CDIO EXPERIENCE FOR NEW FACULTY: INTEGRATING CDIO SKILLS INTO A STATISTICS MODULE

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ABSTRACT

Over the past three years, various CDIO skills such as teamwork and communication, personal skills and attitudes (e.g. critical and creative thinking, holding multiple perspectives) have been introduced into various technical modules for the Diploma in Chemical Engineering (DCHE) in Singapore Polytechnic. Skills in conceiving, designing, implementing and operating a process, product or system using chemical engineering principles have also been integrated in the three-year curriculum.

As part of its CDIO implementation plan, the course management team for DCHE is integrating other CDIO skills such as experimentation and knowledge discovery, and professional skills and attitudes (e.g. ethical practice) into the curriculum.

In this paper, we will be discussing the CDIO experience of a new faculty and how this is achieved through a professional development programme to support the initiative. The programme starts with enrolment of a new faculty into a Certificate in Teaching (CT) course, to be completed within one year. A key feature of the CT course is the need for a new faculty to conduct an action research project as partial fulfilment of the course.

Specifically, this paper focuses on the action research project of a new faculty to introduce suitable CDIO skills into a Year 3 module entitled *Quality Management and Statistics*. The main CDIO skills introduced are experimentation and knowledge discovery, whereby students are required to formulate hypotheses in verifying experimental results under a simulated real-world task scenario in a laboratory. The students need to carry out a series of experiments coupled with statistical analyses to either confirm or nullify the hypotheses. Based on the analysis of their results, the students are also expected to make relevant inferences, and provide suggestions/solutions to resolve the problem in the simulated task scenario.

This paper presents the approach taken in conducting the action research and shares preliminary students' experience in learning the module, particularly in forming their hypotheses. The new faculty's own reflection of his experience in re-designing the learning tasks using CDIO will also be presented.

KEYWORDS – Action research, chemical engineering, CDIO Skills, professional development, integrated curriculum

INTRODUCTION: DESIGNING THE NEW FACULTY LEARNING EXPERIENCE

The Diploma in Chemical Engineering (DCHE) program in Singapore Polytechnic (SP) adopted the CDIO framework as the basis for its curriculum since 2007 (Cheah, [1]). Over the last several years, various CDIO skills such as teamwork and communication, personal and professional skills and attitudes, critical and creative thinking, etc have been introduced in various core modules in the 3-year diploma program (Cheah and Sale, [2]). Skills in conceiving, designing, implementing and operating a process, product or system using chemical engineering principles have also been covered (Cheah and Ng, [3]).

In order to sustain the CDIO capability of the faculty, especially over the past 3 years where many new faculty had joined the institution; the DCHE Course Management Team (CMT) has collaborated with the Department of Educational Development (EDU) to introduce them into the CDIO engineering educational framework. This becomes part of the DCHE's faculty professional development (PD) program. Part of this PD program is the Structured Mentoring Program (SMP) introduced by Cheah and Singh [4], shown in Figure 1 where the Certificate in Teaching (CT) course, among other approaches, is used to introduce new faculty to DCHE.

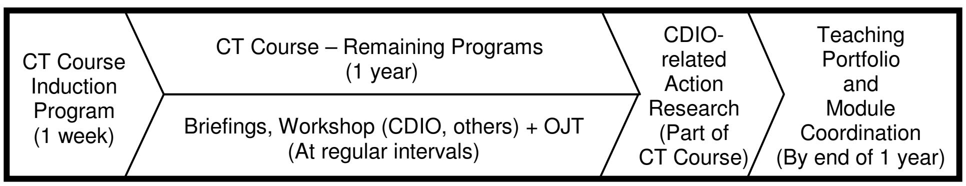

Figure 1. Structured Mentoring Program (SMP) framework for DCHE

The SMP serves to engage new faculty in a multi-prong approach to "jump start" their CDIO competency. A key feature of the initiative is the setting up of a Teaching and Learning (T&L) Unit staffed by experienced CDIO implementers (known as CDIOers) serving as Academic Mentors to new faculty. The CMT and T&L Unit have identified the action research project in the CT course as a useful means to introduce them to CDIO. Under the new PD initiative, the CMT undertakes a more proactive role by working closely with both the new faculty and EDU education advisor in completing the action research project. This essentially entails that we align the CDIO requirements with the action research project executed by the new faculty under the guidance of an experienced "CDIOer" and EDU education advisors.

In this approach, a new faculty undergoes a parallel track of coaching and mentoring by both the Academic Mentor and EDU education advisor. Over the course of a year, the new faculty proceeds to complete his/her CT course, while at the same time being mentored on how to become an effective teaching professional.

The SP Certificate in Teaching (CT) Course

New faculty to Singapore Polytechnic are typically hired from the relevant industries. Many of them lack practical teaching experience. To better prepare them for the academic environment, the new faculty are required to complete a Certificate of Teaching (CT) course over a 12-month period. The first segment is a 5-day induction program which they are supposed to complete before they are allowed to teach. At the end of the 5 days, they are then deployed into full-time teaching. The induction program serves to equip a new faculty with some basic pedagogic skills before he/she begins teaching, and make for a smoother (hopefully) transition from the industry to academia.

The rest of the CT course is spread across the entire academic year, which covers topics such as writing good learning outcomes, designing active learning activities, designing assessments, etc; all carefully designed to hone a new faculty's pedagogic literacy. A new faculty, who would have started teaching by then, attends various remaining segments of the CT course during timetabled hours.

One major highlight of the CT course requires the faculty to design and execute an action research project. The main aim is to encourage a faculty to be able to reflect critically on his/her practices (Schon, 1983, [5]). One cannot deny that new teachers are constantly gaining new experiential insights as they grapple with challenging teaching and learning situations. During such episodes, many teachers will question their pedagogic abilities and efficacy (Cady et al, [6]). If action research is executed properly in a collaborative environment, it will allow new teachers to learn from the expertise of their colleagues while at the same time honing their own pedagogic literacy and practice. Action research is meant to be non-threatening and non-evaluative. More importantly, action research allows the quality of a faculty's reflections and actions "to integrate concrete teaching experiences, models, and strategies of others, and principles of research in teaching into an integrated whole" (Haley, M et al, [7]). This will, we believe, lead to better teaching and learning effectiveness and an increase in self efficacy which would suggest that the learning experience of our students will be enhanced.

The CT course is conducted by EDU education advisors, and requires frequent meetings between the new faculty and the education advisor to reflect and discuss progress of his/her work. All CT participants are then expected to showcase their work including the action research project they conducted in a Teaching Portfolio.

Mentoring by Experienced CDIOers as Academic Mentors

The Academic Mentor coaches new faculty via a series of briefing sessions, on diverse topics starting from the SP Education Model, DCHE course philosophy, and of course, the CDIO Framework. The new faculty are briefed on the "nuts and bolts" of CDIO, including the changing educational landscape leading to the adoption of CDIO, the rising importance of chemical product design, application of the 12 CDIO Standards in the context of polytechnic education, etc. The Academic Mentor also arranges for the new faculty to attend workshops on underpinning knowledge of CDIO skills conducted by EDU education advisors.

Supplementing such briefings are on-the-job (OJT) training for the new faculty, usually in the form of pairing new faculty with an experienced CDIOer in the facilitation of laboratory activities infused with CDIO skills. Here the new faculty gets to understand first-hand how the various concepts learnt in the CT course are translated into practice in the chemical engineering context and develops a deeper understanding of the CDIO approach.

The new faculty (who is the first author of this paper) is also briefed on the approach taken by DCHE to integrate a selected CDIO skill throughout its 3-year curriculum. The "standard" DCHE CDIO integration model as shown in Figure 2 (Cheah and Sale, [2]) serves to systematically introduce various CDIO skills into selected core chemical engineering modules. In DCHE curriculum, students progress through their years of study by following a stage (semestral) system where they are expected to do and complete certain modules at a particular stage before they are allowed to move on to the next stage. Broadly, the approach advocates introducing and teaching students specific skills in Year 1 to create the necessary awareness, which are then extensively practiced in Year 2. By Year 3 they are expected to be able to utilize the skills where appropriate and display the required skill transfer, for example, by applying them in other core modules, as well as through the execution of their final year capstone projects.

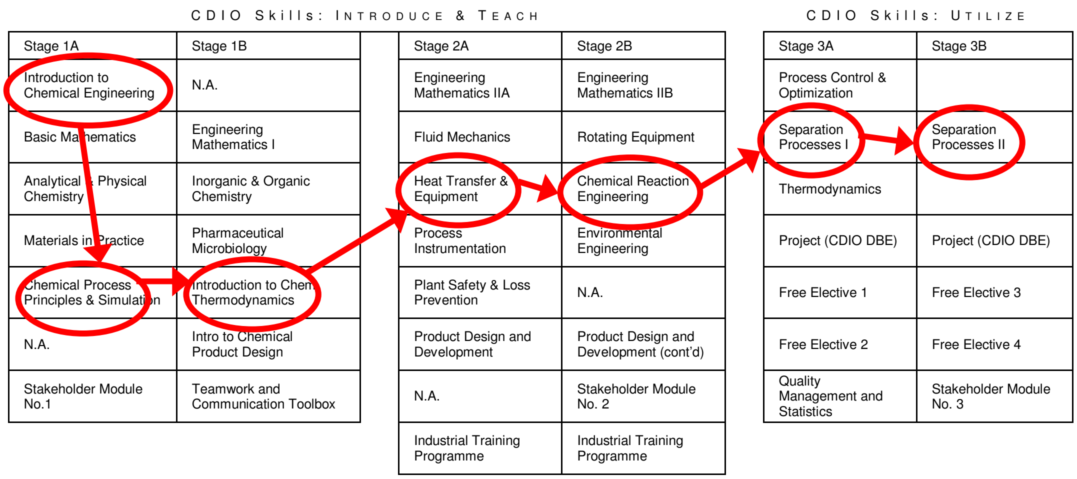

Figure 2. Integrating CDIO skill across a three-year DCHE curriculum

DEVELOPING NEW FACULTY CDIO COMPETENCY: INTEGRATING CDIO SKILLS INTO A STATISTICS MODULE

As shown in Figure 1, the outcome of the completion of the new faculty's CT course is a Teaching Portfolio showcasing his action research work. In this case, the new faculty has been tasked to teach the Year 3 core module *Quality Management and Statistics*. The Academic Mentor works closely with the new faculty in identifying a suitable component of his module materials for integrating selected CDIO skill(s) as well as the appropriate CDIO standards. The team then discusses with EDU education advisor the feasibility and possible topics for action research. The learning activity re-design effort follows the now-familiar approach employed in DCHE: starting with writing clear learning outcomes of student learning (Sale and Cheah, [8]), using scenarios to provide real-world context to student learning (Cheah, [9]), and crafting active, experiential learning activities to engage them.

Evaluating Students' Experience through Action Research

Our discussion on possible topics in the module leads us to decide that "Experimentation and Knowledge Discovery" can be introduced. An assignment for students to practise these skills can be designed that also serves as the basis for the new faculty's action research project.

The main research objectives of the project would include the following:

1. To probe the proficiency of students in transferring and applying knowledge, specifically in terms of hypothesis formulation and experimentation, gained from *Bioanalytics* module, a technical Year 2 core module, to the Year 3 non-engineering *Quality Management and Statistics* module.

2. To evaluate the effectiveness of the real-world scenario-based assignment in enhancing students' learning experience leading to a deeper working knowledge of the module's technical fundamentals.

The new faculty worked closely with both the education advisor and Academic Mentor in designing the learning task for the assignment, oversaw its execution and followed up on its evaluation; thereby developing his own competency in CDIO.

Description of Learning Task

The key feature of the learning task is that we designed it from the start to satisfy several CDIO standards, in particular Standard 3 "Integrated Curriculum", Standard 7 "Integrated Learning Experiences" and Standard 8 "Active Learning". We made use of an existing laboratory activity from another Year 3 module *Separation Processes* that the same cohort of students taking the *Quality Management and Statistics* module is required to complete.

As noted above, the main CDIO skills selected for introduction are "Experimentation and Knowledge Discovery". Other supporting CDIO skills emphasized include teamwork and communication, and personal skills and attitudes.

The CDIO skills of "Experimentation and Knowledge Discovery" had been introduced earlier to DCHE students in another Year 2 core module *Bioanalytics*. In the *Bioanalytics* module students are guided in the approach to formulate hypotheses and test them out by performing experiments in the laboratory. Hence, the students taking the module *Quality Management and Statistics* should not find the concepts of hypothesis formulation and its verification via experimentation unfamiliar.

When it comes to designing the activity for Year 3; consistent with the approach outlined in Figure 2; the team then decided to challenge the students further by requiring them to think and identify some possible issues in a simulated real-world task scenario designed by the team, followed by the formulation of the relevant hypotheses which would then be put to the acid test via a series of experiments planned and designed by the students themselves. This would not be possible without fundamental knowledge of the various chemical engineering principles which the students would have learnt in Years 1 and 2.

Specifically, in the laboratory activity for the *Separation Processes* module, students are required to make use of pycnometers (more commonly known as S.G. bottles) to determine the composition of a given ethanol-water mixture. Pycnometers are simple lab devices used to determine the density of a liquid. They are usually made of glass, matched with a uniquely close-fitting glass stopper with a capillary tube through it. The common sources of errors while using a pycnometer include the mistaken use of a non-matching pycnometer-stopper set and the mishandling of operators while drying the external surface of the pycnometer with wipes.

The team then introduced an assignment for the *Quality Management and Statistics* module that requires students to carry out more experiments on the use of S.G. bottles. Hence, the students can have more opportunities, in an active and experiential manner, to explore the use of S.G. bottles subjected to different experimental treatment combinations. The authors felt that a real-world scenario-based assignment would allow learning and development of the students to fill in the gaps between engineering education and real-world demands on engineers, which is the vision of CDIO educational framework.

The simulated scenario requires the students to role-play as a group of scientists working in a laboratory, which is owned by a local company whose main business is ethanol production. The company received complaints about sub-quality ethanol from its overseas customers and had to bear a huge loss due to compensations. The group of scientists was tasked to investigate the root cause of some erroneous ethanol purity testing results. To bring the learning task to the next level of challenge for the Year 3 students, the scenario was complicated with a number of "distractors", which are factors deemed to be insignificant in causing the erroneous testing results, to "mislead" them. The students (lab scientists) are expected to investigate and analyze the problem and propose at least two feasible hypotheses, after which, they will either confirm or nullify the hypotheses by carrying out a series of experiments involving S.G. bottles coupled with statistical analyses. By applying selected statistical analysis tools, the students do not only gain better appreciation of the accuracy of results obtained, but also a deeper internalization of the concepts covered. Through this assignment, we also hoped to achieve greater integration between the two modules.

Evaluation Methodology

Multiple sources of data collection on the students' learning experience were employed so that the results can be validated. Firstly, the faculty captured his on-site observation into a journal which he kept throughout the conduct of the student assignment. Next, a survey questionnaire was administered at the end of the assignment; to capture the impressions of all the students. Two types of questions were asked for the survey questionnaire: (a) One which the students gave their responses based on the 5-point Likert Scale where "1" denotes "Strongly Disagree" and "5" denotes "Strongly Agree"; and (b) Open-ended questions which the students gave brief opinions on their learning experience. Lastly, a focus group discussion was organized with selected students to zero in on specific issues and to probe the students' experience further.

RESULTS AND DISCUSSION

A total of 54 Year 3 students taking the module *Quality Management and Statistics* were invited to participate in the survey questionnaire. Of the students who were invited, 47 responded to the survey questionnaire, with a response rate of 87%. The focus group discussion was carried out with a group of 12 students. The following sections presents the insights gleaned from the student feedback and the faculty's own reflection.

Students Learning of the Module

Generally, the students agreed that the real-world scenario-based assignment allowed them to think more critically to identify the hypotheses to be tested, with a mean score of 4.13 ± 0.77 out of 5.00 and 90% of the students responded favourably on the Likert Scale ("Agree" and "Strongly Agree"). This is confirmed by the faculty's own observation as well as during the subsequent focus group discussions.

An example stands out during the focus group discussion where one of the students emphasized that she thought the assignment was fun as it required her group to manage their own time, team mates and resources just like working individuals do. She enjoyed having more liberty in carrying the tasks and taking more control of them. Some other student responses were as follows:

> Liked the way it was carried out, i.e. the consultation with the lab manager (lecturer) to clarify issues and propose hypotheses. It's more real.
>
> This assignment was unlike some of the "*sien*" (means boring in local terms) practicals. More fun to work with.
>
> It allowed us to think out of the box. Future assignments should be done this way.

These findings suggest that future assignments and classroom activities may be designed in a similar manner to better engage students.

What the new faculty also found most encouraging is the following statement made by one of the respondents:

> The scenario presented us with several factors. Some could be more significant, some not. We needed to think and analyze the situations critically and weigh the factors using our prior knowledge to eventually make decisions about which hypotheses to test out. I enjoyed the learning journey.

This provides an indication, if not an assurance, that real-world task scenarios are indeed an effective means to enhance the students' learning experience. Moreover, it also confirms that knowledge of chemical engineering principles is vital and plays an important role in allowing the students to make sound decisions.

When asked if they were able to effectively apply the statistical tools in the assignment, the students responded positively to it with a mean score of 4.15 ± 0.69. In addition, all participants from the focus group discussion acknowledged that it is a more motivating experience to apply statistical tests on their own data instead of a given set of experimental data, such as that during tutorials. Experimental data from their own experimentation gives them a sense of ownership and they will have the urge to find out significance of their data using statistical tests, as data on its own carries no meaning.

Teamwork and communication remains as a crucial CDIO element to get the tasks carried out efficiently and effectively. 70% of the questionnaire respondents gave a Likert Scale rating of 4 or 5, respectively for "Agree" or "Strongly Agree", with a mean score of 3.91 ± 0.87. At the time the assignment was taking place, it was the students' final semester in SP prior to their graduation, it was also the period where they were packed with a lot of assignments, reports, and not to mention, final year projects and examinations, this made teamwork and communication even more important as they really had to communicate and work collaboratively to ensure all tasks were completed for a guaranteed graduation.

Faculty Reflection

The new faculty, who was a postgraduate engineering student prior to becoming an academic in SP, perceives himself as one who was brought up and trained by the traditional teaching and learning approach, namely, teacher-centered approach. It would take a fundamental shift in the new faculty's mindset to effectively address curriculum design and deployment as a new member in the Diploma in Chemical Engineering, which had adopted the CDIO framework as the basis for its curriculum. Specifically, some of the challenges he had initially faced were:

1. Developing an understanding in CDIO skills and their potential infusion in modules.

2. Establishing competency in designing module materials and activities within a relatively short period of time.
3. Transition of mindset from a predominantly teacher-centered approach to a more student-centered learning focus.
4. Balance the numerous demand of an academic – juggling between teaching, CT course, and other administrative requirements.

Having recently completed the CT course and the action research project under the DCHE SMP (Figure 1), the new faculty felt that the mentoring process had, to a large extent, not only helped him ease into his new role as a teaching professional, but also an excellent avenue to fast-track his CDIO competency development. In the new faculty's opinion, attending various OJT trainings alongside an experienced CDIOer is an excellent way for him to pick up the "nuts and bolts" of CDIO in a relatively short time of one year. He regarded himself as a "clean sheet" to CDIO before joining SP, but after a year of CDIO immersion under the SMP, he felt that he had gained a better understanding of CDIO standards and skills. The development of CDIO competency was further supported by various EDU- or Diploma-based workshops, often jointly conducted by both EDU education advisors and academic mentors; who worked together to customize the workshops by contextualizing the learning with relevant examples in chemical engineering. In addition, the "CDIO Sharing Sessions" (organized by the DCHE CMT) to promote learning amongst colleagues have also been an important element to growing his CDIO competency.

For example, the new faculty now has a good understanding of "Integrated Curriculum" (CDIO Standard 3), "Integrated Learning Experiences" (CDIO Standard 7) and "Active Learning" (CDIO Standard 8), in particular, designing simulated "authentic" real-world learning task espoused by these standards. The new faculty can now better appreciate the importance of explicitly teaching teamwork and communication to students, again, in a way that reflects the real-world environment under which today's graduates are expected to participate in. Not only were the students more motivated to learn the module, they were also able to transfer the CDIO skills developed earlier and apply them in the current module.

In addition, the new faculty is able to put into practice much of what is being taught in the CT course, by collaboratively defining, designing, implementing and eventually using learning activities for the module *Quality Management and Statistics* he is currently coordinating.

The new faculty also sees two benefits of the DCHE's SMP. Firstly, the SMP provided a systematic pathway of progressive learning and development leading to the execution and completion of his action research project, and then his CT course completion. In the aspect of professional development, the new faculty felt that the SMP activities had helped him grow in his teaching profession via the conduct of the action research project. The provision of mentoring activities was well-coordinated and adequate. Particularly, the ideal timing of the CDIO action research project which came right after the action research workshops by EDU had allowed him to embark on the journey more confidently. "Well begun is half done", this phrase aptly describes the timely and coordinated execution of the project. He now has a deeper understanding of what action research is for, namely, to encourage teaching personnel to consistently and systematically develop a question, gather data, and then analyze the data to get insights to improve their practice (Gilles et al, [10]). The importance of action research in promoting the growth of new teachers is emphasized by Ginns et al, [11], who maintained that it could:

> … empower teachers to examine their own beliefs, explore their own understandings of practice, foster critical reflection, and develop decision making capabilities that would enhance their teaching, and help them assume control over their respective situation. (p.129)

This is further supported by Darling-Hammond and Bransford [12] who summarize that:

> Emerging evidence suggests that teachers benefit from participating in the culture of teaching – by working with the *materials and tools of teaching practice*; examining teaching plans and student learning while immersed in theory about learning, development and subject matter. They also benefit from *participating in practice* as they observe teaching, work closely with experienced teachers, and work with students to use what they are learning. (p.404)

This reflective practice had allowed the new faculty to critically reflect on the changes he made to the learning activity and the students' responses from the questionnaire and focus group discussion could be further explored for the continual improvement of the module as well as his teaching practice.

Secondly and most importantly, the new faculty felt that the work done, apart from benefiting himself, had also brought improvement and enhancement to his students' overall learning experience. That was the very reason why the new faculty chose to join the teaching profession in the first place, and that is to be able to make a difference in students and to inspire youth. Today, we are witnessing the paradigm shift away from teaching to an emphasis on learning. The transition has encouraged power to be moved away from the teacher to the student (Barr and Tagg, [13]). The teacher-centered transmission of information, such as lecturing, has been increasingly criticised and this has paved the way for a widespread growth of student-centered learning as a substitute. Harden and Crosby [14] describe student-centered learning as focusing on the students' learning and "*what students do to achieve this, rather than what the teacher does*". Gibbs [15] draws on similar concepts when he explains that student-centered learning places emphasis on learner's activity rather than passivity. From his personal experience both as a student for more than 15 years and an academic for 1 year, the new faculty cannot agree more that learning should place students on the center stage where learning can be maximized and is therefore more meaningful. As Edwards [16] illustrates in more technical terms:

> Placing learners at the heart of the learning process, assessing and meeting their needs, is taken to a progressive step in which learner-centred approaches mean that persons are able to learn what is relevant for them in ways that are appropriate. (p.37)

To the new faculty, it is an enjoyable experience to see how students like his teaching and learning activities, and exit the classroom with new knowledge gained.

SUMMARY AND CONCLUSIONS

The administration of the real-world scenario-based assignment has enhanced students' learning with the application of CDIO skills, i.e. "Experimentation and Knowledge Discovery", teamwork and communication, and personal skills and attitudes. The setting of a real-world scenario lends the learning activity a sense of authenticity which allows a deeper student appreciation of the module's technical fundamentals. Nonetheless, good teaching practices are not invariant with time, which simply means they are subject to change. Hence, reflective practices and continual improvements are essential for faculty, and this is where action research fits nicely into the scene. Taken together, the Structured Mentoring Program (SMP) is able to introduce new faculty into the Diploma in Chemical Engineering and systematically prepares them for their teaching duties. In view that a new faculty is often laden with various administrative duties besides teaching, it should therefore be noted that careful planning of mentoring activities is vital to a new faculty such that a fine balance can be struck between CT course, SMP and other tasks.

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Biographical Information

Poh-Hui Chua is a new faculty in the Diploma in Chemical Engineering (DCHE), Singapore Polytechnic. He is currently lecturing on topics including introduction to chemical engineering, and quality management and statistics. Besides teaching, he was also given the opportunity to serve as a teacher advisor for the DCHE Student Chapter, a facilitator in the Polytechnic's multi-disciplinary projects, while at the same time, under-studying project-based modules offered by experienced CDIOers.

Sin-Moh Cheah is a chemical engineer turned academic. He is the Deputy Director in Singapore Polytechnic, overseeing various applied sciences diploma, including the Diploma in Chemical Engineering. He has lectured on various topics including chemical engineering principles, separation processes, heat transfer and equipment, and chemical reaction engineering. His current portfolios include curriculum revamp, academic coaching and mentoring, and using ICT in education. His current scholarly interests are learning pedagogy, curriculum re-design and program evaluation. He held various positions in Mobil Oil Singapore Pte Ltd (now part of ExxonMobil) prior to joining Singapore Polytechnic.

Mark Nivan Singh is an education advisor with the Department of Educational Development. He is the co-ordinator of the Certificate in Teaching Programme for new lecturers and thinks he has the best job in the polytechnic. Besides running workshops for new lecturers, he is also involved in helping staff integrate various educational initiatives such as CDIO into the various diplomas. His current interests include professional development of staff and new pedagogy.

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