WORKPLACE LEARNING FOR FACULTY DEVELOPMENT TO SUPPORT A SPIRAL CURRICULUM

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ABSTRACT

This paper shares how the Course Management Team of the Diploma in Chemical Engineering of Singapore Polytechnic uses workplace learning based on the 70:20:10 Model of Learning and Development to develop CDIO competency of its teaching team to deliver its new spiral curriculum course structure. With the spiral curriculum, we hoped to enhance student learning and retention of core chemical engineering knowledge as well as the development of self-directed learning. The DCHE course structure was henceforth redesigned to feature a sequence of 4 “cross-cutting” practical modules of increasing difficulty that use CDIO-designed learning tasks to equip students with laboratory and process skills required in the chemical process industries; and delivered using “block teaching” approach. A “cross-cutting” module, in the context of the DCHE spiral curriculum, is one in which the module content straddles other modules not only within the same semester of study but also across semesters. “Block teaching” refers to teaching in a more “compact” manner, in which a 45- or 60-hour module is completed within lesser weeks instead of over a full semester (15-weeks). The combined impact of “block teaching” and “cross-cutting” modules is that more lecturers are now required to be well-versed in teaching more modules in a more intensive manner. Such condition necessitates the training of lecturers in time for delivering the new spiral curriculum. The solution is to use the 70:20:10 Model to introduce workplace learning to develop lecturers’ competency in using the CDIO approach to deliver the new spiral curriculum. An example is provided where the authors are tasked with developing a new “cross-cutting” module work in collaboration with Academic Mentor experienced in CDIO to prepare the materials, and conduct workshops for other lecturers in the teaching team.

KEYWORDS

Workplace Learning, Chemical Engineering, CDIO Standards 9 and 10

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs". A "course" in the Diploma in Chemical Engineering consists of many subjects that are termed "modules"; which in the universities contexts are often called “courses”. A teaching academic is known as a "lecturer", which is often referred to as a "faculty" in the universities.

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) at Singapore Polytechnic (SP) introduced its spiral curriculum that took effect from April 2018 for Semester 1, Academic Year 2018/2019 (Cheah & Yang, 2018). The revised course structure for the spiral curriculum (Bruner, 1960) requires a new way to teach where lecturers need to be more well-versed in several disciplines and also work closely with other lecturers. This is important to ensure that topics to be learnt are sequenced in a progressive manner so that modules within the same semester of study can mutually support one another, and modules at later semesters build on modules from earlier semesters. The DCHE Course Management Team (CMT) uses workplace learning to

help the DCHE teaching team address the challenges brought about by the implementation of the spiral curriculum.

WHAT IS WORKPLACE LEARNING?

Billet (2014) noted that over the past two decades, through interviews with workers from a range of occupations about how they learn through and for work, consistently they described it being premised upon: (i) engagement in work activities, (ii) observing and listening and (iii) "just being in the workplace". Working is therefore highly intertwined with learning and consequently, as in the words of Michael Fullan: "Learning is the Work" (Fullan, 2011). Learning at the workplace mostly occurs through work-related interactions, where skills are upgraded and knowledge is acquired and is generally described as contributing to the learning of both the individual employee and the organisation as a whole (Cacciattolo, 2015).

But exactly what is learning at the workplace, or more commonly, "workplace learning"? Lee et al. (2004) charged that there is no singular definition or one unified approach to what "workplace learning" is, what it should be, or who it is/should be for. Bratton et al. (2008) noted that the term workplace learning has become an established metaphor for capturing formal, non-formal, self-directed collective and even tacit informal learning activities. According to these authors, it is an interdisciplinary body of knowledge and theoretical inquiry that draws upon adult learning, management theory, industrial relations, sociological theory, etc.

Two other commonly encountered words are: work-based learning, and work-integrated learning, which are sometimes used interchangeably with workplace learning. In Singapore's context, the Institute of Adult Learning makes the following distinctions between workplace learning and work-based learning (IAL, 2016):

- Work-based Learning – prepares students for employment. Examples include internship and trainee arrangements, often undertaken in conjunction with classroom learning.
- Workplace Learning – develops employees through doing the work. This development leverages on learning that happens naturally in the workplace.

Lemanski et al. (2011) further classify work-based learning into three categories: Learning for Work, Learning at Work, and Learning through Work. On the hand, work-integrated learning is an "umbrella" term used for a range of approaches and strategies that integrate theory with the practice of work within a purposefully designed curriculum (Patrick et al., 2009). Table 1 shows the broad comparison between formal learning in educational institutions versus that in the workplace (Tynjala, 2008). Table 2 the comparison between work-based learning and workplace learning (IAL, 2016). Table 3 provides the benefits of workplace learning to both employers and employees (Haan & Caputo, 2012). Billett (1995) highlighted some of the factors limiting the efficacy of workplace learning, as shown in Table 4.

THE CHALLENGE OF TEACHING THE DCHE SPIRAL CURRICULUM

The revised DCHE course structure is shown in Figure 1. A key feature of the revised DCHE course structure is the introduction of modular certificates (MCs) for selected modules, one for each semester of study. There are two semesters in each academic year. The MCs form the series of "stackable credentials" available to adult learners, who want to obtain some form of academic recognition for their skills and competencies. A credential is considered stackable when it is part of a sequence of credentials that can be accumulated over time to build up an individual's qualifications and help him or her move along a career pathway or up a career ladder to different and potentially higher paying jobs (CORD, 2017).

One of the main challenges in implementing the spiral curriculum is the way teaching of modules will be carried out. While "standalone" in the sense of administrative matters, such as module codes, timetabling and examination, the integrative nature of spiral curriculum necessitates that a given module is to be tightly "bound" to other related modules. We termed such modules as "cross-cutting" modules, where the module content straddles other modules not only within the same semester of study but also across semesters. There is one "cross-cutting" module per semester in Year 1 and Year 2, i.e. total of 4 modules.

Table 1. Comparison between Learning in Formal Education and in the Workplace

Learning in Formal Education	**Learning in the Workplace**
Intentional (+unintentional)	Unintentional (+intentional)
Prescribed by formal curriculum, competency standards, etc	Usually no formal curriculum or prescribed outcomes
Uncontextualized – characterized by symbol manipulation	Contextual – characterized by contextual reasoning
Produces explicit knowledge and generalised skills	Produces implicit and tacit knowledge and situation-specific competences
Learning outcomes predictable	Learning outcomes less predictable
Emphasis on teaching and content of teaching	Emphasis on work and experiences based on the learner as a worker
Individual	Collaborative
Theory and practice traditionally separated	Seamless know-how, practical wisdom
Separation of knowledge and skills	Competences treated holistically, no distinction between knowledge and skills

Table 2. Comparison between Work-based Learning and Workplace Learning

Characteristics	**Work-based Learning**	**Workplace Learning**
Driver / Owner	Educational institutions	Employers
Partnerships	Educational institutions as Driver may partner with: • Employers to provide the internship/industry attachment • Consultants	Employers as Driver may partner with: • Consultants • Educational institutions (e.g. online literacy training)
Participants	Students / Trainees / Learners completing a qualification	Employees
Purpose	To expose participants to meaningful and relevant workplace experiences to better connect their learning to the workplace and deepen their skills, before graduation	To address skills gaps, improve performance and develop staff
Time	• Part of a qualification • Time in the workplace varies according to different educational institution's industry section requirements	• Ongoing • Specific work/business/ performance related outcomes often tied to a stipulated period of time dictated by employer

Outcomes for driver	• Qualification that represents skilled and work-ready graduates • Projects undertaken in the workplace are a source of holistic, authentic activity/service/ product that can be used for learning and assessment purposes	• Improved performance • Improved professional judgement • Development of a learning culture that supports innovation • Flexible, professional development appropriate to individual and collective (e.g. team) needs

Table 3. The Benefits of Workplace Learning and Skills Development

Benefit to Employers	**Benefit to Employees**
1. Improved productivity and growth – high literacy skills mean a more flexible workforce that can adapt to new technologies and processes quickly and effectively 2. Improved revenue per employee 3. Improved income – a company can increase its income by increasing its output by changing one of four factors: resource, physical capital, technology of human capital 4. Improved product cycle time 5. Cost savings – through improved efficiencies and reduction in error 6. Improved sales 7. Improved product quality 8. Improved health and safety records 9. Improved employee retention – training opportunities can often lead to enhanced employee morale and learning culture within a company 10. Improved knowledge transfer among employees 11. Better communication – as morale improves due to literacy gains and employees improve their skills, communication within the organization often changes for the better	1. Higher income – there is a strong association between literacy skills and income 2. Low incidence of unemployment – improved literacy makes employees less vulnerable to lay-off and displacement, and if they are laid off they find it easier to get new jobs 3. Higher labor market participation – well educated and trained individuals have more and better employment opportunities 4. Improved job security and enhanced job opportunities – workplace learning programs enable employees to work smarter and better, and, ultimately to take on increase responsibilities 5. Improved self-confidence – employees who improve their literacy skills gain the ability and confidence to empower themselves 6. More training – individuals with higher literacy skills and/or education are more likely to receive further training 7. New attitudes – employees tend to experience significant positive change in attitudes when they take part in workplace learning programs 8. Broader benefits – employees who gain literacy through their workplace take their improved communications and teamwork skills home and into their communities

`Table 4. Factors Limiting Efficacy of Workplace Learning

Limiting Factor	**Consequence and (possible rectifying response(s))**
Undesirable knowledge	• Inappropriate learning outcomes • (Selection of circumstances and expert others)
Access to activities	• Development of knowledge inhibited by paucity of experience • (Develop a learning curriculum to allow a pathway of experiences - from simple to complex, but also those that reveal the entire characteristics of work activity)
Reluctance of experts	• Limits on access to expert guidance may reduce modelling, coaching and support • (Establish conditions whereby experts are encouraged to act as mentors and guides)
Absence of expertise	• Limits on access to expertise will reduce guidance and support • (Provide access to various forms of expertise) • (Assist making external expertise relevant to particular circumstances)
Knowledge which is opaque	• Depth of understanding may be inhibited if knowledge is remote from learner • (Making explicit what is hidden) • (Use of instructional interventions to make knowledge accessible)
Instructional media	• Limits on types of knowledge and their embeddedness in practice • (Provide authentic experiences initially) • (Integrate instructional interventions with authentic experiences)

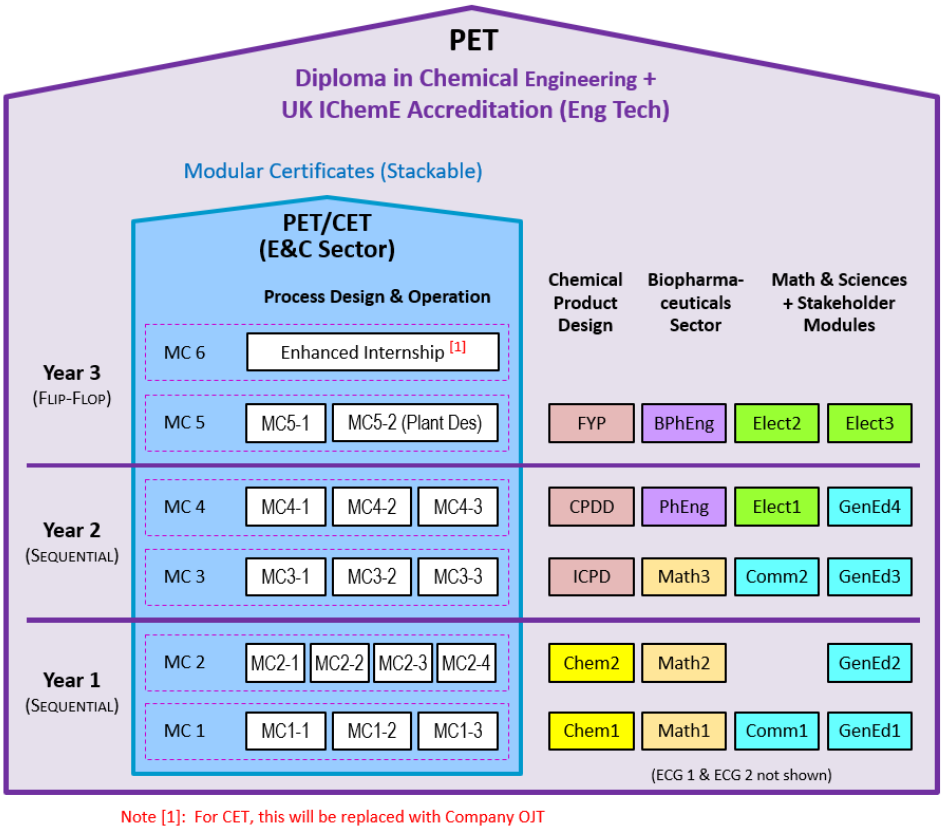

Figure 1. Revised Course Structure for Chemical Engineering with Spiral Curriculum

To facilitate the sequencing of topics in each semester, we use "block teaching" to align and sequence the core modules that are intertwined with the "cross-cutting" module. In such "block teaching", coverage of the core modules will be done in a more "compact" manner, in which a 45- or 60-hour module is completed within lesser weeks instead of the usual 3 or 4 hours per week over a full semester (15-weeks).

Our spiral curriculum was introduced in Semester 1, Academic Year 2018/2019 in April 2018. We rolled out "block teaching" in Semester 2, Academic Year 2018/2019 for our Year 1 students. The teaching schedule for the modules in MC2 is shown in Figure 2.

<table>
<tr><td colspan="20">Week No: Semester 2, Academic Year 2018/2019</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr>
<tr><td colspan="7">Laboratory & Process Skills 2</td><td rowspan="4">MST</td><td colspan="3" rowspan="4">Term Break</td><td colspan="8">Laboratory & Process Skills 2</td><td colspan="2" rowspan="4">Sem Exam</td></tr>
<tr><td colspan="5">Core DCHE 1</td><td colspan="8">Core DCHE 1</td></tr>
<tr><td colspan="4"></td><td colspan="3">Core DCHE 2</td><td colspan="7">Core DCHE 2</td><td></td></tr>
<tr><td colspan="4"></td><td colspan="3">Core DCHE 3</td><td colspan="8">Core DCHE 3</td></tr>
</table>

Figure 2. Revised Course Structure for Chemical Engineering with Spiral Curriculum

As an example, consider MC2 for Year 1 students, with the "cross-cutting" 45-hour module *Laboratory and Process Skills 2*.This module was developed by the two authors. This module provides, in an integrative manner, the hands-on activities for topics covered in the 3 core modules (60-hours each) within the same semester, namely *Chemical Engineering Thermodynamics, Fluid Flow and Equipment*, and *Heat Transfer and Equipment*, shown as *Core DCHE 1*, *Core DCHE 2* and *Core DCHE 3* respectively in Figure 2 and delivered in "block teaching" format. Activities in *Laboratory and Process Skills 2* are designed to closely

sequence the topics in *Core DCHE 1*, *Core DCHE 2* and *Core DCHE 3*. This "cross-cutting" module also "backwards integrates" with learning from modules in previous MC1 (such as *Introduction to Chemical Engineering* and *Laboratory and Process Skills 1*); as well as "forward integrates" to support the acquisition of new knowledge from modules in later MC3 (such as *Process Instrumentation and Control*, *Process Operations Skills 1*).

THE AIM OF THIS WORK: DEVELOPING FACULTY COMPETENCY

In this paper, we are concerned with workplace learning for our lecturers. A key challenge of a spiral type course structure is that more lecturers are now required to be well-versed in teaching more modules in a more intensive manner. This is in contrast to previous course structure whereby each lecturer tends to focus on teaching 1 or 2 modules only. These lecturers may only have academic knowledge about the topics they are now required to teach, acquired many years back during their university days. More importantly, many of our lecturers do not possess extensive working experience in all chemical plant operations, and as such will have difficulty relating the topics in the spiral curriculum to real-world work situations.

CDIO Standards 9 and 10 relate to developing faculty competency so that can deliver such a spiral curriculum. More specifically, lecturers need to acquire the background technical knowledge in order to deliver the many modules with activities designed based on integrated curriculum and integrated learning experiences designed using the CDIO Framework. For example, a lecturer who had been teaching *Core Module 1* in the past must now be acquainted with the topics in *Core Module 2* and *Core Module 3*, in order to be able to effectively facilitate student learnings in their learning tasks in *Laboratory & Process Skills 2*; which contain elements of all 3 core modules.

Like other employees in today's world, there is a lack of time to attend full-time re-training away from work. Furthermore, such training programs are usually expensive, and availability may also clash with a lecturer's teaching commitments. To this end, we turn to the 70:20:10 model for workplace learning so that lecturers learn on the job.

WHAT IS THE 70:20:10 MODEL FOR WORKPLACE LEARNING?

The 70:20:10 Model is a learning and development model in which 70 percentage of learning happens in the workplace through practice and on-the-job experiences; 20 percentage comes through other people via coaching, feedback, and networking; and 10 percentage is delivered through formal learning interventions. It is a model that is easy to understand but equally easy to misunderstand. The 70:20:10 concept makes intuitive sense, as most of what employees learn, they learn on-the-job during the course of doing their work - that is where they spend most of their time. Practical examples of 70:20:10 are shown in Table 5. However, there appeared to be inconclusive "evidence" regarding the origins of the 70:20:10 rule (Kajewski & Madsen, 2012). Despite the lack of empirical data supporting 70:20:10, the percentages remained popular, widely quoted and used by many organizations. As noted by Arets et al. (2016), it is not about the fixed ratio, but rather, it is all about the mix in learning approaches that can be designed to bring about change. The numbers 70:20:10 merely served as a useful reminder that most learning occurs in the context of the workplace rather than in formal learning situations and that learning is highly context dependent.

Blackman et al. (2016) who studied the model for its effectiveness as a model for middle management capability development in the Australian public sector, cautioned that it is important the elements in the 70:20:10 model should not be perceived to be implemented in isolation. Rather, an integrated and complementary approach must be adopted.

Table 5. Practical Examples of 70:20:10

70 – Learn & Develop Through Experience	20 – Learn & Develop Through Others
• Apply new learning in real situations • Use feedback to try a new approach to an old problem • New work and solving problems within the role • Increased span of control • Increased decision making • Champion and/or manage changes • Cover for others on leave • Exposure to other departments/roles • Take part in project or working group • Coordinated role swaps or secondments • Stretch assignments • Interaction with senior management, e.g. meetings, presentations • Day-to-day research, web browsing • Leadership activities, e.g. lead a team, committee membership, executive directorships • Cross-functional introductions, site/customer visits • Research and apply best practice • Apply standards and processes, e.g. Six Sigma • Work with consultants or internal experts • Internal/external speaking engagements • Budgeting • Interviewing • Project reviews • Community activities and volunteering	• Informal feedback and work debriefs • Seeking advice, asking opinions, sounding out ideas • Coaching from manager/others • 360 feedback • Assessments with feedback • Structured mentoring and coaching • Learning through teams/networks • External networks/contacts • Professional/Industry association involvement or active membership • Facilitated group discussion, e.g. Action Learning
	10 – Learn & Develop Through Structured Courses
	• Courses, workshops, seminars • eLearning • Professional qualifications/accreditation • Certification • Formal education, e.g. University, Business School

AEEM (Adding, Embedding, Extracting Model) for workplace learning (Figure 3) is a useful model that can be used for exploiting development opportunities in the workplace and making informal learning more effective (Jennings, 2014).

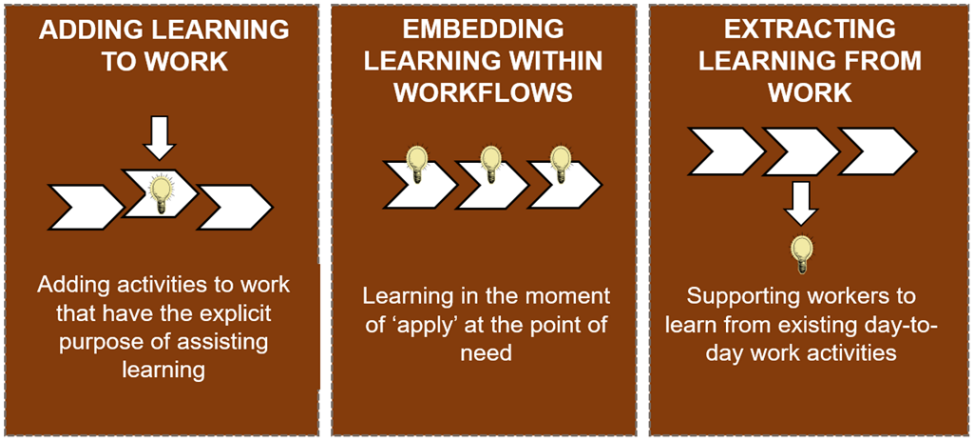

Figure 3. The Adding, Embedding, Extracting Model (AEEM) for workplace learning

Implementation of workplace learning can be enhanced with the use of proper performance support (Arets et al., 2016). Rossett & Schafer (2006) define performance support as "a helper in life and work" that provides "a repository for information, processes, and perspectives that

inform and guide planning and action". Performance support comes in many forms whether it is getting guidance via a checklist, common time slot for meetings, help desk, access to experts, etc.

WORKPLACE LEARNING IN DCHE USING THE 70:20:10 MODEL

The approach taken by the DCHE Course Management Team (CMT) is to use the 70:20:10 Model to introduce workplace learning to build up staff capability in chemical process plant operations. The 70:20:10 Model had been introduced by the SP Management recently to build up staff capability using an Individual Development Plan (IDP) where each lecturer plans for his/her personal and professional development. The IDP is to be used by a lecturer for any new teaching and learning needs, e.g. develop a new module, lead a project, or any other work-related competencies.

Workplace learning based on the 70:20:10 model was used to address the challenges brought about by the "cross-cutting modules" and "block teaching". The DCHE Course Chair formed three curriculum development teams, one for each year of a study led by one CMT member. All lecturers involved in the curriculum development work used the IDP to capture his/her developmental needs as part of their training records. Table 6 shows the work done in the three stages of the AEEM, using the "cross-cutting" module *Laboratory and Process Skills 2* as an example.

Table 6. Examples of Work Done in New Module Development

Adding learning to work	Embedding learning within workflows	Extracting learning from work
As members of the Year-1 Curriculum Development Team to rationalize, streamline, and sequence the content for "block teaching" in consultation with Senior Academic Mentor Time is set aside (Wednesday, 1 – 5 pm) during the developmental phase so that all involved do not have teaching duties during this period, hence can meet up for discussions	Lecturer in charge of developing an activity prepare suggested lesson plan for the activity, model answers and sample calculations, along with brief guidance notes Lecturer in charge of developing an activity conduct a boot camp for the rest of the teaching team, at least 2 weeks before the start of the semester On-going consultation with lecturer developing content: Just-in-time clarification (e.g. calculations or result analysis), updates on errors previously not spotted	Carry out regular updates among teaching team members via email, after every activity, on new learning if any, or insights Conduct After Action Review of the entire module at the end of the semester, identify areas of improvement, prepare new resource needs, if any Prepare facilitation notes based on teaching experience during the entire duration of the pilot launch, to assist in the next run of the module

Working with two other lecturers, the authors lead the development work for the module *Laboratory and Process Skills 2*, and together, the team designed 11 activities for students in Year 1, Semester 2. Preparing the teaching team for the delivery of the new module was quite extensive. The teaching team for the module is made up of eight lecturers, comprising three who developed the module (i.e. the authors and one of the two lecturers mentioned earlier) and five other lecturers who were not involved in the module development. Three of these five lecturers were full-time staff while the remaining were adjunct lecturers. The lecturer who developed an activity took the lead to provide proper performance support for the rest of the teaching team. The first author, for example, conducted a 3-hour boot camp for the three

activities that he designed. To help the teaching team, he also drafted some brief guidance notes and prepared model answers for each activity. Similar performance support was provided for the remaining eight activities.

The second author, who serves as the module coordinator, takes responsibility on all administrative matters related to module development, including coordinating with the technical support team assisting in the running of each activity

REFLECTION: CHALLENGES AND LEARNING POINTS

One of the key challenges in the development of the module is that of coordination. During the earlier phase of module development, numerous discussions were carried out to scope and sequence the activities. This was done in parallel with the planning of how the "block teaching" for the 3 core modules is to be done. The development team also had on-going discussions with other colleagues who had the relevant industry/academic experience for each of the activity being developed, and worked closely with module development teams for the 3 core modules in the same semester as well as module development teams for core modules in the past and subsequent semesters to ensure industry relevance, integrativeness and progressiveness.

Another challenge is to keep all team members updated and abreast of the latest version of each activity. The 11 activities in *Laboratory and Process Skills 2* is conducted one per week over a period of 13 weeks within a 15-week semester – one week is taken up for mid-semester test (MST) during which no classes are conducted, and one week for make-up class in the event of a public holiday (Figure 2). The module is delivered to 7 classes each week. Despite the best of intentions, and having cross-checked the design of each activity, not all mistakes were picked up before the start of the semester. As it turned out, several minor mistakes were discovered during the delivery of the module.

The teaching team may not have been fully prepared to deliver each activity exactly as intended. Simply put, the lecturer who designed an activity best knows exactly how it is to be delivered. However, he/she may not be able to share every single aspect or insight required for exact delivery during the boot camps. Indeed, some insights only came to us later, at the time of our own delivery of the very activity itself. Due to timetabling constraints, the authors' own class is scheduled in the middle of the week. Hence, it is not always possible to share these insights in time with other teaching team members whose classes preceded our own.

Furthermore, to conduct numerous boot camps for a large teaching team presents its challenges due to the availability of all members, in particular, adjunct lecturers. Lecturers who are full-time staff also had other work commitments. As a result, all boot camps had to be conducted twice, so that all members are briefed on what to do for each activity. Even then, several one-to-one sessions had to be arranged for individuals who were unable to attend any session. There was also an instance where an adjunct lecturer pulled out at the last minute due to other commitments. All these translate to more time and effort for the authors, who had to ensure all members were sufficiently prepared to facilitate the learning process effectively.

The most important benefit from the development of this new module in accordance to the spiral curriculum and preparing colleagues for the module delivery was the stretch opportunity offered. It accorded much room to develop technical skills sets (particularly for lecturers who had little to no relevant process industry experience), work collaboratively and grow professionally. Colleagues who had the relevant industry or academic experience were able to develop as mentors and to help ensure knowledge continuity to younger colleagues. The teaching team had also to be willing to get out of their comfort zone and take on teaching the new module, of which some content could have been learnt only "just-in-time" from the boot

camps before they had to teach students. The other benefit gained was the enhanced understanding of the entire course structure and the content of all the related modules in the preceding semester, current semester and the subsequent semesters, that would help in teaching or future module development.

The teaching of *Laboratory and Process Skills 2* ended in end-February 2019. A meeting for After Action Review was carried out in March 2019. The entire module team got together to share their learning experience, having all facilitated a class or two for the semester. A positive climate was maintained whereby everyone spoke freely about the pluses and minuses of the first run of the module. Broadly, team members expressed satisfaction with the on-the-job workplace training that was put in place. The mutually-supporting nature of our implementation of 70:20:10 model for workplace meant that every lecturer had a role to play in training fellow colleagues and in return be trained. Lecturers teaching some of the technical topics for the first time, in particular, reported the usefulness of the boot camp. Everyone also contributed positively to ways to improve the module in the future. Looking ahead, the authors will embark on preparing some facilitation notes based on experience gained for this first round of the module run.

CONCLUSION

This paper presented an approach used to implement workplace learning for lecturers teaching the Diploma in Chemical Engineering based on the 70:20:10 Model. While many of the activities described in this paper are not new, what is new here is the way professional development for lecturers can take place, at least for the team. With the 70:20:10 Model and DCHE workplace learning through the development of the new module and preparing colleagues for module delivery, we clearly see the benefit of shifting from formal training that takes place away from work, to informal learning as part of work. The ultimate goal would be to use workplace learning and development to promote a culture of lifelong learning whereby every lecturer can be a self-directed learner, for their students.

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