CONTINUAL IMPROVEMENT IN CDIO: ENHANCING FACULTY COMPETENCY IN REFLECTIVE PRACTICE

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ABSTRACT

An increasingly popular tool used by teachers to continually update and expand their professional knowledge base and to improve their teaching practices so as to address the learning needs of students is reflective practice; which requires teachers to look at what they do in the classroom and think about why they do it, if it works and why it works; and vice versa. This paper advocated for the specific elaboration on the use of reflective practice in the CDIO Framework. It consists of 2 main parts. The first part questions of the meaning of reflective practice in the "traditional" sense as currently used in the literature. The second part proposes an "extended" use to drive continual improvement at the program level. For the first part, the paper first presents a quick literature review of reflective practice and other similar sounding words such as reflection, reflexivity, etc and strives to clarify the subtle differences among them. The paper then argues that the word 'reflection' as used in CDIO Standards 9 and 12 also needs further elaboration as they appeared to address 2 different target groups, namely students and lecturers respectively. The paper argued that clarity is necessary as witnessed by the increasing number of papers presented at International CDIO Conferences had used the terms interchangeably and can cause confusion among the CDIO community; as evidenced by the "quick-and-dirty" review on past papers retrieved from the CDIO Knowledge Library. The first part concludes with sharing of an evidence-based reflective practice toolkit from Singapore Polytechnic which had made reflective practice mandatory for all teaching staff. The second part of the paper argues for the use of reflective practice beyond individual lecturers, and advocated for use in continual improvement alongside the self-evaluation process based on the 12 Core CDIO Standards. This part briefly discusses papers from the earlier "quick-and-dirty" study to look for those with focus on program evaluation. The paper then shares the author's own approach which is derived from the metaphor of *Mirror*, *Microscope* and *Binoculars* widely used in service learning projects. More specifically, the paper demonstrates how the same metaphor can be used to guide the self-evaluation by mapping each item to the 12 CDIO Core Standards. Lastly, this paper concludes by proposing performance indicators that can be used to assist lecturers in assessing the effectiveness of his/her reflective practice process which is applicable to both teaching and learning setting as well as program evaluation.

KEYWORDS

Reflection, Reflective Practice, Continual Improvement, CDIO Standards 9, 10, 11 and 12

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 a as 'faculty' in the universities.

INTRODUCTION

In their paper, Cosgrove & O'Reilly (2019) suggested that engineering education in general and CDIO in particular, should embrace a third dimension – that of reflexivity – to complement its existing 2 dimensions of theory and practice. The author agrees with this. There is in fact an increasing mention on the use of reflections as presented in CDIO papers, either to improve students learning, enhance faculty professional development, or guide decisions in program evaluation. Often case, the word 'reflection' is used quite interchangeably alongside 'reflective practice' and 'critical reflection', and more recently, another similar sounding word: 'reflexivity'. Readers may be confused over the meaning and intent of these words, and how to use them in their own curriculum redesign efforts.

This paper will not go into any details the earlier thinking on the topic of reflection from great contributors such as John Dewey, David Kolb, Donald Schon, Jack Mezirow, Graham Gibbs, Stephen Brookfield, etc; as these had been very well covered by other authors elsewhere (see for example Fook, 2015; Finlay, 2008; Khan, 2006; Moon, 2001)

LITERATURE REVIEW: REFLECTION, REFLECTIVE PRACTICE, REFLEXIVITY

What is 'reflection', 'reflective practice', and 'reflexivity'? Often times, the words 'reflection', 'reflective practice' and 'reflexivity' are used interchangeably, even appearing in a same paper. What about other related terminologies such as 'reflective writing', 'reflective learning', 'critical reflection', 'situated reflective practice', etc? Confusion over these words had persisted over the years (Alexander, 2017).

The following widely quoted paragraph from Smyth (1992) attest to the confusion about 'reflection': "…*reflection can mean all things to all people…it is used as a kind of umbrella or canopy term to signify something that is good or desirable…everybody has his or her own (usually undisclosed) interpretation of what reflection means, and this interpretation is used as the basis for trumpeting the virtues of reflection in a way that makes it sound as virtuous as motherhood*." Another observation came from Loughran (2002) who charged that "r*eflection has developed a variety of meanings as the bandwagon has traveled through the world of practice. Its allure is caught up in the seductive nature of a notion that rings true for most people as something useful and informing in the development and understanding of, in this case, teaching and learning in teacher education practices*."

One explanation for this is because, taken literally, 'reflection' is a word we use in everyday conversations. In common-sense terms, reflection lies somewhere around the notion of learning (Moon, 2001). We reflect on something in order to consider it in more detail (e.g. "Let me reflect on that for a moment"). Usually we reflect because we have a purpose for reflecting – a goal to reach. Sometimes we find ourselves 'being reflective' and out of that 'being reflective', something 'pops up'. Moon (1999) suggests that the differences in approach are accounted for largely by different focuses – either on the process of reflection, on the purpose for it or the outcomes of reflection – in effect, how it is used. Moon (2001) further noted that "there is no point in defining reflection in a manner that does not relate to the everyday use of the word if further confusion is not to be created"; and offered the following definition: "*Reflection is a form of mental processing – like a form of thinking – that we use to fulfil a purpose or to achieve some anticipated outcome. It is applied to relatively complicated or unstructured ideas for which there is not an obvious solution and is largely based on the further processing of knowledge and understanding and possibly emotions that we already possess*."

Along the same line of reasoning, reflection can be contrasted with reflective practice. Reflection is broader and relevant to all aspects of living – it is a way of approaching an understanding of one's life and actions. Reflective practice, on the other hand, is more focused on professional practice (Fook, 2015). Eby (2000) suggested that reflective practice can be seen as a synthesis of reflection, self-awareness and critical thinking. Many writers also make a distinction between reflection and critical reflection. Critical reflection is widely attributed to Jack Mezirow, who contended that reflection may lead to transformative learning that results in new and transformed meaning schemes and perspectives (Mezirow, 1991). Fook (2015) suggested that critical reflection be considered as being a subset of reflective practice. Critical reflection, when used specifically to improve professional practice, is reflective practice that focuses on how a practice might change in order to bring about change in the social situations in which professionals work. In order to be able to critically reflect, obviously one must be able to reflect. However, not all reflective practice will lead to critical reflection – that is, to fundamental changes.

Reflexivity, like reflection, has its fair share of definitions (for example, see Fook, 2015) and objections (see for example, Alexander, 2017). It has its origin in social research and is typically associated with the ability to recognize that all aspects of ourselves and our contexts influence the way we research (Fook, 2015). Therefore, in order to be reflexive, we need to be aware of the many and varied ways in which we might create, or at least influence, the type of knowledge we use.

Finlay & Gough (2003) suggested that one think of reflection, critical reflection and reflexivity as forming a continuum. At one end stands reflection, defined simply as 'thinking about' something after the event. At the other end stands reflexivity: a more immediate and dynamic process which involves continuing self-awareness. Critical reflection lies somewhere in between. For the remainder of this paper, the author will use the term 'reflective practice' in a more inclusive manner to embrace the full spectrum from 'reflection' to 'reflectivity' (Finlay & Gough, 2003).

REFLECTIVE PRACTICE IN CURRENT CDIO STANDARDS (VERSION 3.0)

Currently, in version 3.0 of the CDIO Standards (Malmqvist et al, 2020), there are 2 mentions of 'reflection': once in Standard 11 Learning Assessment and once in Standard 12 Program Evaluation. The reference to 'reflection' in Standard 11 is towards student reflections as one of the possible ways of assessing students in their learning. On the other hand, in Standard 12 the reference to 'reflection' is with regards to 'instructor', presumably implying reflecting on the various aspects of the rest of the CDIO standards. A key question that can arise from this is: "Does faculty knows how to evaluate student reflections?" This in turn begs another question of equipping faculty with the right competency. According to Dewey (1933), reflection does not consist of a series of steps or procedures to be used by lecturers. Rather, it is a holistic way of meeting and responding to problems, a way of being as a lecturer. It involves intuition, emotion, and passion and is not something that can be neatly packaged as a set of techniques for lecturers to use (Dewey, 1933). Reflective action is also a process that involves more than logical and rational problem-solving processes.

Another related question is then: "How do we teach students reflective practice?" McLeod, et al (2015) had noted that lack of adequate training of lecturers to teach reflective practice had been an on-going challenge. Marcos, et al (2009) from their extensive surveys of the literature (comprising 50 conceptual papers, 122 articles on teacher development, and 49 teacher

accounts of reflection) found that there are lack of alignment between what had been advocated in research (models of reflection) with what teachers actually did in teaching. The authors concluded that the concept of teacher reflection on action is still very much in flux despite the many years of study.

Currently there is no explicit reference in the CDIO Standards to developing faculty capacity to engage in reflective practice as part of their professional development to improve their teaching competence, or to facilitate reflections among their students (Standards 9, 10). The next section discusses how members in the CDIO community used reflective practice in the works reported.

SOME "INVESTIGATIVE" WORK DONE: REFLECTION AS USED IN CDIO PAPERS

A literature search was carried out on 13 Feb 2021, looking for articles in the CDIO Knowledge Library using the keywords 'reflective practice', 'reflection', 'reflections', 'reflexivity OR reflexive'. The returns after 4 rounds of searching were 35, 74, 39 and 8 papers respectively. There are a total of 23 repeat returns, i.e. different keyword search returned the same papers. Removing the repeats, the final number of unique papers is 133. Each of these papers was then scanned using a keyword search 'reflect' or 'reflex' to identify if usage of words such as 'reflective practice', 'reflection', 'reflections', 'reflexivity', 'reflexive', or other related words such as 'reflective learning', 'reflection journal', 'reflective thinking', etc can be found in the full paper. Papers with none of these words but showed the 'everyday use' of the word 'reflect' for example: the "*the decision made reflected the constraint faced*…." were deemed not relevant and discarded. There is no paper with the word 'reflex'. The final number of papers that form the basis for review is then 93. All the papers did not make distinctions between the words 'reflection', 'reflexivity' etc; and just used them interchangeably – including past paper from this author! The papers were then classified into 3 baskets: looking at how the words are used in each paper: (1) improving student learning, (2) enhancing staff competency, and (3) assisting program evaluation. The results are shown in Table 1 below.

Table 1. Number of Papers and Use of Reflection (as of 13 Feb, 2021)

Purpose of Reflection	Number of Papers
Improve student learning	68
Enhancing staff competency	26
Assisting program evaluation	4

One may notice that the total number of papers in Table 1 added to more than 93. This is because some papers covered the use of reflection in more than 1 areas. Notwithstanding that, it can be seen the major use of reflection as reported by members of the CDIO Community is in improving student learning. The most frequent approach used is to require students to submit reflection journals.

The "quick-and-dirty" approach by the author obviously had its limitations. Notwithstanding the ability of the search engine in the Knowledge Library to precisely return the necessary papers, obviously a wider net can be cast to ring in more works that are captured in other databases. However, the purpose here is just to have some sensing of what is it liked "out there in the CDIO community", and therefore the author deemed that effort is sufficient for his needs.

EVIDENCE-BASED REFLECTIVE PRACTICE IN SINGAPORE POLYTECHNIC

Reflective practice had been widely used in teacher and nursing education. The main outcome of reflection as either stated or implied by most authors is learning. Loughran (2002) summed it up well, when he noted "reflection as a meaningful way of approaching learning about teaching so that a better understanding of teaching, and teaching about teaching, might develop." Boud et al (2005) suggested that learning can occur in 4 areas: (1) new perspectives on experience, (2) changes in behavior, (3) readiness for application, and (4) commitment to action. Detailed discussion of these benefits are beyond the scope of this paper, and interested readers can read up in various literature, for example York-Barr, et al (2005).

In the tertiary education such as Singapore Polytechnic (SP), many if not all, of our lecturers were hired directly from the industries. The foremost consideration for employment is the relevant work experience that they bring into the classroom, to help bridge theory and practice. These lecturers are not schooled in the practice of doing reflection in their prior professional role. Now in the educational context, they are expected to "think like a teacher", for example, in addressing challenges associated with student learning. Without reflection, a problem is unlikely to be acted on if it is not viewed as a problem (Loughran, 2002). Often, it is assumed that reflection is an introspective after-the-fact description of teaching (Ward & McCotter, 2004). However, if done incorrectly, rationalization and justification of practice may then be misconstrued as reflection.

Rogers (2001) noted that reflection is most likely to be facilitated with the use of deliberate and planned techniques. Specifically, research indicates that reflection can be facilitated through individual and group activities as well as with the use of a skilled mentor or coach (e.g. e.g. Loughran, 2002; Schon, 1987), writing assignments of various types (e.g. reflection journals, portfolios) as well as directed discussions, for example seminar group discussion (Loughran, 2002), and critical incidents (Brookfield, 1990).

Recently, SP made reflective practice a required item for all its teaching staff. This initiative was launched alongside another drive to encourage staff to take up action research, to try out different teaching approaches in one's respective module and feel what it is like to teach in a particular manner. The approach to reflective practice in SP is grounded in Schon's 'Reflection-on-Action' (Schon, 1983) and Brookfield's 4 Lenses of Reflection (Brookfield, 1995). It makes use of a series of structured questions based on a specific developmental experience (Seibert & Daudelin, 1999) to guide the reflection process. It was designed by Dennis Sale before his retirement from SP and is termed evidence-based reflective practice tool (EBRPT), which can equally be used as a guide for the design of learning events (Sale, 2020). It is termed 'evidence-based' as it involves more than personal reflections in isolation, but also other valid evidence sources (e.g. students, peers, expert mentors, surveys). When conducted thoughtfully it enables a better understanding of what is happening, and how, in terms of student learning. From this basis the lecturer can frame and enact more effective and creative instructional strategies with a high predictive capability for enhancing the learning experience and attainment levels for students (Sale, 2020).

The EBRPT is a heuristic (set of guiding principles) for conducting evidence-based reflective practice when evaluating learning experiences (e.g. lessons, modules). It specifically focuses on Reflection for 'Prediction' (i.e. pre-lesson analysis and inference and interpretation) and 'Diagnosis' (i.e. post-lesson analysis and evaluation) and on the impact of the instructional strategy in terms of evidence-based teaching framing (i.e. effective strategy/method use, application of core principles of learning). It is not exhaustive or summative in terms of

capturing all relevant features and processes relating to learning in a complex interactive classroom context. However, it facilitates a thinking process that enables appropriate analysis and subsequent inferences and interpretations about what has occurred, with what consequences (e.g. impact on learning), concerning key aspects of the learning experience. The EBRPT can be customized to any reflection needs, by modifying the list of questions based on the topic of interest. An example of the EBRPT that was used by the author for his work in implementing flipped classroom (Cheah & Sale, 2019) using Sale's Core Principles of Learning (Sale, 2015) is shown in Appendix 1.

USING REFLECTIVE FOR CONTINUAL IMPROVEMENT IN CDIO IMPLEMENTATION

Using reflections for program improvement had been reported by various contributors from the CDIO Community. To the best knowledge of the author, there are 4 papers based on his "quick-and-dirty" study as reported in Table 1. This is briefly summarized below.

Clark and Robin (2011) reported on the use of reflection in an interactive workshop to evaluate the impact of introducing CDIO across the first-year undergraduate curriculum in Aston University; facilitate by an Engineer and a Social Scientist, both of whom have expertise in Engineering Education Research and Evaluation. Edelbro et al (2017) described the use of joint (group) reflections at Luleå University of Technology in an industry engagement process to discuss the competence of graduates from the Department of Civil, Environmental and Natural Resources Engineering and future needs in the industry. This is in response to the dwindling interest from students despite a very positive prospects for professionals in the field. Gonzales, et al (2013) reported on Pontificia Universidad Javeriana's use of reflections to support its CDIO implementation in its four undergraduate programs (Civil, Electronics, Industrial Engineering and Software), which resulted in the introduction of 6 types of workspaces that support the CDIO standards and integration of competencies. Lastly, Garcia, et al (2014) presented a case study of the implementation for the Electronics Engineering program in the university.

AUTHOR'S WORK: USING REFLECTIVE PRACTICE FOR CONTINUAL IMPROVEMENT

The author had been using the CDIO Standards to inform areas of improvement needed in the Diploma in Chemical Engineering (DCHE) since it adoption of the CDIO Framework in 2007. With the mandate of SP Management that all lecturers are to engage in reflective practice, there was an epiphany on the part of this author that his work in continually improving the DCHE curriculum can benefit from an approach to reflective practice that he adopted recently: one that look at reflection at 3 levels using the metaphor of *Mirror*, *Microscope* and *Binoculars*.

This approach was initially developed for reflection in service learning projects and is widely attributed to Cooper (1997; quoted in McCarthy, 2013). This approach helps one to frame his/her reflection from different perspectives, as follows (Ferrell, 2015):

- The *Mirror* perspective asks students to reflect on the micro level: how did they, as individuals, act in the experience? How did they work within the team? Students may also reflect on their values, their assumptions and biases, and how they were influenced, challenged, or successful in their project.
- The *Microscope* perspective is dedicated to encouraging students to reflect about the project itself, including how it benefitted the community they worked in and the members

of that community. The microscope may be focused on topics such as what impacts the student's project had, how their experiential learning confirmed or contrasted with their classroom learning, and whether or not they would do anything differently if they were to do the project over again.

- The *Binoculars* perspective helps students to look at their experiences in order to reflect on their learning, including identifying areas where they could further enhance their learning and continue their development as critical thinkers. This perspective also encourages students to consider social issues on a larger scale by thinking more holistically about the outcomes of their project within a wider context.

As examples of its application, reference shall be made to the work done in studying the impact of Industry 4.0 on DCHE the details of which had been reported elsewhere (Cheah & Yang, 2018). In this adaptation, the *Binoculars* metaphor is useful in helping one to look far and forward into the external environment that can affect how a program had been designed in terms of the adequacy of its curriculum in meeting stakeholder requirements. An environmental scan was conducted using STEEP (Social, Technological, Economical, Environmental, Political) analysis to ascertain the needs for new knowledge, skills and attitudes required in the workplace as the chemical processing industries adopted Industrial Internet of Things technologies, under the Singapore Government' SkillsFuture Initiative. This had led to the redesigning of new learning workspaces and acquisition of new pilot plants equipped with smart sensors and state-of-the-art control systems. Virtual reality had been introduced as part of safety orientation, and we are in the process of adding digital twin to the learning resources. We also formulate plans for some lecturers to go for industrial attachments to update their know-how in terms of the chemical industries' use of industrial internet of things technologies to improve their chemical plant operations.

Next, the author uses the *Microscope* and advises the Course Management Team (CMT) in a major revamp in the course structure to introduce a new spiral curriculum for DCHE, which aligns to the Skills Framework for Energy & Chemicals Sector (Cheah & Yang, 2018). The *Microscope* metaphor is very appropriate as carrying out gap analysis and skills mapping is akin to the process of looking at a specimen under the microscope, in that one is moving along the course structure to identify suitable modules to integrate appropriate skills and attitudes; so that they can be systematically developed in a progressive manner to the desired levels of proficiency. The desired outcomes of each module can then be written using suitable taxonomy (e.g. Bloom). Also as part of this revamp, self-directed learning (SDL) was integrated across DCHE's 3-year curriculum, starting from Year 1 (see for example, Cheah, et al, 2019).

Lastly, the author uses the *Mirror* to evaluate his own skills in designing integrated learning experiences that integrates SDL into DCHE core modules. He also practices SDL himself by undertaking to learn story-boarding skills so as to able to design learning tasks based on digital twin for students to learn in an asynchronous manner. This effort also permits him to converse better with the programmer of the project, speaking "their languages", quite literally.

MOVING AHEAD: ENHANCING FACULTY COMPETENCY IN REFLECTIVE PRACTICE

With more and more lecturers asking students to submit reflection journals or portfolios, it is imperative that they have a clear understanding of reflective practice, and should themselves engage in reflective practice to improve their own teaching competence. Therefore, this paper suggests that use of reflection and reflective practice is made more explicit in the CDIO

Framework, not only to improve the lecturer's teaching but also for program evaluation. All lecturers must contribute to the continual improvement of a program of which he/she is very much a part of. A program is only as good as the team of lecturers delivering it.

Table 2 shows how the metaphor of *mirror*, *microscope* and *binoculars* can be applied to various CDIO Standards. Given the interconnected nature of the CDIO Standards, such "mapping" will necessarily be broad, but it is the author's belief that this will help lecturers focus better during the reflection process.

Table 2. "Mapping" of the 3 Levels of Reflection to CDIO Core Standards

Type	Focus of Reflective Practice for Continual Improvement (Standard 12)
Mirror	Faculty reflects on his/her own competence in conducting reflective practice; critically challenging one's own approach in light of the evidence obtained (e.g. use of EBRPT) in personal, interpersonal, product, process, system and service building skills (Standard 9); and skills in designing integrated learning experiences and in using active and experiential learning techniques (Standard 10). Faculty also reflects on his/her skills in facilitating students' development of their own reflective practice, as well as their reflections of how well they develop the various CDIO skills and how to assess them (Standard 11).
Micro-scope	Faculty reflects on how the course(s) he/she teaches fit into the program structure in terms of an integrated curriculum (Standard 3) or Design-Implement Experiences (Standard 5), so as to progressively develop and assess the desired skills and/or attitudes to the required levels of proficiency (Standards 2 and 11). This in turn can suggest appropriate learning activities to develop the said competency (Standard 7) and approaches to active and experiential learning (Standard 8). Faculty can also reflect on to what extent his/her own module(s) made use of competencies imparted to students in earlier stage(s) of study; and in what way his/her own module(s) contribute to furthering development of competencies in later stage(s) of study.
Bino-culars	Faculty reflects on how changes in various aspects of the external environment (social, technological, economics, environmental, etc) affect the stakeholders' requirements for the program's graduates (Standards 1, 2). These will also inform of the relevance of the topics in the CDIO Syllabus, which in turn will inform the need to review and redesign a program's structure (Standard 3), and possible also to content of Introduction to Engineering (Standard 4). This also includes the study on reconfiguring the program's learning workspaces to support the desired learning environment (Standard 6). The findings will in turn point to faculty professional development needs (via the *Mirror*, and Standards 9, 10); and a relook at various other CDIO Standards related to teaching and learning as covered in *Microscope*.

Just to be clear, this paper does not advocate the creation of another CDIO Standard. Rather, the author is drawing on his work as described earlier, and the call of Cosgrove & O'Reilly (2019) noted at the beginning of this paper, to suggest that reflective practice be made explicit in the CDIO Framework, using the metaphor *mirror*, *microscope* and *binoculars*. Being explicit serves to convey the message that it is necessary to train faculty in reflective practice, given its complex and situated nature, such that it cannot work if applied mechanically or simplistically (Finlay, 2008). This point is well captured by Larrivee (2000), who noted that: "*Unless teachers develop the practice of critical reflection, they stay trapped in unexamined judgments, interpretations, assumptions, and expectations. Approaching teaching as a reflective practitioner involves fusing personal beliefs and values into a professional identity, resulting in developing a deliberate code of conduct*." This is best done with explicit mention of faculty professional development program on reflective practice in Standards 9 and 10.

More specifically, the author would suggest that the "Description" for Standard 12 be amended to read as follows (where italics represent the author's modifications):

> "Program evaluation is a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. A CDIO program should be evaluated relative to these 12 CDIO Standards and any optional standards that it has adopted. Evidence of overall program value can be collected with course evaluations, *outcomes from* instructor *reflective practice*, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. The evidence should be regularly reported back to instructors, students, program administrators, alumni, and other key stakeholders. This feedback forms the basis of decisions about the program and its plans for continuous improvement. *Instructor should use an evidence-based reflective practice that systematically review his/her program or course(s) for areas of improvement.*"

Lastly, the author would also like to propose the use of some "performance indicators" that can assist lecturers in assessing the effectiveness of his/her reflective practice process. Without reinventing the wheel, the author finds the work of Koole, et al (2011) appropriate for this need. These authors viewed reflection as 3 phases in a cyclical process; and offered 3 "operational indicators" as shown in Table 3. In addition, Jay & Johnson (2002) in their efforts to guide teacher educators in teaching reflection to pre-service teachers, suggested a typology of reflective practice as shown in Table 4.

Table 3. Performance Indicators for Reflection Process (Koole, et al, 2011)

Aspect of Reflection Process	Indicators
Reviewing the experience	The ability to describe an event/situation adequately
	The ability to identify essential elements and to describe own thoughts and feelings
Critical Analysis	The ability to ask searching questions
	The ability to answer searching questions and being aware of the frames of references in use
Reflective Outcome	The ability to draw conclusions
	The ability to describe concrete learning goals and plans for future action

Table 4. Typology of Reflection: Dimensions and Guiding Questions (Jay & Johnson, 2002)

Dimension	Definition	Typical Questions
Descriptive	Describe the matter for reflection.	What is happening? Is this working, and for whom? For whom is it not working? How do I know? How am I feeling? What am I pleased and/or concerned about? What do I not understand? Does this relate to any of my stated goals, and to what extent are they being met?
Comparative	Reframe the matter for reflection in light of alternative views, others' perspectives, research, etc.	What are alternative views of what is happening? How do other people who are directly or indirectly involved describe and explain what's happening? What does the research contribute to an understanding of this matter? How can I improve what's not working? If there is a goal, what are some other ways of accomplishing it? How do other people accomplish this goal? For each perspective and alternative, who is served and who is not?
Critical	Having considered the implications of the matter, establish a renewed perspective.	What are the implications of the matter when viewed from these alternative perspectives? Given these various alternatives, their implications, and my own morals and ethics, which is best for this particular matter? What is the deeper meaning of what is happening, in terms of public democratic purposes of schooling? What does this matter reveal about the moral and political dimension of schooling? How does this reflective process inform and renew my perspective?

Critical reflection requires one to continually examine one's own thoughts, perspectives, biases, and actions. Lecturers new to reflective practice may initially be very uncomfortable with the process, perceiving it as a form of self-criticism. Especially when the practice is mandated by higher management, there is fear that the outcome can be used as a tool of accountability and/or competence recording (McGarr & O'Gallchóir, 2020). Hobbs (2007) in fact argued that requiring individuals to be open and honest in the context of assessment tends to provoke strategic response and often hostility. This may be the case even if the reflective process is carried in solitude, out of fear that this outcome will be used in performance evaluation should it ever become available. Not everyone may be so readily in "coming to terms" with his/her teaching experience, in particular negative ones, or one that contradicts his/her own belief, or in admitting mistake made.

For reflective practice to be useful, the author supports the stand that the outcome of reflective practice is to be used strictly for continual improvement and not for appraisal. This will encourage lecturers to reflect constructively and in a more systematic manner (as opposed to "reflecting on anything" in the broadest sense of the word), assisted by the use of metaphors and guidance questions shared earlier. There will be a progressive developmental pathway for lecturers to hone this important competency to develop into a critical thinker to continually improving one's teaching and learning, which subsequently leading them to reflect more critically on how they use the CDIO Framework for designing or redesigning a curriculum, not only within one's own module(s) but for the whole program. Such collective efforts will better drive continual improvement effort that not only bring benefits to students learning, but also help the lecturers themselves to grow professionally; and produce an up-to-date and relevant curriculum.

In his capacity as Lead Teaching and Learning Specialist in SP, the author can put together 2 staff development programs to drive the use of reflective practice in DCHE. One program can

be aimed at the DCHE Course Chair and members of the CMT. The focus here is at the diploma level, looking at change drivers in the school's operating environment and its impact on the diploma's current teaching. The *mirror*, *microscope* and *binoculars* metaphor can best be used alongside CDIO Standard 1, 3, 5, 9, 10 and 12 to identify areas in the curriculum that merit reviewing and areas where faculty competence needs to be strengthened.

The other program can focus on improving the lecturers' teaching and learning competency in the modules there are teaching. Here it is also worth noting that the Course Chair and the CMT members are also lecturers themselves, and they are also module coordinators and module team member themselves. As lecturers, everyone can use EBPRT with the *mirror*, *microscope* and *binoculars* metaphor, as part of each's action research effort. In this case, the focus is likely centred more on CDIO Standards 2, 7, 8 and 11. The lecturers can also use the performance indicators (Table 3) and guiding questions (Table 4) for self-evaluation purposes in appraising their own experience in developing competency in reflective practice.

CONCLUSION

This paper takes the position that given the importance of reflective practice in teaching and learning, and its increasing use within the CDIO Community, there is a need to establish some common understanding of the terms used. The paper also shared the approaches to reflective practice in the author's own institution and how he uses the metaphor of *mirror, microscope and binoculars* as part of his reflective practice to drive continual improvement using the CDIO Framework. The paper proposes that reflective practice should be made explicit in the CDIO Framework and provides some suggestions on how the metaphors can be used, along with broad guidance questions and operational performance indicators to help lecturers evaluate the effectiveness of their own reflection process. The author suggests that this enhancement be included in the existing Standards 9, 10 and 12, with specific references that faculty uses reflective practice to review his/her effort teaching. The aim is to assist lecturers develop their reflective practice competencies in a progressive manner much like the development of competencies espoused in the CDIO Framework; not only to improve one's teaching and learning but to also contribute effectively to a program's continual improvement.

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APPENDIX 1 Sample of Evidence-based Reflective Practice Tool

EVIDENCE-BASED REFLECTIVE PRACTICE TOOL (EBRPT)	
Topic reflected on: ***Utilizing Core Principles of Learning***	
In the learning experience, was there:	Evidence of Effectiveness *What specific Strategies, Methods and/or Resources were employed to enhance this aspect of the learning process, and how effective were they? (Based on your observation and any other feedback if available (e.g., peer observation, student feedback)*
Communication to Students of the Learning Goal/Outcomes, Purpose and Expectations	
Activation of Prior Learning and connections to new knowledge presented?	
Emphasis on Key Concepts and Principles that underpin understanding of this topic?	
Use of activities that involved Good Thinking to facilitate understanding?	
Variation in the modes and methods of information presentation and interaction?	
Application of practices consistent with Human Memory processes (e.g., chunking of content to minimize cognitive overload; rehearsal/review activities)?	
Incorporation of Formative Assessment to provide quality two-way feedback?	
Use of Deliberate Practice to enhance understanding and/or skill acquisition?	
Interactions/activities to foster a climate conducive for building rapport, encouraging Success and a sense of Fun?	
An aspect(s) of Creativity (e.g., Story, Humour, Activity, Presentation Style, Example) that significantly enhanced motivation in this learning experience?	