EDUCATION FOR ENGINEERS OR RE-ENGINEERING EDUCATION? CDIO IN NON-ENGINEERING PROGRAMMES

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ABSTRACT

The CDIO Initiative aims to equip the next generation of engineers with relevant knowledge, skills, and attitudes. As an educational framework, it still resides largely within the purview of engineering education. However, because it employs active learning tools such as group work and project-based learning, the applicability to curricula and programs outside of the engineering field has become a topic of discussion. In general, benefits of employing the CDIO approach include stronger connections to professional contexts, enhanced programme development and quality assurance, and a higher commitment to the continuous improvement of educational quality. This paper surveys the application of CDIO to one such non-engineering educational environment at a private university in Japan. We review the rationale behind the university's joining the CDIO Initiative, outline four non-engineering adaptations of CDIO standards, and highlight several changes in curriculum design using the CDIO self-evaluation rubric. Implications for future modifications based on these outcomes are also discussed.

KEYWORDS

Non-engineering programmes, self-evaluation rubric, curriculum design, best practices, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

The CDIO INITIATIVE is an innovative educational framework for producing the next generation of engineers (CDIO, 2020). While it was developed for the context of engineering education, there has been significant discussion concerning the application and implementation of CDIO to non-engineering programmes. Reported benefits have included better educational design, better meeting of stakeholders' needs, improved quality assurance and a stronger connection to the professional context (Crawley et al., 2014; Malmqvist et al., 2016; Tangkijviwat et al., 2018).

The authors discuss the original motivation of Hokkaido Information University (HIU), a private Japanese non-engineering institution, for joining the CDIO initiative, and look at how the curriculum has changed as a result of applying CDIO standards. The notion of "best practices" – some techniques, strategies, technologies and relationships used to improve learning outcomes – employed before joining the CDIO initiative, is also discussed. Successful

programmes resulting from implementing the CDIO framework are briefly outlined, and the progress of the university, two years after joining the initiative, is evaluated.

THE UNIVERSITY

HIU, founded in 1989, is part of the eDC group (Electronics Development group Company). The group is comprised of five closely meshed entities; a university, a string of technical colleges, a software development corporation, a space development company and a research institute. These five entities interconnect to form an institution that focuses on learning, industry and research. HIU is the primary learning institution in the group, and the faculties and departments that comprise it adhere to the group's vision; namely, providing information-based knowledge and skills. HIU applied and was accepted into the CDIO Initiative in March 2018. As HIU is not an engineering university, polytechnic or institute of technology, its involvement with the initiative is, perhaps, somewhat special.

RATIONALE FOR JOINING THE CDIO INITIATIVE

The founding principles of HIU state:

"In the spirit of academia-industry cooperation, we seek to nurture advanced information and communication technology professionals, instilling them with an understanding of the value of internationalization, cultivating their innovation and sense of humanity, and ensuring they are capable of contributing to the development of our information-oriented society through a specialized education based on solid practical groundwork" (HIU, 2020).

These principles and the language that expresses them are similar to the CDIO Initiative's vision of CDIO-based education, which stresses activities that are "rich with student design-build-test projects, integrating learning of professional skills such as teamwork and communication, active and experiential learning, and a quality assurance process (CDIO, 2020)."

If HIU's founding principles are referenced with CDIO Standards, similar objectives become apparent: For example:

"In the spirit of academia-industry cooperation **(Standard 3)**, we seek to nurture advanced information and communication technology professionals **(Standard 2 & 5)**, instilling them with an understanding of the value of internationalization **(Proposed Standard - Internationalization & Mobility)**, cultivating their innovation and sense of humanity **(Standard 7)**, and ensuring they are capable of contributing to the development of our information-oriented society **(Standard 12)** through a specialized education based on solid practical groundwork **(Standards 1 & 7)**".

Further, the CDIO programme is appropriate for information-oriented education and can be applied to skills that are taught at HIU. For example, **Conceiving** may refer to defining customer needs, applying the requisite skill and considering the appropriate technology (such as in network design or programming); **Design** involves constructing the necessary scaffolding for a system, network or game; **Implementing** means realising the design in a working system, process or model (such as a game, database, website, or network), and **Operating** entails maintaining, adjusting and evolving the product (games, networks, websites) as needed.

CDIO IN NON-ENGINEERING PROGRAMMES

More than a decade of collaboration with Thailand's Rajamangala University of Technology Thanyaburi (RMUTT), one of the earliest adopters of the CDIO initiative in Asia, has helped fuel interest at HIU in learning more about, and ultimately joining, the CDIO Initiative. This interest is due in part to RMUTT having effectively applied CDIO-based curriculum development to non-engineering programmes in their Mass Communication Technology Faculty. RMUTT faculty members have reported that there has been a continuous improvement in the quality of education since they applied CDIO standards to design and develop their curriculum (Tangkijviwat et al., 2018).

More recently, this broader adaptation of CDIO has been followed up with RMUTT's application to Digital Media, Hotel Management, Health & Beauty and Thai Traditional Medicine courses, amongst others. The same is apparent at the Mongolian University of Science and Technology (MUST), which has used the framework to enhance creativity and communication through project-based learning, with a special emphasis on English education (Sangijantsan, 2019).

Already sharing common CDIO objectives, and with over 30 percent of the tenured faculty having engineering backgrounds or graduating from engineering faculties (including the current president), HIU saw value in joining the CDIO Initiative, becoming the third tertiary institution in Japan to be accepted.

INITIAL SELF-EVALUATION OF HIU

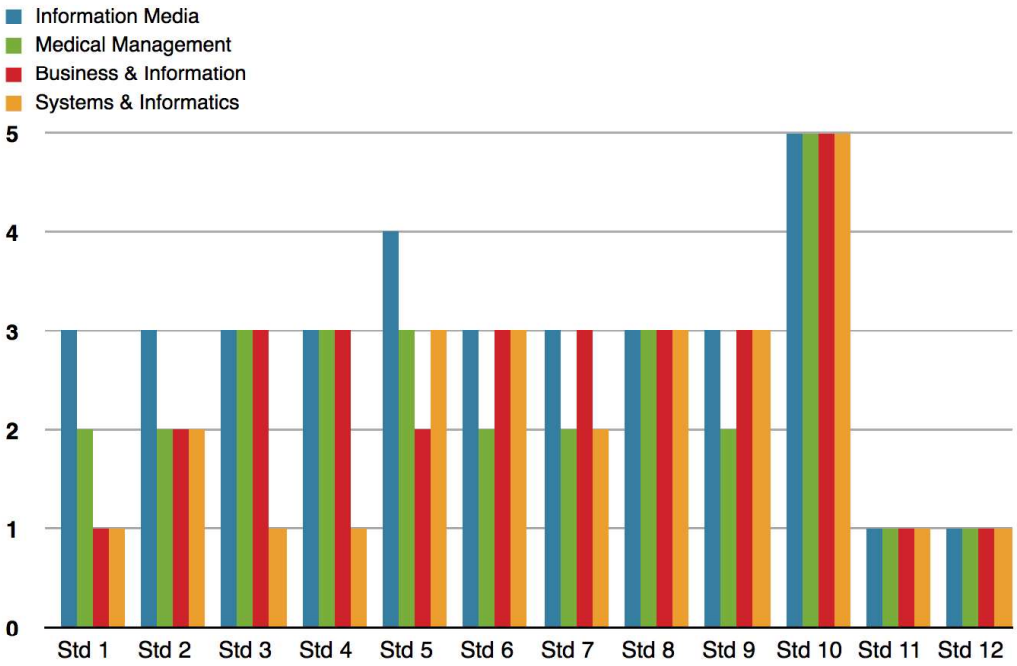

FIGURE 1: Self-evaluation by CDIO Standards, December 2017

Excluding the School of Distance Learning (off-campus students), and the General Education Group (whose teachers are formally affiliated with other departments), teaching faculty at HIU belong to one of four departments: Information Media, Systems & Informatics, Business &

Information, or Medical Management. Figure 1 shows an initial self-evaluation for each of the four departments carried out at the end of 2017. Involvement on a scale of zero to 5 is shown for each of the 12 CDIO Standards.

The initial self-assessment revealed that the Department of Information Media was more advanced than other departments in terms of the self-assessment rubric. There are several reasons why this may be the case. These include the fact that Information Media was the only department that had already been conducting project-based learning (Standard 5), one of HIU's best-practices, on a regular basis for several years. Similarly, CDIO as context (Standard 1) – also a best practice - was more advanced because Information Media put effort into connecting the educational context to what is needed in the professional world. The best-practice that equates to Standard 2 - review and validation of learning outcomes, by faculty and industry - was also perceived to be progressing well. Due to a robust Faculty Development programme that has been in place since 2010, enhancement of faculty teaching competence (Standard 10) was evaluated as high for each department. Conversely, program evaluation and assessing student learning (Standards 11 and 12) were generally assessed as being poorly undertaken. The Department of Systems and Informatics, which involves programming and system design, rated their progress significantly lower than other departments. This assessment is a little surprising, as programming and system design skills have a clear overlap with engineering education (hence, system engineer, network engineer), and therefore lend themselves more readily to adoption of the CDIO framework. If the university is regarded a whole, and the self-evaluation is viewed as a totality by averaging departmental rubric scores, a clearer picture of the general progress of the university becomes apparent. This is expressed by the line superimposed on the bar graph in Figure 2.

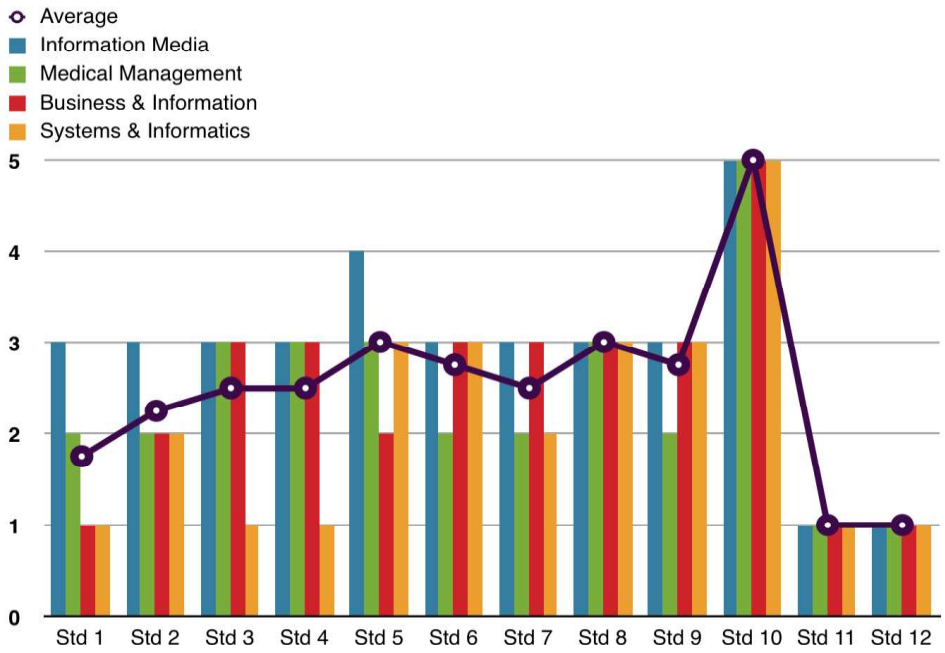

FIGURE 2: Self-evaluation by CDIO Standards, showing average rubric score, December 2017

Despite higher self-evaluations by Information Media, and lower evaluations by Systems & Informatics, if the assessment is viewed as an average, extreme scores cancel each other out.

On average, then, these results show the university in 2017 as having a moderate adherence to CDIO standards, hovering just below an average of 3.

TOWARDS MORE ADOPTION OF THE CDIO FRAMEWORK

Over the last two years, since joining the CDIO Initiative, many faculty members in HIU have undertaken efforts to improve curriculum design, learning outcomes, and faculty skills, while attending to stakeholder needs, through the application of CDIO standards. As noted, while Information Media tends to fit the CDIO framework more effectively than other departments because of its employment of project-based learning, active learning, and a revised curriculum, other departments have been targeting their own weaker points in an effort to improve learning outcomes. These efforts are depicted in Figure 3.

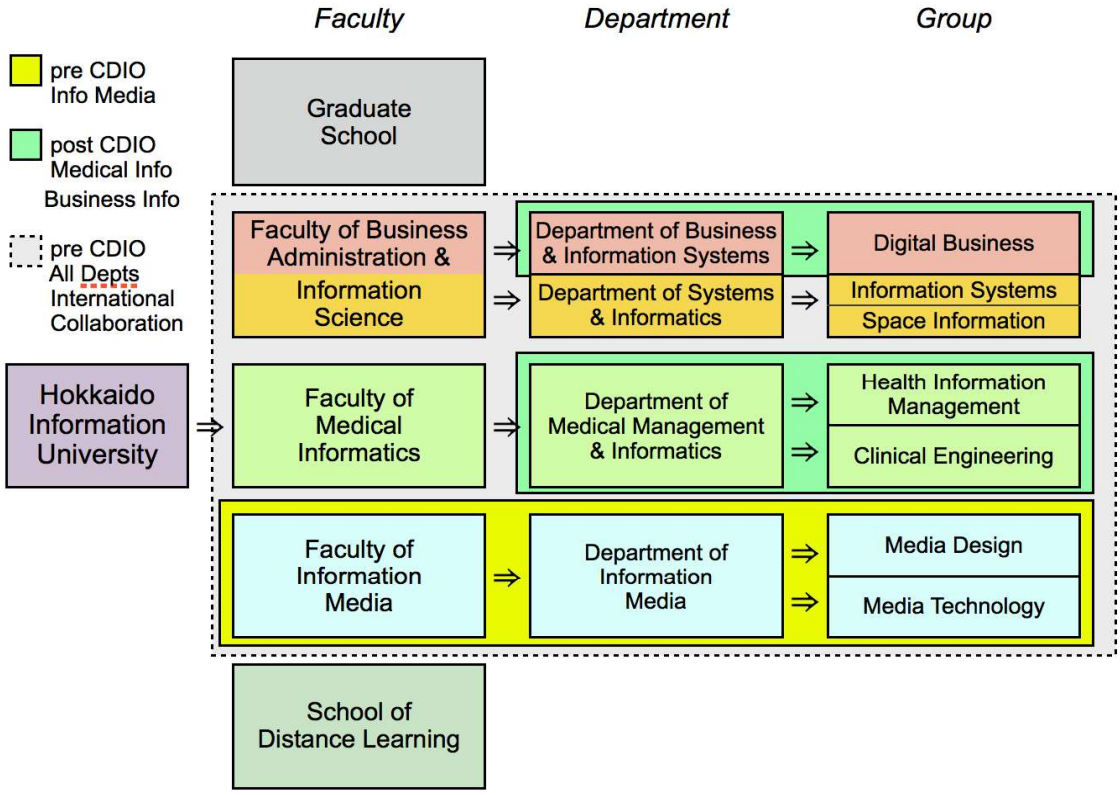

FIGURE 3: Application status of CDIO standards to programmes, by faculty, department, and group, before (yellow) and after (green) joining the CDIO Initiative.

As we mentioned above, the Department of Information Media was already somewhat aligned with CDIO Standards before HIU's acceptance into the Initiative in 2018. This is indicated by yellow (pre CDIO Info Media) in Figure 3. The areas in green depict more recent, post-2018 efforts by both the Clinical Engineering group in the Department of Medical informatics, and the Digital Business group, in the Department of Business & Information Systems, to incorporate the CDIO framework into its existing programmes (post CDIO Medical Info, Business Info).

The larger grey (broken-lined) rectangle signifies an international student collaborative exchange workshop which already existed before the CDIO initiative, and was not originally designed with reference to CDIO standards. Except for post-graduate studies (Graduate School) and the distance-learning program (School of Distance Learning), it can be seen that CDIO standards now apply to most of HIU's curriculum.

A brief discussion of some of the programmes within the curriculum follows.

CDIO APPLICATION: FOUR CASES

The Application of CDIO Standards to Clinical Engineering Education

Shimizu et al. (2018) discusses the task of clinical engineers as the operation, monitoring and maintenance of medical equipment in hospitals. Shimizu, a tenured faculty member in the Department of Medical Management & Informatics, discusses the importance of practical training rooms and medical simulators in providing the necessary skills to perform tasks required of medical engineers working in Japan. In particular, Shimizu focuses on Standard 2 - Learning Outcomes - what Crawley et al. (2014) refer to as setting "specific, detailed learning outcomes for personal and interpersonal skills, . . . (encouraging) product, process and system building skills, . . . (and ensuring) disciplinary knowledge, consistent with program goals." There is also a clear focus on the importance of the Integrated Curriculum (Standard 3), where off-campus clinical practice in a controlled environment at a hospital is undertaken after on-campus programmes, leading to a more effective education. This also ties into Standard 4 (introductory courses – as reworded by Malmqvist et al., 2016). Standard 6, the provision of an Engineering Workspace, is evidenced in the clinical engineering practice room at HIU, which simulates an actual hospital environment, and is essential in helping students develop the appropriate operating skills. These facilities also allow active learning (Standard 8) through teamwork and a heavy emphasis on the practical operation of simulators and related devices.

A Practical Application of Business Systems in enPiT2

Myojin et al. (2018) discuss the application of the CDIO framework to enPiT2. enPiT2 (Education Network for Practical Information Technologies) is a nationwide cooperative effort between multiple universities and industries, under the auspices of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). Its goal is to develop human resources who can maximize information technology in practical contexts, with specific respect to four themes; big data, security, embedded systems, and business system design.

Myojin is a tenured professor in the Department of Business & Information Systems. Much of what is covered in Myojin et al. (2018) centres on the efficacy of using active learning techniques (Standard 8) to promote student learning, and addressing challenges through a task-based learning approach, or a design implement experience (Standard 5). Looking at the business system contextually -- as being conceived, designed, implemented and operated -- are the essence of Standard 1.

Boosting Foreign-Language Communication Confidence Through a Short-term ICT-based International Workshop

Rian et al. (2019) and Anada et al. (2018) refer to a short-term ICT-based international exchange programme between HIU and RMUTT. The main part of the programme consists of

two 8-day workshops, held at each university. Throughout the workshops, students work in small groups to produce web sites, short films and computer programs, all in English. There are 4 stages to the programme; selection, competition, collaboration, and sharing.

The programme involves conceiving, designing, implementing, and operating ICT-based projects, primarily in English, which is a foreign language to both Japanese and Thai students. Not only does the programme focus on design implement experiences (Standard 5) through a collaborative teamwork approach using active learning strategies (Standard 8), it also relies upon learning outcomes (Standard 2) and integrates personal skills with disciplinary knowledge (Standard 7). The programme also pays attention to the syllabus, with students communicating and presenting in non-native languages (CDIO Syllabus 3.2 & 3.3) and completing pre-programmed design seminars (CDIO Syllabus 4.3.4). It also references the proposed CDIO Standard of Internationalisation and Mobility (Campbell & Beck, 2010).

Availability of CDIO as a Driver of Creating Shared Value

Fukuzawa (in press), a tenured faculty member of the Department of Business and Information Systems, examined whether the CDIO framework could be successfully applied to teaching the business concept of Creating Shared Value (CSV). Students were assigned a task, and in collaboration with a company, completed a complex design and creation project. Based on results obtained from the class, which was conducted as a project-based learning (PBL) project (Standard 5), Fukuzawa noted that students working in conjunction with companies (CDIO Syllabus 4.2) in a workspace appropriate to their needs (Standard 6), we're able to create, design and implement a business system (Standard 1). It was also noted, however, that the learning assessment (Standard 11) was more difficult than expected, making an objective programme evaluation (Standard 12) hard to implement. The conclusion was that a more rigorous application of Standards 11 and 12 may yield better results.

EVIDENCE OF IMPROVED CURRICULUM DESIGN

The four cases outlined above show that most of the CDIO standards and some of the syllabus have been considered concerning improving curriculum design. This is summarized in Table 1.

As Table 1 shows, most CDIO Standards were referred to in designing the above-mentioned programmes or projects. While the table lists only the Departments of Medical Management & Informatics, and Business & Information Systems, some other faculty members were also involved in the programmes discussed by Rian and Myojin, making them more interdisciplinary than the table may imply. However, it should also be noted that the Department of Systems & Informatics had the lowest self-evaluation by CDIO standards, indicating that a more proactive approach would be beneficial. Conversely, despite having had the highest initial self-evaluation in 2017, the Department of Information Media is conspicuously absent. This does not mean that Information Media did nothing; rather that the authors are not aware of new programmes designed using CDIO standards. It should also be noted that the proposed optional CDIO Standard 13 (Campbell & Beck, 2010) has been included. Further, while both Fukuzawa and Rian noted the relationship of their programmes to the CDIO syllabus, the main focus of this paper is to show how curriculum design has improved by paying closer attention to CDIO standards and the accompanying rubric.

TABLE 1: Standard focused on, in relation to faculty member, department(s), and initial self-evaluation score. MMI = Dept of Medical Management & Informatics, BIS = Dept of Business & Information Systems. Information Media Department and Systems & Informatics Department not directly involved in the programmes. *Standards 4, 5 and 6 are reworded according to Malmqvist's application of CDIO standards to non-engineering courses (2016). Self-Evaln refers to the Self-Evaluation by CDIO standards conducted in 2017 before joining the CDIO initiative. Optional Standard 13 has been proposed by Campbell & Beck (2010).

Std #	Standard	Faculty Member	Dept	Self-Evaln
1	The Context	Fukuzawa	MMI	1
2	Learning outcomes	Shimizu, Rian	MMI, BIS	2, 2
3	Integrated Curriculum	Shimizu	MMI	3
4	Introductory course*	Shimizu	MMI	3
5	Professional practice experiences*	Myojin, Rian, Fukuzawa	BIS	2
6	Workspaces for professional practices*	Shimizu, Fukuzawa	MMI, BIS	2, 3
7	Integrated learning experiences	Rian	BIS	3
8	Active learning	Shimizu, Myojin, Rian	MMI, BIS	3
9	Enhancement of faculty competence	0		2, 3
10	Enhancement of faculty teaching competence	Shimizu, Fukuzawa, Rian	MMI, BIS	5
11	Learning assessment	Fukuzawa	BIS	1
12	Programme evaluation	Fukuzawa	BIS	1
Opt 13	Internationalisation and Mobility	Rian	BIS	N/A

In December 2019, departments were again asked to perform a self-evaluation using the CDIO rubric. This was conducted 2 years after the initial self-evaluation, and departments were asked not to refer to the earlier self-evaluation. The results can be seen in Figure 4.

The 2019 results for both the Departments of Medical Management & Information, and Business & Information Systems, are more conspicuous here (Figure 4) than they were in 2017 (Figure 3). The Department of Systems & Informatics self-evaluation remains, meanwhile, virtually the same as in 2017.

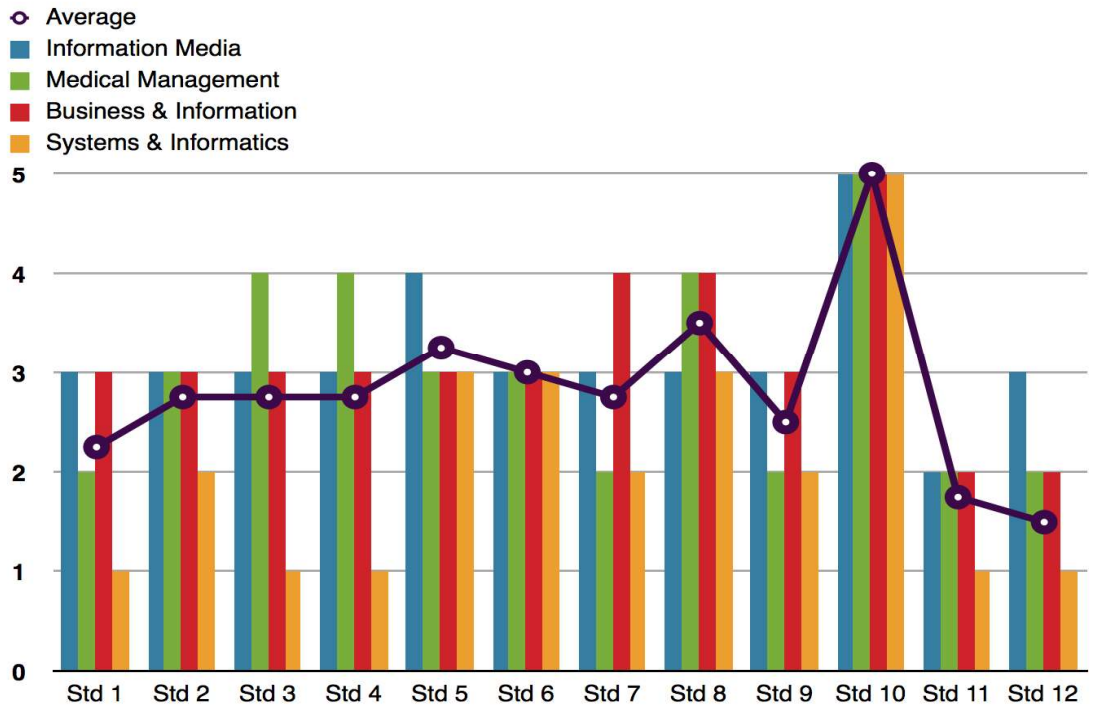

FIGURE 4: Self-evaluation by CDIO Standards, showing average rubric score, December 2019

As with the 2017 self-evaluation (Figure 3), the combined departmental average (Figure 4) is shown as a line graph. Compared with the earlier graphs (Figure 1 and Figure 2), it may be difficult to see any changes. It is not the authors' intention to compare departments in terms of CDIO adoption progress. Rather, the intention is to show that the university as a whole is progressing, and that some departments are progressing more quickly than others. A visualization of the progress might become more evident if the two line-graphs representing self-evaluations before and after CDIO adoption are compared (Figure 5).

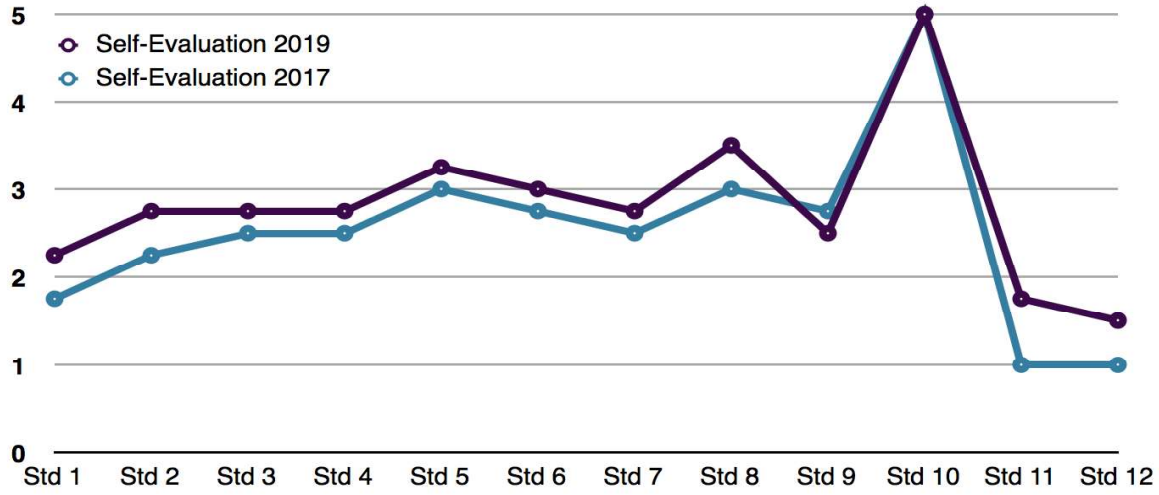

FIGURE 5: Comparison of self-assessment using CDIO assessment rubric; 2017 - 2019

A comparison between the two self-evaluations, taken two years apart, does not show as big a change as might have been expected. Standard 10 (Enhancement of Faculty Teaching Competence) remained the same. This may be due in part to a robust, ongoing Faculty Development programme that has resulted in faculty confidence in terms of relevant knowledge and skills. It may seem unusual that Faculty Teaching Competence (Standard 10) has remained at the top, while the Enhancement of Faculty Competence (Standard 9) was scored lower. The data showed that Systems & Informatics rated themselves lower than before. This may be because of an increased awareness of how to self-assess accurately, or perhaps the department may have felt that there were obstacles such as personal, interpersonal, or system-building skills problems. In either case, the evaluation itself is not at the bottom level, but it should be addressed. Other gradual increases may have resulted from other departments, especially Medical Management & Information, and Business & Information Systems, feeling more confident in their curriculum design procedure. Change has been gradual, as noted by the similarity in shape of the two lines in Figure 5.

OVERALL PROGRESS

If the progress of HIU in terms of adopting the CDIO initiative is to be analysed based on self-evaluations, these results suggest that the university is moving – at least, incrementally – towards better curriculum design. More programmes and projects are being designed with conscious reference to CDIO Standards, more attention is being paid to stakeholders in the education process, and a general interest in improving the relevance and quality of education has been increasing. The number of faculty taking part in CDIO events – such as workshops, regional meetings and annual meetings – is rising, as is the number of students taking part in the CDIO Academy. There has also been an increase in integrated learning experiences and design-implement experiences. Additionally, the curriculum demonstrates better integration than it did previously, with some cross-departmental subjects having been approved. Learning assessment and programme evaluation are still areas that need improvement, and progress is expected in these areas by continued application of the appropriate standards.

LIMITATIONS

The authors were interested in trying to objectively evaluate how well HIU, as a non-engineering university, has been adopting the CDIO framework. Specifically, we looked at an average change in self-evaluation responses in terms of adherence to CDIO standards in designing and realizing projects, programmes and the curriculum. Case-study reports on programmes designed around CDIO standards, such as the four outlined in this paper, provide a good way to evaluate change. Despite reference to the CDIO Syllabus by both Rian et al. (2019) and Fukuzawa (in press) in their programmes, it might be viewed as a statement of goals for engineering education. The main focus of this paper was on the application of CDIO Standards to non-engineering programs. Developing a sustained awareness among faculty members of CDIO concerning the design and structure of department curricula, and how that awareness can help improve educational outcomes, was and remains an objective.

The conclusion that HIU appears to be slowly but soundly adopting the CDIO initiative is based on self-evaluations conducted over two years, and evidence of application of the CDIO standards in recent programmes offered by several departments. The authors plan to conduct another self-evaluation based on the implementation of newer programmes designed around CDIO Standards in another two years.

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