were attended by co-educated working professionals

EXAMPLES OF CO-EDUCATED WORKING PROFESSIONAL PARTICIPATION IN UNIVERSITY-INDUSTRY COLLABORATION RESEARCH PROJECTS

There are cases where projects initiated under the university-industry collaboration research system and involving the participation of co-educated working professionals have become the focus of university students' graduation research. This section introduces one such advanced example.

Our university is located 24 km from a mechanical design company. In autumn 2015, the president of the company visited the university and consulted us about the possibility of collaborating on a technological development project under the university-industry collaboration system. As a result, they realized that there was a gap between the employees' knowledge and the expertise required for the research. Therefore, it was decided that employees would utilize the co-educated working professional system and have supplementary lessons to identify and supplement any insufficient knowledge and skills. As a result, in 2016, two employees attended lectures for two subjects (“system mathematics” and “control engineering”), which were among required subjects for second graders of the Robotics Department. One student was a man in his forties who graduated from the Electric Engineering Department in KIT. The other student was a woman in her twenties who found employment after she finished high school, without entering any university. They occupied the most front seats in the classroom. Moreover, their submitted reports included the solutions to many exercises. The preparation and review were carried out for about 1-2 hours in the weekday mornings and on weekends. Their efforts led to excellent results. The evaluation provided by their lecturer, the associate professor Kawai, was also high. Therefore, the commencement time of the joint research project was adjusted.

The contract for a joint research was concluded in the following year, 2017. This technological development research became the graduation research project of a senior student in Doi laboratory (one of the authors of this paper). The theme of the project was “development of universal controller for conveyer robot arms.” That is, software development and control of real machines with regard to the development of a robotic arm were investigated, studied, and researched. The woman working professional visited Doi laboratory every Friday and participated in the experiments and seminars. This was possible thanks to the well-appointed equipment and laboratory at the university. Moreover, the study and research were advanced because of an environment that facilitated quick responses from and communications between members who were engaged in joint action. The female working professional worked on the development of the controller for the model robot arm (image shown in Figure 3) in cooperation with the senior student while utilizing the knowledge acquired as a co-educated working professional under the professor’s guidance. They operated on graphics and controlled a real machine that synchronized with it, while actually experiencing “Conceive-Design-Implement,” as shown in Table 5. Finally, they were able to make the visible pilot-type. She was able to acquire basic knowledge of mathematics, physics, and software through this activity because she was able to understand how to use the required software and tools for controlling the robotic arm. Moreover, when the robotic arm was controlled, the transportation function of the object, which was needed in operation at the company, was implemented with an obstacle avoidance mechanism, and its effectiveness was verified. That is, the element of “Operate” was included along with “CDI” in the student's graduation research project, as well as a literature [8]. In the future, we plan to develop a Graphical User Interface (GUI) for the robotic arm that will be able to utilize a web browser. The demand for such technology has increased in many industries. Moreover, the developed software will apply the technology utilized in the robotic arm owned by the department. They enable and promote talented researchers and developers, and they aid in producing useful technology for use in society.

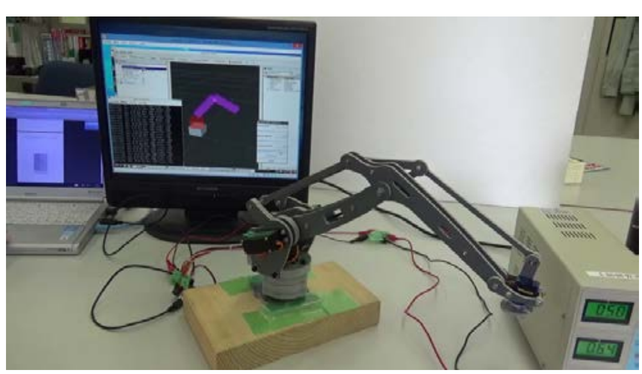

Figure 3. Synchronous movement of the robotic arm and simulator using Robot Operating System (ROS) (https://youtu.be/HrmcG7ollAI)

Table 5. Element of CDIO included in graduation research project

<table>
<tr><th>Element</th><th colspan="3">Activity</th></tr>
<tr><td>Conceive</td><td colspan="3">After various research problems had been examined closely, the investigative purpose was constructed.</td></tr>
<tr><td>Design</td><td>The method for clarifying the problem was planned.</td><td rowspan="2">→</td><td rowspan="2">If necessary, re-design and re-implement.</td></tr>
<tr><td>Implement</td><td>The prototype was made through a process of experimentation and analysis.</td></tr>
<tr><td>Operate</td><td colspan="3">The practicality of the machine was verified.</td></tr>
</table>

SUMMARY

The purpose of the CDIO initiative is to enable student studies to take on an important perspective that is necessary to renew engineering education, which has been biased toward knowledge acquisition rather than implementation of research findings in actual society. At Japanese university, the graduation research project functions as a culmination of undergraduate education. This special project originally contained the elements of “Conceive-Design-Implement.” In addition, Table 6 has shown how such research can also feature the inclusion of the element of “Operate” when the graduation research is performed as part of a university-industry collaboration project, under reference to [9] and [10]. Therefore, it is fitting that in the future, the university-industry collaboration research will be increased in order to feature all elements of “CDIO” in the graduation research project. Alternatively, CDIO makes it necessary to always verify the possibility of practical use of a project’s result because the element of “operation” is also considered.

Table 6. Link between experience by students working on industry related project and CDIO standards

Standard	1	2	3	5	6	7	8
Scale checked by ourselves	4	3	5	5	5	4	4
Originally included to graduation research project		+		+	+	+	+
Effect of university-industry collaboration research project	+		+				
Check by this paper	+	+	+	+		+	+

Moreover, to promote this kind of university-industry collaboration based research, a new system was established which enabled working professionals to participate in several-times classes as a chance to acquire basic knowledge and skills in areas where they are deficient. This paper also introduced a case that became the graduation research project of the participating student while the company employee who had participated in this system helped to promote the university-industry collaboration research.

Studying these projects from a CDIO based perspective can produce insights with regard to the educative effect for students working on industry related project in the context of students’ learning and experience, improvements in the knowledge. Also abilities of working professionals from the partner companies, and the potential profit or benefits of such arrangements for participating companies can be confirmed. Further research can be conducted in the future to focus on these areas.

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