SUSTAINING CDIO CAPABILITY: PROFESSIONAL DEVELOPMENT FOR ENGINEERING FACULTY

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ABSTRACT

The Diploma in Chemical Engineering (DCHE) adopted the CDIO framework as the basis for its curriculum since 2007. Over the last several years, specific CDIO skills have been introduced in various core modules in the 3-year diploma program.

The course management team has recognized the need to continually sustain the CDIO capability of its faculty. The paper describes the efforts undertaken by the course management team to provide the necessary deep learning (Marton, [1]) of the CDIO initiative to new faculty and returning faculty. The goal was to get the new and returning faculty to learn about the CDIO initiative in the same manner as the initial "pioneering" batch of CDIO implementers, known as "CDIOers". This paper first discusses professional development of the faculty with regard to CDIO skills in the polytechnic which, in the author's view, is insufficient in its present format to sustain the development of faculty competence in CDIO skills.

Learning from identified gaps in the present arrangements, this paper will argue for an integrated approach to the professional development of faculty by integrating faculty training, pedagogy and curriculum development. This is to be further supported by getting faculty to participate in reflective practice upon completion of a CDIO assignment.

The paper then describes approaches taken by the course management team to initiate the faculty CDIO skill acquisition process. The advantages and disadvantages of the various approaches will be discussed, as well as reflections by faculty on their usefulness.

Finally, the paper will discuss the issues and challenges faced by the course management team and mentors in adopting the approaches. We will identify some key learning points and outline future directions in facilitating a more effective approach towards professional development in this area.

KEYWORDS

Faculty on-the-job training, chemical engineering, CDIO skills, professional development framework

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) adopted the CDIO framework as the basis for its curriculum since 2007. Subsequently, over this duration, a systematic approach for integrating CDIO skills into the DCHE curriculum has emerged, as accounted for by Sale and Cheah [2], Cheah [3], and Cheah and Sale [4]. Various CDIO skills such as teamwork and communication, critical and creative thinking, displaying multiple perspectives (collectively known as "CDIO Skills" in this paper) and skills in conceiving, designing, implementing and operating a product, process or a system (collectively known as "C-D-I-O Skills") have been introduced in various core modules in the 3-year diploma program ([5], [6], [7], [8]. The CDIO framework has also been used in final year student capstone projects ([9], [10]) as well as an overseas community service effort ([11]).

In the "formative" years of integrating CDIO into the curriculum, participating faculty have acquired the necessary deep understanding of the various skills through producing a customized SP-CDIO syllabus, as well as the related underpinning knowledge for such skills. The faculty also conducted an extensive gap analysis and mapped the CDIO skills into the core modules and also designed various learning activities and assessment schemes for each skill. Since rolling out the CDIO chemical engineering curriculum, some 14 core modules (out of a total of 36 modules in the whole diploma) have CDIO and/or C-D-I-O skills infused in the chemical engineering curriculum.

New faculty (those joining the Polytechnic in the last 12 months or less), however, did not have the opportunity to participate in the extensive curriculum revamp compared to the "pioneering" batch of faculty, by virtue of them joining the polytechnic after the initial implementation. The same can also be said of other existing faculty, who did not initially actively participate, either choosing to watch on the sidelines wondering if this was going to be a passing "fad" or faculty who missed out on the opportunity due to other reasons such as study leave or maternity leave. We have termed them "returning faculty" for the purpose of this paper.

Without an on-going professional development program to introduce them to the "nuts and bolts" of CDIO, these faculty will simply "inherit" one or more CDIO-enabled modules and would be executing the various activities without the deep internalization mentioned above. At best, the significant learning experience that would have been gained behind the curriculum re-design effort is largely lost. At worse, the learning experience that the students may go through may not reflect the efforts of the CDIOers in improving the teaching and learning experience for our students.

THE CURRENT SYSTEM FOR PREPARING NEW FACULTY

The current professional development in the polytechnic, in the author's view, is insufficient in its present format to sustain the development of faculty competence in CDIO skills. New faculty are required to go through a 'standard" Certificate in Teaching (CT) program upon joining the institution. The CT program is administered by the Department of Educational Development (EDU), and taught by experienced educational advisors. The CT program consists of various segments to be completed by a new faculty over a one-year period. The first segment is a 5-day induction program to equip a new faculty with basic knowledge of pedagogy and teaching skills, before one starts teaching in the classroom. However, because each diploma program in SP has customized the CDIO programme to suit its own needs, the CT program, which is meant to be a generic programme that covers pedagogic literacy, does not lend itself to cover the various diploma's CDIO needs within its limited timeframe.

Hence, the burden of “CDIO induction” thus falls onto the shoulders of each of the diploma’s Course Management Team (CMT). Often, the CMT is already very pre-occupied in the day-to-day running of the diploma to be able to effectively engage any new or returning faculty in building up his/her CDIO competency.

With the adoption of CDIO, EDU has also developed various workshops on CDIO, such as understanding underpinning knowledge of CDIO skills. These workshops can be customized somewhat to the needs of each diploma, but requires the input from the relevant CMT to provide the necessary context under which a given CDIO skill can be integrated. This placed additional strain on an already-busy CMT.

Also, even though the institution does encourage and support faculty attending professional development programmes, often faculty tend to focus on technical competence of their profession, resulting in inadequate attention being given to learning CDIO skills. More importantly, the process of engaging faculty in professional development is often hampered by competing initiatives requiring the immediate attention of lecturers.

ENHANCED INTEGRATED PROFESSIONAL DEVELOPMENT OF FACULTY TO ATTAIN CDIO SKILLS

CDIO Standard 9 “Enhancement of Faculty CDIO Skills” calls for the support of faculty to improve their own competence in the *personal, interpersonal, and product and system building skills* described in CDIO Standard 2.

We have proposed an enhanced professional development plan that leverages on the strengths of existing systems and offers an integrated approach to the professional development of faculty by linking faculty training, pedagogy and curriculum development. This is to be further supported by getting faculty to participate in reflective practice upon completion of a CDIO assignment. Schon [12] argues that reflection-in-action or reflective practice comes into play when people deal with “situations of uncertainty, instability, uniqueness and value conflict”. More importantly, Schon also points out that to deal with such situations, one can carry out an experiment which serves to “generate both a new understanding of the phenomena and a change in the situation.” Using Schon’s analytical framework, we are encouraging faculty to engage in Action Research. The framework is shown in Figure 1.

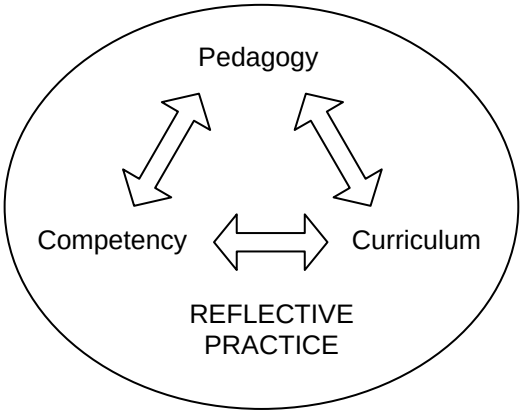

Figure 1. Alignment of Pedagogy, Curriculum and Competency

The DCHE CMT set up a Teaching & Learning (T&L) Unit with the purpose to systematically (i) prepare new faculty to be fully equipped with CDIO know-how and to function effectively as module coordinators, and (ii) enable returning faculty to get up to speed with CDIO and continue their duty as module coordinators. Members of the T&L Unit include experienced "CDIOers" serving as Academic Mentors to help in coaching and guiding both new and returning faculty in using CDIO to revamp their modules. As shown in Figure 1, this requires the 3 parties, namely the CMT, the Training Manager, and the mentors to work closely together to plan out the development program for new and returning faculty.

The DCHE T&L Unit designed a structured mentoring program (SMP) that integrates staff competency development in teaching pedagogy with other personal developments and professional training, by linking curriculum review with pedagogy training needs; and staff development program with curriculum design and development. This is to ensure consistency of curriculum design or re-design using CDIO.

The DCHE SMP for faculty development in CDIO is shown schematically in Figure 2. The top figure shows the induction of new faculty to the CDIO framework through a combination of briefings, workshops and various on-the-job training (OJT) programs. The SMP leverages on the requirement of the CT program that a new faculty must complete an action research project, by requiring the new faculty to base the topic of his/her action research project on CDIO-related initiative. At the end of the CT program, a new faculty is expected to submit a teaching portfolio that would capture the key learning points of the entire CT programme. This serves as a scaffold for faculty in training them to serve as a module coordinator which requires them to oversee the review and development of the module under his/her charge.

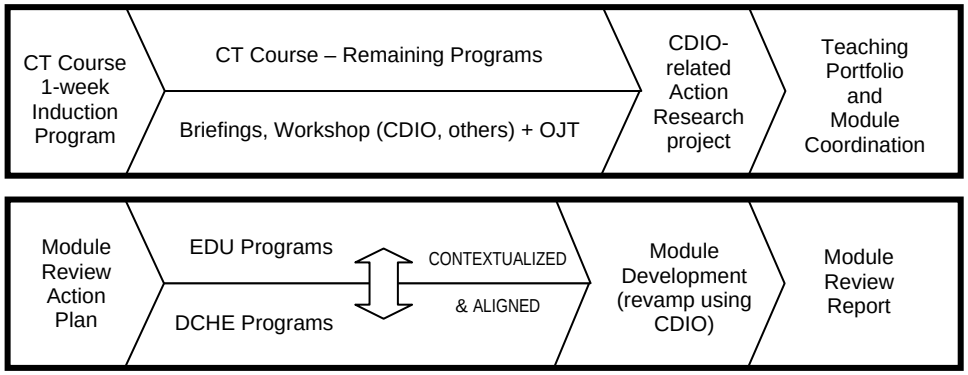

Figure 2. Structured Mentoring Program (SMP) framework for DCHE

The lower figure shows the approach to build up CDIO capability for both new and returning faculty. As module coordinator, a faculty is expected to continually review and improve on his/her module for example based on inputs from external review panel and other stakeholders. Working with the Academic Mentor, the module coordinator formulates the necessary action plan to improve the module. The Academic Mentor then analyzes the potential training needs and in consultation with the training manager, plans and engages the necessary training agency for the required training. The training is customised to suit the unique needs of the course.

PULLING IT TOGETHER

The various CDIO programs can largely be grouped into 2 approaches. The first approach is through a re-visit of the earlier gap analysis, conducted 3 years ago when CDIO was first introduced. Over the years, much has changed and the course management team felt that the time was right to take stock of the curriculum with regards to integration of CDIO into the

modules. The new faculty or returning faculty is paired up with existing "CDIOers" (including the author) who serve as mentors to lead the effort in the second round of gap analysis. The CDIOers first shared the various underpinning knowledge of CDIO skills with the new or returning faculty through a series of briefings such as "*Introduction to CDIO*", "CDIO *and Chemical Engineering*" (which describes the rationale for DCHE to adopt CDIO), "*SP's Customised CDIO Curriculum*", etc. They then attend workshops on "*Understanding Underpinning Knowledge of CDIO Skills*", and "*Outcomes-based Education*", which are often jointly conducted by senior education advisors from EDU and DCHE academic mentors. These workshops are often customised to meet DCHE needs with suitable examples and working document that are familiar to faculty. The team then conducted in-depth interviews with other faculty members who had introduced CDIO into their modules. From the gap analysis, the team updates the CDIO skill coverage map for the diploma, and in the process, gained understanding of how CDIO is being introduced into the curriculum.

The second approach was to show the new or returning faculty "the ropes", by engaging them in on-the-job (OJT) training. For this approach, several methods were employed, such as shadowing more-experienced CDIOers, coaching and mentoring in module development to introduce selected CDIO skill(s), execution of student final year (capstone) projects, and involvement in new CDIO initiatives. This was again achieved via the assistance of selected CDIOers as mentors.

The workflow for faculty engagement in the program is shown in Figure 3. As a new faculty starts his/her teaching career, he/she is put in charge of coordinating a selected module, and may be required in teaching or serve as laboratory facilitator in one or more other modules. The new faculty undergoes a series of briefings and workshops designed to jump start the faculty's CDIO competency.

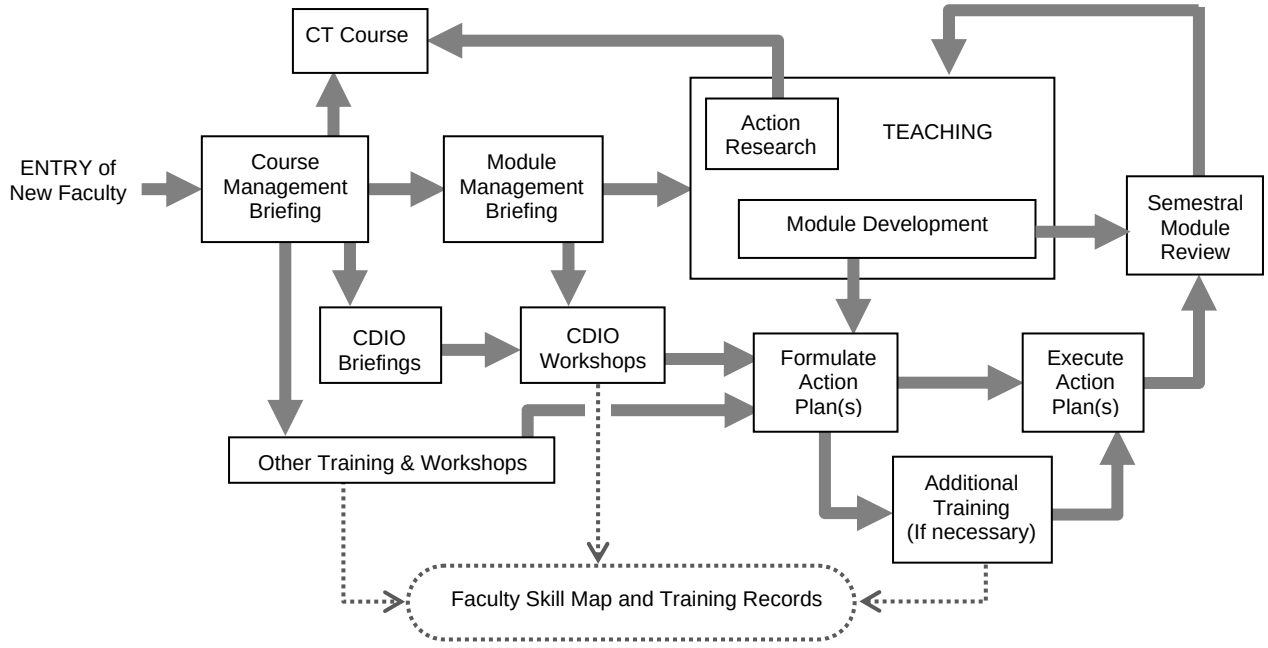

Figure 3. Work Flow for Faculty Engagement in CDIO

Some of the salient features are briefly explained below:

- The Course Manager conducts briefing on overall course management requirements, e.g. module review and development
- The Academic Mentor conducts briefing on the CDIO framework, Standards and Skills, and the underpinning knowledge for the CDIO skills

- The Academic Mentor arranges for existing module coordinator to brief new faculty on fine details of intended learning outcomes of key CDIO activities (lab, assignment, case study, etc) in module(s) the new faculty is taking over or helping out, including CDIO skill coverage map
- The Academic Mentor works with the Training Manager to set up training calendar and timeframe to complete all necessary CDIO trainings

In the first year of the new faculty's teaching career, the Academic Mentor together with EDU's senior education advisor, coaches the new faculty in completing the action research requirement of his/her Teaching Portfolio. An account of this initiative had been covered in a separate paper by Chua et al [13]. Besides the action research, a new faculty also goes through a series of OJT programs to "jump start" his/her CDIO capability.

The preferred method of OJT is by pairing up a new or returning faculty with experienced CDIOer to jointly conduct selected CDIO-enabled laboratory or workshop sessions. The CDIOer provides both on-site coaching and off-site reflection of practice. Where the timetable of the new faculty permits, he/she can also "shadow" and observe a CDIOer conducting laboratory or workshop sessions; and taking down notes, observing the questioning techniques and following-up etc; and conclude with a debrief by the CDIOer.

The Academic Mentors may also sit in the new faculty's CDIO-enabled laboratory or workshop sessions and gives feedback to help improve practice.

Other forms of OJT are also utilized, especially when pairing is not possible. These include, undertaking the supervision of CDIO-type final year capstone projects, designing new CDIO-type laboratory activity (see for example [4], [5]) or assignment (i.e. those requiring students to conduct literature review, critique via a written report, or make a PowerPoint presentation) or new CDIO initiatives by the CMT, such as integrating "*Experimentation and Knowledge Discovery*" into the DCHE curriculum.

The advantages and disadvantages of the various approaches are shown in Table 1 below. Usually a combination of approaches is used. For example, a new faculty can be simultaneously undergoing OJT via pairing and shadowing, and also at the same time, undertake supervision of final year projects. There is also an online tutorial on implementing CDIO for new faculty.

Table 1
Advantages and Disadvantages of Various Approaches

Approach	Advantages	Disadvantages
Pairing	"Live", on-the-spot practice of CDIO skills alongside an experienced CDIOer; shortens learning curve relatively quickly.	Completely engaged with groups within his/her own supervision; unable to fully observe experienced CDIOer in action. Subjected to limitation of time-table planning.
Shadowing	Opportunity to silently observe experienced CDIOer in action; and taking notes of learning points at the same time.	Subjected to limitation of time-table planning. Internalization may not be as deep as the pairing approach, as there is no actual active participation.
Gap Analysis, and curriculum revamp	Can provide high level of appreciation through in-depth study of module's coverage of CDIO skills.	Not effective if a module is already sufficiently CDIO-enabled, as actual participation in revamping the module is low.

Table 1 – cont'd

Final Year Project	Faster for new faculty to internalize CDIO framework, as results is usually observable first-hand in a relatively short time.	Not all projects are amenable to CDIO (e.g. industry-sponsored one with strict protocol to follow), or limited in the type of CDIO skills that can be practiced.
New initiative	"Pioneering spirit" can arouse strong motivation and greater ownership vs. "incremental improvement" in some curriculum revamp effort.	Some sufficient prior experience is needed, which a new faculty may lack; also such opportunity may not be readily available when needed.

Reflections by New Faculty of Learning Experience

At the time of this paper, a total of five new faculty had at various stages completed their CT programs, and participated in various OJT programs outlined above. They were then approached to share their experience with the authors of the paper. A total of 6 questions were asked about their experience on the mentoring programme designed for them. All respondents agreed that the mentoring process has helped them ease into their new role as a lecturer in the school of Chemical and Life Sciences. They also felt that the mentoring activities have helped them grow as lecturers in the school.

When probed further and asked which particular activities were most useful, the new lecturers highlighted the value of the CDIOers who have mentored them, describing them as "adept and very caring." They feel that the mentors have always helped them and have become, in one staff's term, their "anchor".

What the authors have also found most satisfactory is the following comment from one of the new lecturers:

> "The perfect timing of AR mentoring which came right after the CT AR Workshops allowed me to practise what was taught in the workshops while the memory was still fresh in mind. The conduct of AR mentoring also fulfils a few purposes at the same time, i.e. completing the teaching portfolio for CT graduation, writing a paper for a conference, and getting a better grasp of CDIO and AR through hands-on practices. I thought that was highly beneficial in view that time is always limited for lecturers."

This gives us the confidence that tying the Action Research requirement by getting lecturers to work on a CDIO project is an effective way to develop a sound foundation for CDIO implementation. Furthermore, it seems to tie in with Schon's [12] own observations that "when someone reflects-in-action, he becomes a researcher in the practice context", not relying on proven methods and received wisdom but developing strategies and theories as s/he goes along. "Thus reflection-in-action can proceed … because it is not bound by the dichotomies of Technical Rationality." We intend to fine tune the process even more.

With every new programme, there are also several things which the new lecturers did not like. For example, they pointed out that the mentors who mentored them needed to have mentoring skills such as giving feedback effectively and working well with peers. Another lecturer also felt that due to their heavy workload, he found it tough to follow up on recommended readings as he simply did not have the time.

All respondents however, responded positively when asked if they managed to balance their mentoring activities with the demands of their daily work. They did however offer, in the opinion of the authors, some useful ideas on how the processes can be improved. They felt

that the mentoring needed to be more structured and varied rather than the mentors instructing them what to do. They wanted more useful tools to use and develop as part of their professional knowledge-base. The respondents also felt that by plunging them into the deep end and getting them to work on their Action Research tied to a CDIO idea was the "best way to learn compared to listening". Another respondent also suggested that mentors work one on one to give more interaction time and also for the newer staff to have a more intimate learning experience. As Bate, Bevan & Robert [14] illustrate in more technical terms:

> … people cannot want it until they have tried it. The concrete experience of participating in a movement is crucial, meanings and value being formed after the experience not before it. (p.31)

Similarly, Guskey [15] makes the point that educators do not typically change their own beliefs from most professional development opportunities. Their practice is only likely to change when they see evidence that the change positively affects student learning.

While familiar, the authors have also identified several challenges which dogged the experience.

CHALLENGES

Stuart and Tatto [16] noted that "every initial teacher preparation program has to operate within certain structural and institutional parameters. Decisions have to be made about length and location of the course, its timing within a teaching career, and the place of the practicum. …. Resource constraints are also relevant to these decisions". This is certainly true for the DCHE CMT. In the process of implementing its SMP to build up its CDIO capability, the team faced several challenges, and these are briefly discussed below.

Duration of CT Program

The 1-week program is a compromise between manpower needs for deployment as soon as possible, versus a more fully-trained new faculty able to "hit the ground running', so to speak. Manpower demand is often unpredictable, due to sudden resignation or other factors such as maternity leave; that results in urgent need of new faculty to fill the void. A new faculty, upon recruitment, is required to fill a teaching void almost immediately, leaving very little time for any preparatory work other than the 5-day induction program.

Balance between time for CT course, SMP and other tasks

There is also often insufficient time for a new faculty to attend all the trainings within the first year of his/her joining the Polytechnic. Besides teaching, a new faculty is laden with various committee work and familiarization with administrative demands such as laboratory safety protocols, purchasing procedures, student counselling. This often overwhelms new staff.

Timetabling

Our experience of the past year has proved that it is very difficult to pair-up a new or returning faculty with experienced CDIOers. Various constraints, including the need to block-off selected time slots for the conduct of common modules and key individuals for various committee works meant that the degree of freedom that remains in any timetabling effort is very limited. This is therefore difficult for the CMT to successfully pair-up the teaching team for OJT in CDIO. It is equally challenging to arrange for shadowing of a CDIOer by the new faculty.

Modules already CDIO-enabled

The first set of CDIO skills, such as teamwork and communication, are the “low-hanging fruits” that were already very well embedded into the curriculum during the early days of the revamp exercise three years ago. See for example [5], [6]. Similarly, the C-D-I-O skills also readily lend themselves for integration into various ”dedicated” modules such as *Product Design and Development* [7], and *Final Year Project* [10]. These modules have already been infused with the CDIO standards and skills. When the module is passed on to a new or returning faculty, it does not offer much opportunities to introduce any more new CDIO skills.

Lack of Faculty Experience in Certain CDIO Skills

Some CDIO skills (e.g. displaying global mindset, understanding of foreign culture, or technical entrepreneurship) are relatively more challenging for faculty to infuse into their respective modules. This largely reflects the lack of exposure of the part of the faculty themselves, mainly due to lack of opportunity whether in the present appointment or past job experience. It would indeed takes time to build up faculty competency in these areas, requiring a well-planned and effective faculty professional development program.

Lack of Faculty Experience in Reflective Practice and Other Skills

Many of the existing faculty, including some of the experienced CDIOers, have not been trained in reflective practice. Some experienced CDIOers also lacked facilitation skills in coaching and mentoring new faculty. Faculty also lack facilitation skills as well as skills in conflict management.

THE PATH FORWARD: PROFESSIONAL DEVELOPMENT FRAMEWORK

The previous sections outlined the DCHE CMT’s SMP which is aimed at inducting a new faculty in his/her CDIO capability. Looking forward, the CMT has recognised the need to continuously strengthen such capability via an effective professional development (PD) program. Again, to quote Stuart and Tatto [16], who said that “... the professional preparation of teachers is seen in terms of life-long learning, where initial training, induction, and in-service development are seen as part of a continuum”. Figure 4 below outlines a proposed PD framework that ties in capability and competency building of faculty with the long-term needs of the Diploma in Chemical Engineering, consistent with the organizational needs of Singapore Polytechnic.

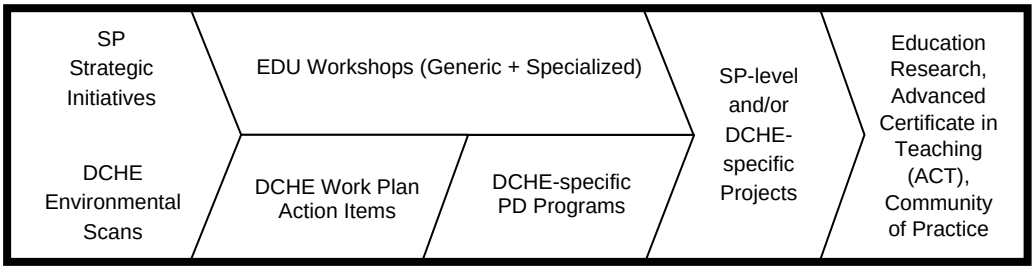

Figure 4. Proposed DCHE Professional Development Framework

The DCHE CMT regularly conducts environmental scans for changes in its operating environment that affects its curriculum, for example, increasing importance of soft skills and chemical product design that led to its adoption of CDIO back in 2007. From the results of the environmental scans, along with SP-wide strategic initiatives (i.e. those impacting all diplomas), the CMT formulates its action items through its annual work plan seminar. From

here, the CMT identifies the specific core competency that faculty needs, for example, skills in chemical product design and sustainable development.

Where competencies can be developed in-house via available EDU programmes, (for example, design thinking) the CMT will again partner with the education advisors and Academic Mentors to jointly conduct the PD programs. Here, as in Figure 2, generic knowledge and skills will be contextualized with examples from chemical engineering. However, for specific programs related to development in chemical engineering (such as process intensification), the CMT with the assistance of the Training Manager will source for the relevant PD programs outside campus.

The long-term goal for the above PD framework is to enable faculty to continually engage in educational research whereby the technical expertise are always developed with a pedagogic mindset; hence ensuring that any curriculum development effort is properly aligned with the CDIO framework. Faculty can further hone their CDIO skills by participating in selected communities of practice, professional development programmes (e.g., in-house Advanced Certificate in Teaching Practice, specialized workshops, etc), and participation in educational conferences both locally and overseas. In their learning journeys, faculty will be encouraged to maintain reflective practice in order to make the necessary transfer of learning to the real world of situated practice.

CONCLUSIONS

There is no consensus on the best way to prepare teachers. Stuart and Tatto [16] noted that "programs evolve, change, and develop out of the local context and in response to the perceived need of the time and place." This paper has presented a framework for rapidly building up the CDIO capability of new and returning faculty, and has proposed a professional development framework based on alignment with overall institution development needs, program requirements as well as individual faculty's competency needs. Though based on the experience of the Course Management Team of the Diploma in Chemical Engineering, we believe that the approach is practically useful for others who face similar challenges in attempting to build up the CDIO capability of their faculty.

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Biographical Information

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