# Bringing CDIO to Japan

**Anastasia Rynearson[1], Robert Songer[2]**

1. Kanazawa Technical College, Kanazawa, Japan arynearson@neptune.kanazawa-it.ac.jp
2. Kanazawa Technical College, Kanazawa, Japan rsonger@neptune.kanazawa-it.ac.jp

**Abstract**

Japan's higher education system has been undergoing a transformation since the 1990s. Pressure from the government, society, industrial globalization, and other factors are causing universities to re-evaluate how they educate their students. Globally, many of these factors are also at play, and institutions worldwide have been considering the same reforms. Some engineering universities have banded together to create an educational framework, Conceive – Design – Implement – Operate, or CDIO, as a response to the global call for better engineering graduates. In 2010 the first Japanese organization, Kanazawa Technical College, joined CDIO as a Collaborator, recognizing the need for change and the ability of CDIO to meet that need. Comparing the ideals of a CDIO-based program with JABEE requirements, it is found that they are highly similar, and that following CDIO meets many of the desires of Japanese industry today. CDIO would be beneficial for all Japanese institutions of higher learning.

*Keywords: CDIO, hands-on, global engineering education, engineering education reform*

## 1. Background

Japan has long built its industrial strength on manufacturing. As the world changes, manufacturing is cheaper elsewhere and the greater human capital is the ability to design and create ideas rather than things. As developed countries struggle to compete on a global level, Japan has arguably greater hurdles to face due to a shrinking population and fewer technical graduates [1]. In order to compete in the global arena, Japan must focus on more technical professions and produce graduates who are not only able to flourish in Japanese industry but also in the global industrial sector [2]. The ability of graduates hinges upon the institutions that educate them; Japanese universities have a large responsibility to their students and their country to teach in the best possible manner.

## 2. Conceive – Design – Implement – Operate: CDIO

The CDIO Initiative is a worldwide organization with over 50 member institutionsin over 25 countries. This organization is made up of universities and other institutions of higher education that want to create better graduates, with not only deep learning of disciplinary knowledge but also personal and interpersonal skills that employers desire. CDIO is based on the premise that professional engineers, at the most basic level, "Conceive – Design – Implement – Operate complex value-added engineering products and systems in modern team-based environments"[3]. The three main goals of CDIO are to:

- Educate students to master a *deeper working knowledge* of the technical fundamentals
- Educate engineers to lead in the *creation and operation* of new products and systems
- Educate future researchers to understand the importance and *strategic value* of their work [3]

To assist in meeting these goals, CDIO advocates teaching and learning reform, focusing on hands-on active learning. Students are asked to not only solve closed-form problems demonstrating their ability to use engineering thinking and equations, but also to formulate and consider open-ended problems that do not have a single correct answer. Rather than being able to memorize basic facts or utilize equations correctly for an exam, students are asked to understand the underlying concepts and ideas, moving past the lower levels of Bloom's Taxonomy, knowledge and comprehension, and into the upper reaches of application, analysis, synthesis, and evaluation [4]. In addition to expectations regarding students, educators are expected to find new and innovative ways to assess what their students have learned and to gather feedback regarding classroom techniques and student abilities in order to find better ways to teach what their students must learn.

CDIO encourages educators to not only utilize proven methods of teaching students but also to research and attempt new ways to promote learning of disciplinary skills as well as the personal and interpersonal skills that are increasingly sought after by industry. The aim of all educators should be to provide their students with the best possible education, and CDIO has brought together engineering educators to work towards finding the best practices for modern engineering education.

## 3. Adoption of CDIO at Kanazawa Technical College

Before embarking upon an educational reform program, the first step is to assess the desirability of the planned changes. As with any project in the engineering disciplines, a critical look at existing conditions from the perspective of the customer gives the best indication of where to start. When the product of one's labor is engineering graduates, the customers are the graduates themselves in addition to the industries who employ them. Kanazawa Technical College (KTC) performs a survey every five years in an attempt to understand the quality of graduates being produced. This survey is given to employers of KTC graduates as well as alumni who have graduated since the previous survey was given. The survey data acquired for the purpose of this analysis includes the alumni's perceptions on the necessity of specified skills and attributes, their self-evaluation of their ability to satisfy that need at their time of hire, the reported level of need from industry for the specified skills, and industry's perception of the ability of KTC alumni to satisfy the required need. 21 items were assessed in 2004 with one additional item added in the 2009 survey [5, 6, 7, 8]. The alumni survey in 2009 omitted questions about the perceived requirements and instead only inquired about capabilities. Figure 1 shows the results on a scale of 0.0 to 3.0 with 0.0 indicating an unnecessary skill or attribute/unsatisfied requirement and 3.0 indicating a highly necessary skill or attribute/completely satisfied requirement.

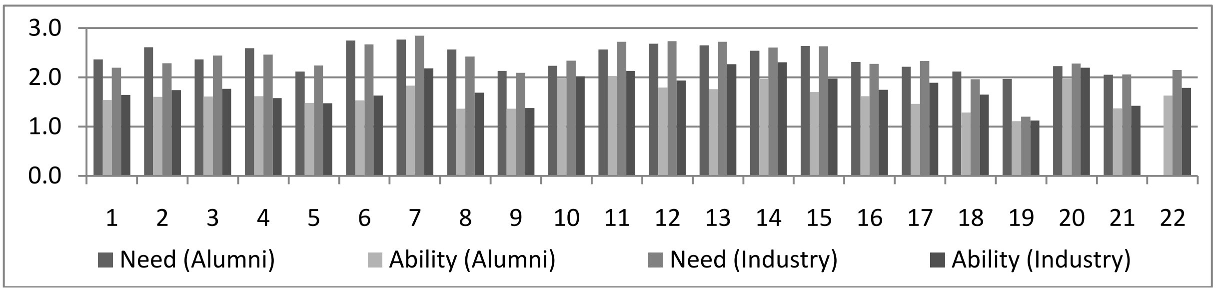


**Figure 1: Averaged results of alumni and industry surveys from 2004 and 2009**

Results of the survey show a considerable difference between the need for graduates to have these skills and their ability to satisfy each one upon graduation. The largest difference between need and ability from both alumni and industry perspectives can be seen in item 6, the ability to work autonomously. Conversely, the items in which need and ability are most evenly matched is number 20, functional computer and internet skills, followed by number 10, the ability to see things from another person's perspective. The most notable observation, however, is that no single ability rating surpasses the expressed need. Using this scale, a need may be fully satisfied but considered unnecessary; the lack of such results raises some important questions about education quality.

In order to determine where to focus educational reforms based on the CDIO framework, a comparison of the existing measurements of skills and attributes should be compared to those outlined by the CDIO Syllabus. For this purpose, all of the survey questions have been mapped to the second level subheadings of the CDIO Syllabus as shown in Table 1 alongside a list of the skills and attributes surveyed. Elements regarding disciplinary knowledge have been omitted for the purposes of this study.

**Table 1: Correlation of survey items to the CDIO Syllabus with list of surveyed skills and attributes**

| CDIO Syllabus | Survey Items | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 2.1Engineering Reasoning and Problem Solving | | | ■ | | | | | | | | | | | | | | | □ | | | | |
| 2.2 Experimentation and Knowledge Discovery | ■ | ■ | | | ■ | | | | | | | | | | | | | | | | | |
| 2.3 System Thinking | | | | □ | | | | | | | □ | | | | | | | | | | | |
| 2.4 Personal Skills and Attributes | | | | □ | | ■ | | | | | ■ | ■ | ■ | | ■ | | | | | | | |
| 2.5 Professional Skills and Attitudes | | | | | | | | | | □ | | | | □ | | | | | | | ■ | |
| 3.1Teamwork | | | | | | | □ | | ■ | □ | | | | | | | | | | | | |
| 3.2 Communication | | | | | | | ■ | ■ | | | | | | | | | | | | | | |
| 3.3 Communications in Foreign Languages | | | | | | | | | | | | | | | | | | | ■ | | | |
| 4.1 External and Societal Context | | | | | | | | | | | | | | | | ■ | | | | | | ■ |
| 4.2 Enterprise and Business Context | | | | | | | | | | | | | | | | | | | | | | |
| 4.3 Conceiving and Engineering Systems | | | | | | | | | | | | | | | | | | | | | | |
| 4.4 Designing | | | | | | | | | | | | | | | | | | | | | | |
| 4.5 Implementing | | | | | | | | | | | | | | | | | | | | | | |
| 4.6 Operating | | | | | | | | | | | | | | | | | | | | | | |
| ■ Strong Correlation □ Weak Correlation | | | | | | | | | | | | | | | | | | | | | | |

1.) Ability to gather information from a wide range of sources
2.) Ability to organize collected data
3.) Ability to think about matters logically
4.) Ability to perceive a single situation from multiple perspectives
5.) Ability to form a hypothesis to aide in task resolution
6.) Autonomous regulation of one's conduct for the purpose of task resolution
7.) Ability to communicate in a cooperative and mutually creative way
8.) Ability to summarize and express one's opinion easily
9.) Ability to gather a group and lead towards a desired goal
10.) Open-mindedness for thinking from another person's standpoint
11.) Intellectual curiosity for new knowledge and skills
12.) Vigor for always taking on a new challenge
13.) Diligence in keeping a steadfast perseverance
14.) Integrity towards peers
15.) Basic common knowledge and social etiquette as a member of society
16.) Self-awareness of a personal responsibility to society as an engineer
17.) Basic knowledge and skill in one's specialized field of study
18.) Socially applicable, practical knowledge and skill
19.) International communication ability in reading and writing foreign languages
20.) Functional ability to use computers and the Internet
21.) Personal intent of a future career plan and an approach towards self-fulfillment
22.) Shared values that should concern an engineer (like safety), as well as decision-making and behavior based on these values

The first notable details are the lack of survey questions regarding a graduate's knowledge in the engineering business context or skill with system conception, design, implementation, and operation. As professionals entering industry upon graduation with the equivalent of an Associate's degree from a technical college, it is understandable that not all students will work at a job with duties that require skill or knowledge in each of these categories. Many companies might never expect a new graduate to understand system design, for example, until after considerable industry experience has been acquired. In such a strictly hierarchical society, responsibility for following an engineering project in its entirety from start to finishis often only expected of senior team members. Nevertheless, it cannot be assumed that a need does not exist simply because it isn't questioned.

Other important observations can be seen by comparing the CDIO syllabus to the survey from a slightly higher level. In particular, it can be seen that out of all the elements within the interpersonal skills section of the CDIO Syllabus, the skills most poorly rated in terms of ability over need are those that correlate strongly to communication. Furthermore, the results for each question pertaining to the personal and professional skills and attributes section (such as motivation, intellectual curiosity, and common knowledge) reveal a strong need from industry that is going unmet.

Other surveys from across Japan indicate that this trend in desirable attributes for new graduates exists at a national level. The Nikkei Job Search Navi Editorial Department (in Japanese, 日経就職ナビ編集部) surveyed 100 of the most popular companies among job seeking graduates and asked the question "Which traits are given the most consideration when screening employment applicants?" Of the 68 companies to respond, an overwhelming 73.5% of them selected "communication ability" with "initiative" following at 45.6%, "enthusiasm" at 36.8% and "cooperation" at 20.6%. These most desirable traits for new hires align with the expressed needs for communication skills, motivation, and teamwork ability among the KTC survey results. Additionally, the Japan Business Foundation (in Japanese, 社団法人日本経済団体連合会) administers an annual questionnaire which asks companies about the factors given the most consideration when screening applicants. The 2010 results show "communication ability" to be the most desirable at 81.5% with a steady rise each year from 50.5% in 2001. This is significant compared to the results for "independence", "cooperation" and "challenging spirit" which have each fluctuated between 40% to 60% over the past ten years [9]. This data shows both a consistent and growing desire within Japanese industries for personal and interpersonal skills in new graduate hires. The research leading to the creation of the CDIO framework has taken similar global trends into account and integrated the results into a syllabus in which two out of the four primary elements do not concern technical skills but rather interpersonal ones.

## 4. Cultural Hurdles

For any reform, there are obstacles one must face. The most common instructional method in Japan is lecture, with assessments at the lower levels of recall and understanding. The Japanese consistently have very high scores in standardized tests, where memorization is key, but generally do not excel at open-ended problems [10]. CDIO advocates moving past knowledge and understanding into analysis, synthesis, and evaluation, which is difficult for students who have spent the majority of their educational careers without consideration for these deeper levels of cognition. It is difficult as well for educators who have not previously considered alternative methods of teaching and assessment. In addition, higher education in Japan is typically the proving grounds for a student's adaptability and potential to grow into what a company requires of its employees. Japanese industry historically has been one of lifelong employment, starting at the very bottom and working one's way up in seniority in nearly every case. Under this system, companies have been less interested in what a new hire has learned at university and more interested in the level of aptitude for learning. Traditionally, a student who passes the entrance exams to a prestigious university is set for life, and in some cases that is still the truth today. However, industry is changing and lifetime employment at a single company is becoming a thing of the past, rendering the previous hiring methodologies obsolete [2].

## 5. CDIO vs. JABEE

In Japan, higher education has long been overseen by the government. In the 1990s, Japan began allowing institutions more autonomy to educate their students in whatever manner they saw fit rather than by strict governmental control [10]. There was no accreditation outside of government accreditation until 2001, when the Japan Accreditation Board for Engineering Education, JABEE, began accrediting institutions, finalizing their criteria on November 25, 2003 [11]. As signatories of the Washington Accord, JABEE has similar standards to many other accrediting bodies such as the US-based Accreditation Board of Engineering and Technology, ABET [12]. The main CDIO documents, the Syllabus and 12 Standards, were made with ABET's criteria for accreditation in mind, and contain many of the same aspects as JABEE's criteria.

**Table 2: CDIO Syllabus vs. JABEE Criterion 1**

| CDIO Syllabus | JABEE 2009 Criterion 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h |
| 1.1 Knowledge of Underlying Science | | | ● | | ● | | | |
| 1.2 Core Engineering Fundamentals | | | ○ | ○ | ● | | | |
| 1.3 Advanced Engineering Fundamental Knowledge | | | | ● | ● | | | |
| 2.1 Engineering Reasoning and Problem Solving | | | | ● | ● | | | |
| 2.2 Experimentation and Knowledge Discovery | | | | | | | | |
| 2.3 System Thinking | | | | | ○ | | | |
| 2.4 Personal Skills and Attitudes | | | | | | | ● | |
| 2.5 Professional Skills and Attitudes | | ● | | | | ○ | | ○ |
| 3.1 Multi-disciplinary Teamwork | | | | | | | | |
| 3.2 Communications | | | | | | ● | | |
| 3.3 Communications in Foreign Languages | | | | | | ● | | |
| 4.1 External and Societal Context | ● | ● | | | | ○ | | |
| 4.2 Enterprise and Business Context | | | | | | | | ○ |
| 4.3 Conceiving and Engineering Systems | | | | | ● | | | |
| 4.4 Designing | | | | | ● | | | |
| 4.5 Implementing | | | | | ● | | | ● |
| 4.6 Operating | | | | | ● | | | |
| ● | Strong Correlation | | | ○ | Weak Correlation | | | |

(a) An ability and intellectual foundation to consider issues from a global and multilateral viewpoint.
(b) Understanding of the effects and impact of engineering on society and nature, and of engineers' social responsibility (engineering ethics).
(c) Knowledge of mathematics, natural sciences and information technology and an ability to apply such knowledge.
(d) Specialized engineering knowledge in each applicable field, and an ability to apply such knowledge to provide solutions to actual problems.
(e) Design abilities to organize comprehensive solutions to societal needs by exploiting various disciplines of science, engineering and information.
(f) Japanese-language communication skills including methodical writing, verbal presentation and debate abilities, as well as basic skills for international communication.
(g) An ability to carry on learning on an independent and sustainable basis.
(h) An ability to implement and organize works

Criterion 1, dealing mainly with the knowledge required of graduates, correlates well with the CDIO Syllabus. The Syllabus is structured in a highly organized manner with explicit topics which are a part of the more broadly stated aims of JABEE's Criterion 1 [13]. Institutions that are accredited by JABEE will already have many aspects of the Syllabus present in their curriculum, and the additional aspects will add breadth to what students are already being taught. Every part of Criterion 1 maps to some level of the Syllabus, and therefore the Syllabus does not seem to be missing any components that are considered necessary for engineering programs in Japan.

**Table 3: CDIO Standards vs. JABEE Criteria**

| CDIO Standards | JABEE Criteria | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1. The Context* | | | ○ | | | |
| 2. Learning Outcomes* | ○ | | ○ | | ● | ● |
| 3. Integrated Curriculum* | | | ○ | | | |
| 4. Introduction to Engineering | | | ○ | | | |
| 5. Design - Implement Experiences* | | | ○ | | | |
| 6. Engineering Workspaces | | | | ● | | |
| 7. Integrated Learning Experiences* | | | ● | | | |
| 8. Active Learning | | | ○ | | | |
| 9. Enhancement of Faculty Skills Compentence* | | | | | | |
| 10. Enhancement of Faculty Teaching Competence | | | ● | | | |
| 11. Learning Assessment* | | | ○ | | ● | |
| 12. Program Evaluation | | | | | | ● |
| ● Strong Correlation | | ○ | Weak Correlation | | | |

Criterion 1: Establishment and Disclosure of Learning and Educational Objectives
Criterion 2: Quantitative Curriculum Requirements
Criterion 3: Educational Methods
Criterion 4: Educational Environment
Criterion 5: Evaluation of Students' Level of Achievement against the Learning and Educational Objectives
Criterion 6: Educational Improvement

While the Syllabus deals with curriculum content, the 12 Standards deal with faculty competence as well as curriculum development and implementation, as do the rest of the JABEE Criteria. Of the 12 Standards, seven are required for any institution to consider itself a CDIO Collaborator or to fully adopt the CDIO program [3]. Those seven are marked by an asterisk in Table 2, and are considered the minimum necessary for a program to produce graduates who are able to join industry as fully functional engineers able to conceive – design – implement – operate. Supplemental criteria by major are also provided, typically specifying required disciplinary areas of knowledge and faculty skill components. With the supplemental criteria, all seven required Standards have at least a weak correlation to JABEE criteria, and only Criterion 2, discussing the number of credit hours required for a degree, has no correlation with the 12 Standards [13]. Because CDIO is a global organization based on teaching rather than accreditation of programs, they do not deal with administrative aspects such as required credit hours. Comparing accreditation requirements with the CDIO documents shows that many aspects of what is considered a good engineering education are the same in both the Western countries that have developed the CDIO program and in Japan.

## 6. Conclusions

In the OECD Review of Japanese tertiary education, it is recommended that Japan's institutions focus on comparing their teaching and learning practicesto international best practices and research. Engineering is explicitly stated as a key discipline to review and consider. Additionally, even though the OECD team states they are not reviewing teaching practices observed when visiting Japanese classrooms, they mention that the current pedagogy seems to be out of date when compared to current international techniques [10]. CDIO is an explicit framework meant to update and enhance educational pedagogy for any engineering institution that recognizes the need for change. The documents are open source, so any institution may understand and implement any portions of CDIO that they believe will be beneficial without committing to full adoption of CDIO and membership as a Collaborator.

Due to pressures from industry, globalization, the government, and an emerging era of negative population growth, Japanese higher education must change. Universities must produce graduates who are able to compete in the changing Japanese markets as well as internationally, and they must actively attract more students than ever before because of the shrinking pool of applicants. The tools that CDIO provides can assist universities with solving nearly every problem that they face, from active learning that is attractive to applicants to deeper working knowledge that is attractive to industry. A transformation must be made, and CDIO offers a well-trodden path to a better engineering education.

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**Biography**

Anastasia M. Rynearson is an Assistant Professor of Mechanical Engineering at Kanazawa Technical College. She is part of an initiative to enhance students' technical and conversational English by teaching English language engineering courses to Japanese students and is on the CDIO committee at KTC. She is interested in improving engineering education for pre-university students and plans to pursue a doctoral degree in that area in the near future.

Robert W. Songer is an Associate Lecturer in the Department of Global Information Technology at Kanazawa Technical College. Robert graduated in 2008 from the Rochester Institute of Technology in Rochester, New York with a Bachelor's degree in Software Engineering. Before acquiring his current position at KTC, Robert experienced working as a software developer for academia, the professional language services industry, and Microsoft.