IMPROVING TEACHING OF SELF-DIRECTED LEARNING VIA TEACHER MODELLING

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ABSTRACT

Self-directed learning (SDL) is a higher order competency that requires simultaneous development of a myriad of interrelated technical and generic skills, knowledge and attitude. The Diploma in Chemical Engineering (DCHE) from Singapore Polytechnic (SP) used the CDIO Framework to integrate development of SDL competency into its 3-year curriculum. Explicit teaching of SDL based on the SDL Model developed by SP was done in Year 1. SDL learning tasks were purposefully integrated throughout the curriculum to enable students to develop SDL with other core skills and domain knowledge needed. While we considered the integration effort to be generally successful from findings of the 3-year longitudinal study of the Academic Year (AY) 2018 cohort, we noted a disparate level of SDL readiness amongst students. Evidence of SDL transferability was seen as students progress from Year 1 to Year 3, although some students still faced challenges using SDL in Year 3. Most students surveyed in Year 3 displayed behaviour analogous to a self-directed learner during their final year capstone projects, and used SDL when they worked on their internship projects. The literature shows teachers can positively impact student learning and engagement through behaviour modelling where thought processes are verbalised hence made visible so they can be imitated by students. This paper shares the approach taken to further improve development of SDL competency through introduction of teacher modelling in a Year 1 practical-based module. In this pilot study, the teacher models how a self-directed learner approaches learning tasks in an integrated learning session. Students then use the same approach to complete similar learning tasks in subsequent session. Survey findings showed teaching modelling was useful and improved students' understanding of how SDL can be applied and most students were able to use the same approach in the second session. From qualitative responses collected, some students seemed unable to understand how to apply SDL and needed more guidance, indicating inconsistent development of self-directedness. More than half the students seem unable to manage the negative emotions that appear upon encountering challenges. The paper concludes by sharing future works to improve the teaching of SDL in DCHE students.

KEYWORDS

Self-Directed Learning, Modelling, Chemical Engineering, CDIO Standards 7, 8, 9, 10, 11

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 "faculty" in the universities.

INTRODUCTION

This paper presents work done that strives to improve the development of self-directed learning (SDL) competency in Diploma in Chemical Engineering (DCHE) students in Singapore Polytechnic (SP). SDL is now made explicit as one of SP's six desired graduate attributes as it is recognised as an important competency needed for students to become lifelong learners. This work is built on the learning gained from past efforts from the last three years (Wong, et al; 2021; Cheah, 2020; Cheah, et al, 2019) where we used the SP-customised CDIO syllabus to define the underpinning knowledge (notable CDIO Syllabus sub-category 2.4.6) of what constitutes to SDL, and referenced the CDIO standards in the design of the various learning tasks. Findings from our previous studies, in which SDL was explicitly taught to Year 1 students indicated that not all students are able to demonstrate the level of readiness required of them at the end of their Year 1 study. We used the SDL Model promoted within SP for use by all diplomas within the institution. The model spelt out the key non-sequential steps students can undertake to become more self-directed in their learning: Plan, Select, Monitor and Evaluate. In addition, the model also highlighted two main factors students should consider when analysing their learning: metacognition and managing emotion.

The model is not without its limitations. Understandably, from the institutional perspective, it is necessary to introduce a model or framework that lecturers can easily identify with to encourage widespread adoption, and integrate SDL into all diplomas in SP. Another key finding of our previous efforts, is that a significant percentage (21.4%; n = 70) of students, from a longitudinal survey of the first cohort of students where SDL was explicitly taught in Academic Year (AY) 2018, reported they needed some help in applying SDL even as they are in the process of completing their Year 3 Final Year Project (FYP), i.e. Capstone Project, as well as their Internship Project and assignments (32.4%; n = 37). Some of the comments below highlighted the differences in terms of SDL-readiness among the Year 3 students on SDL in their FYP or Internship:

> "*There should be more guidance and resources available*."
>
> "*Guide them on which websites to find the articles needed*".
>
> "*Some prompts from lecturers would be very helpful. Since an issue with self-directed learning is that students often get lost and are not too sure what the best course of action would be. As such, lecturers could help guide students in the right direction without directly giving them the answers*."
>
> "*I think whatever was taught through the 2 years is adequate*."
>
> "*Students struggling with their understanding chemical engineering concepts have a need, whether self-acknowledged or not, to improve. Under the lens of SDL, these students would not be viewed as being "lazy" or 'stupid", but that they are simply using older, entrenched methods of learning that are not working well. The metacognitive tools of SDL would open these "weaker" students to using a range of learning tools - creating mental models, rehearsing the information etc. that could help them better than any peer mentoring program*."

In addition, we noted a fairly consistent percentage of Year 1 students in the subsequent two cohorts (i.e. AY 2019 and AY 2020) also reported that they had difficulty acquiring the skills from the various activities designed to help them develop SDL skills. These findings clearly showed that the students are at different level of SDL readiness, even as they progressed through Year 1 of study together, learning the skills of SDL, and taking part in the same learning tasks designed to develop their SDL skills.

The inconsistent level of SDL skills acquisition leading to different SDL-readiness levels can be, to a certain extent, attributed to students' socioeconomic background, and their varied motivational levels for learning Chemical Engineering. However, we also want to find out if there are other underlying factors that may have possibly contributed to these findings to further improve the teaching of SDL. As noted by Jossberger, et al (2010) the first step in learning how to be self-directed is to gain the skill to self-regulate one's learning activities and task performances. Therefore, for this study, we look into how lecturers can help students develop their SDL skills by modelling the behaviour of a self-directed learner, i.e. how a self-directed learner would approach learning activities and tasks.

LITERATURE REVIEW

This section provides a scan of the literature on SDL, looking into factors that can affect the development of SDL competency, in particular the different dimensions of SDL, and students' own readiness for SDL.

Factors to Consider in Developing SDL Competency

The development of SDL aptitude involves a complicated interrelationship of factors that make us human (Lord, et al, 2010). Everyone is capable of learning to be self-directed, but the extent to which self-directness develops to, will vary. This is simply due to the inherent difference in individuals, and their external influences, such as learning motivation, self-efficacy, self-esteem, conscientiousness, openness to experience, even intelligence (Cazan & Schiopca, 2014). This is echoed in another study done by Slater, et al (2017) who found that demographic, discipline and personality factors are associated with an individual's readiness for SDL. Suffice to note that to become truly self-directed, a myriad of these behavioural factors, coupled with the attainment of the mastery of a broad range of knowledge, skills and attitudes, are needed. Therefore, to support the development of students to be self-directed, it is important to balance these factors, and to provide the context when designing learning activities to engage students.

Patterson et al (2002) identified six competencies students need to become self-directed: self-assessment of learning gap, evaluation of self and others, reflection, information management, critical thinking and critical appraisal. Not unexpectedly, the authors cautioned that each of the skills are not mutually exclusive but are interrelated in such a way that simultaneous of all or a combination of some of them can be expected.

In order for students to have positive experiences in SDL, faculty must create learning environments that meet students' psychological needs and take into account their expectancies and values. Since SDL is primarily characterised by developing student autonomy, it can therefore be argued that it is important to consider students' view on self-directed learning. Silen & Uhlin (2008) found that students need to feel in charge, in order to take responsibility for their learning. Being in charge allows them to feel able to make changes to their learning situation, understand the rationale behind learning, and obtain feedback. Stefanou et al (2004) shared a framework in which student autonomy can be promoted at 3 different support levels – organisational, procedural and cognitive – with varying degree of student choice. According to Katz & Assor (2007), who based their analysis on the self-determination theory of motivation (Deci & Ryan, 2000), proposed that choice can be motivating when the options meet the students' need for autonomy, competence, and relatedness.

Bouchard (2009) highlighted the need to pay careful analysis of various dimensions of self-directed learning in order to determine whether our choices will promote or hinder the emergence of effective learning behaviour. This resonates well with the point made by Garrison (2000) who studied the theoretical challenges of distance learning; in that the teaching tasks normally associated with the role of a teacher in a formal setting must now be passed on to the learner in a self-directed setting. He offered the analysis from the perspectives of the learners in the choices they make during the learning process. Building on the work of Long (1992) who offered two fundamentals ways – namely psychological and pedagogical – where learning could be learner controlled; Bouchard (2009) offered four dimensions for analysis: algorithmic, conative, semiotic and economic. The first two are updates to Long's psychological and pedagogical ways; and the last two are new additions to represent changes in today's learning environment made available by technological advances to supplement traditional printed text (e.g. podcasts) and alternative forms of education (e.g. MOOCs). These have impacts of where and how learners choose to learn, and the perceived cost-benefit trade-off.

Role of Teacher in Developing Student SDL Competency

Candy (1991) noted the path to self-directed learning is dependent upon the individual's self-management skills in learning, his or her self-concept, and the learner's understanding of his or her own role and that of educators in the learning process. To enhance self-directedness, it is therefore not sufficient for the adult educator to simply provide the opportunity for learners to be autonomous. The approach can be counter-productive if learners lack appropriate skills or self-confidence or if they prefer traditional instruction. Raidal & Volet (2009) reported that students in formal education had been found to preliminarily need support and guidance for learning in the form of teacher-directed activities, so that they can become more self-directed over time. Likewise, Silen & Uhlin (2009) noted that becoming a self-directed learner is a learning process, and there is a strong need for teachers to take part in facilitating that learning. Teachers play a critical role in effectively promoting individual SDL development both through their instructional choices and their interactions with students. Studies by Douglass & Morris (2014) showed that while students acknowledged much of their learning was within their control, they did note that faculty do have a significant impact on their desire and ability to learn. Noteworthy are clear and relevant grading criteria, use of real-world cases or scenarios, and enthusiasm displayed by the faculty.

Hattie (2003) noted that besides students themselves, teachers are the second most important persons that can make large impact in student learning attainment. In the context of self-directed learning, Hiemstra (2013) suggested that many teachers employ traditional teacher-directed approaches because their views of behaviourism, often modelled after their own teachers and their own experiences as learners, are seen as the best method. Granted, indeed there are some teachers who still truly believe that their role is to "tell" students the knowledge they need to know.

Teachers also play an important role to equip students to become more self-directed. Grow's (1991) proposed Staged Self-Directed Learning (SSDL) Model (Table 1) suggest the evolution of the teacher's role to support students as they develop self-directedness.

Table 1. Grow's 4-Stage SSDL Model

Stage	Student	Teacher	Examples
1	Dependent	Authority, Coach	Coaching with immediate feedback. Drill. Informational lecture. Overcoming deficiencies and resistance.
2	Interested	Motivator, Guide	Inspiring lecture plus guided discussion. Goal setting and learning strategies.
3	Involved	Facilitator	Discussion facilitated by teacher who participates as equal. Seminar. Group projects.
4	Self-directed	Consultant, Delegator	Internship, dissertation, individual work or self-directed study-group.

Another important reason why the role of teachers is important is that the capacity for self-directed learning have general components; and some are domain-specific and bound to the socio-material context (Candy, 1991). Some domain knowledge is necessary for learners to be able to take responsibility for their own learning (Bolhuis, 2003). The ability to learn in one domain cannot simply be transplanted to another. Knowledge domains have their own networks of meaning such as problem statements, concepts and rules that are expressed in a partly domain-specific language. Access to this knowledge is the main difference between experts and novices in a knowledge domain. An individual's learning potential depends on expertise in the learning domain in three ways:

1. being knowledgeable of the problem statements and procedures of knowledge acquisition (i.e. knowing what and how to learn) in the domain
2. having access to a relevant knowledge base to build on
3. being motivated to learn in the domain; motivation to learn is domain-specific

The progression from novice to expert includes development of three interacting aspects: learning to learn, knowledge base and motivation. When competence in a domain increases, the learner begins to develop his or her own domain related goals, chooses and employs more strategies and shows increasing ability to operate independently (Bolhuis, 2003). It is therefore important to scaffold the learning process in such a way that the scaffolding and support are gradually faded over time. The key challenge is to balance the amount of scaffold and support against the needs of students, especially in a case whereby different students are at different stages of SDL-readiness. Azevedo et al (2004) suggested the use "adaptive scaffolding" which involved a delicate balance of providing support while continuing to foster a student's own self-regulatory behavior during learning (e.g. planning, setting learning goals, and monitoring their emerging understanding). This necessitates the teacher to continuously diagnose students' emerging understanding and provide timely support during the learning process. Francom (2010) offered the following suggestions to develop students' SDL:

- match the level of self-directed learning required to learner readiness
- progress from teacher to learner direction of learning over time
- support the acquisition of subject matter knowledge and learner self-direction together
- have learners practice self-directed learning in the context of learning tasks

Teacher Modelling and Self-Directed Learning: Approaches

Since learning is a complex process influenced by a wide range of factors, and that "observational learning is an integral part of human development" (Bandura & Walters, 1963), Bandura, based on his social learning theory (Bandura, 1977) suggests that observation and modelling can play a fundamental role in the learning process. For Bandura, learning takes place in a social setting via observation. Such learning also involved cognitive processes, as learner internalise and make sense of what they see in order to reproduce the behaviour themselves. Jung (1986) suggested that an alternative formulation of the concept of role model emphasises the motivational, as opposed to the learning, function of role models.

Likewise, Gibbons (2002) noted that modelling is one of the ways to engage and motivate students to engage in self-directed learning. The teacher should be a model of the process – one who is committed to it and is actively employing it. Whenever a teacher demonstrates a concept for a student for example, when a math teacher works through a problem on the board, he or she is actually modelling how the problem is solved (Haston, 2007). Modelling is also used in numerous educational settings, particularly with performing ensembles, and interestingly, in art and design education (Groenendijk, et al, 2013). Role modelling is widely accepted as a highly influential teaching and learning method in medical education (Sutkin, et al, 2008). Teacher modelling is also a common element identified across academic reading programs, one of which is sustained silent reading (Methe & Hintze, 2003). Their study showed that teacher modelling of the process is effective in increasing student engagement.

When used appropriately, teacher modelling for student imitation is a useful tool. Student learning is enhanced when teachers verbalise their thought processes while simultaneously engaging students in learning activities. Cognitive thoughts normally not seen are now observable, and shown through the teacher's actions. Modelling can also be used as a scaffolding technique, where the teacher first model the task for students, and then students begin the assigned task and work through the task on their own.

From our literature review, there appear to be a dearth of studies on how teacher's classroom behaviours affect students' propensities towards self-directed learning. What we found are mostly studies related to more general aspects of teacher competency and behaviours, classroom management skills, etc., and the impact on student learning. We will not delve too much into these factors. Noteworthy to highlight is the work of Blazar & Kraft (2017), who reported that teachers who are effective at improving test scores often are not equally effective at improving students' attitudes and behaviours. Suffice to note that their study investigated the impact of "teacher effects" (which the authors explained as the "relationships between teaching practice and student outcomes") and the outcomes of self-reported self-efficacy in math, happiness in class, and behavior in class. Their results showed that teachers can and do help students develop attitudes and behaviours that are important for success in life.

Bandura (1977) suggested that the status of the model has a great influence on whether this person will be taken as a model or not. A "high-status" model can positively affect the perceived importance of an activity and can bring about a desirable behavioural response more readily by providing the observer with on-going visual feedback compared to a "low-status" model. Shahmohammadi (2014), in a study on importance of teachers' role in creating self-regulative behaviours in students, reported that the students' self-regulation has to a high extent correlates with the teacher's educational and social behaviours. The teacher's model and his/her respect toward the students' character encourages them in an effective self-regulation. In addition, the teacher's effort in explaining the lesson content is significant in increasing students' interest in self-regulation. In another study, albeit more limited in scope as it focused on classroom incivilities (and not related to students' self-regulation of learning), Stork & Hartley (2003) reported that students' perceptions about professors' behaviours generally fall into two domains: his/her competence and interest; and respect for the individualism of students. In addition, to further enhance students' modelling of teacher behaviour, Dynan et al (2008) proposed that a structured learning environment be employed. In a structured learning environment, students were given explicit and detailed instructions for completing each of their assignments and semester projects. In other words, their ability to self-define their work was intentionally limited. Students were asked specific questions related to their work each week. Their results showed that structure match enhances SDL skills and that courses designed to enhance students' readiness for SDL can do so.

OUR WORK DONE IN TEACHING SDL VIA TEACHER MODELLING

We used the model of student engagement as proposed by Bandura – that learning involved four different stages: (1) attention, (2) retention, (3) reproduction and (4) motivation (Horsburgh & Ippolito, 2018). The first stage is attention where learners need to be attentive to the behaviour to be learnt. They need to be able to see the behaviour that they want to reproduce or that others want them to reproduce. The second stage requires learners to internalise and retain what they have seen. This involves cognitive processes in which a learner mentally rehearses the behaviour or actions that are to be reproduced. In the third stage, learners need the opportunity to reproduce the modelled behaviour by converting the information obtained from attention and retention processes into action. Finally, in the fourth stage, learners need to be motivated to continue to imitate the behaviour they have observed.

Our earlier works on SDL since AY 2018 were already reported in past CDIO Conferences (see Wong, et al, 2021; Cheah, 2020; and Cheah, et al (2019). Very briefly, we introduced SDL into the module *Laboratory and Process Skills 2* offered to all DCHE students in Year 1, Semester 2. This module was designed to transition students from the more familiar laboratory work settings (i.e. laboratory skills) to the chemical plant work setting (i.e. process skills). SDL, and good thinking heuristics such as metacognition (CDIO Syllabus sub-categories 2.4.4 and 2.4.5) using Sale's Model of Thinking (Sale & Cheah, 2011), were explicitly taught in Week 1 of the module, and emphasised throughout all 10 activities (4 hours duration each) in the module. This allowed students to simultaneously learn, within the same activities, disciplinary knowledge in chemical engineering together with thinking skills and SDL skills to become more self-directed (i.e. CDIO Standard 7 Integrated Learning Experiences).

Studies showed that intentional curriculum design can potentially impact students' self-directed readiness and competence (Kraznow & Hyland, 2016). To deliberately introduce teacher modelling into the learning tasks, we focused on one of the integrated learning experiences centred on connecting laboratory skills to process skills based on the common set of chemical engineering principles, namely that on investigation on the use of sensible heat versus latent heat for heating/cooling applications (use of cold water or ice to lower the temperature of warm water). More specifically, we expanded the learning duration from one session to two consecutive sessions. This was made possible in an already-compact curriculum by removing another learning activity. We now have two 4-hour sessions in a 2-week period to firstly model SDL behaviour to students in the first session on how to use the SDL model in tackling the given tasks by verbalising the thought process through a series of "talk-aloud" questions. Students fill in a workbook (CDIO Standard 8 Active Learning) that we had prepared to scaffold the learning process, so that the thought processes of a self-directed learner are made explicit to students.

In the second session, and under observation by the lecturers, students use the same approach to complete similar tasks, with additional challenges to assess their understanding of the concepts learnt in the first session. More specifically, students now had to deal with binary liquid mixture (salt solution simulating seawater) instead of pure substance (pure water) used in the first session. Feedback was provided where needed as part of formative assessment, and students submit a group report on their work done along with a reflection journal on their learning experience (CDIO Standard 11 Learning Assessment).

The learning tasks were piloted in October 2020 for AY 2020/2021 and are summarised:

- Determine the different types of heat involved by measuring the thermal energies transferred when warm water is cooled using pure cold water versus using ice.
- Compare and contrast the relative merits of using ice versus cold water for cooling applications.
- Use the results to analyse the case of heating using superheated steam versus saturated steam, and investigate if there will be potential cost savings when heating using one type of steam versus the other.
- Repeat the same task to determine the thermal energies transferred when warm water is cooled using cold salt solution versus using ice.
- Relate the difference to the changes in properties (related to cooling) when binary liquid mixture is used instead of pure liquid.
- Use available resources to put together a cooling medium that is more effective than cold water, but easier to transport than ice.
- Extend learning to a case study simulating real-world application of using treated water versus seawater for industrial cooling application.

A short survey was conducted for 106 students to find out they were able to learn how to be more self-directed based on our attempt in modelling the thought process.

DISCUSSION OF FINDINGS, REFLECTIONS AND IDEAS FOR MOVING AHEAD

Results show that students agree or strongly agree that they were able to model the behaviour of a self-directed learner by planning (92.5%), referring to previously learnt knowledge (89.6%), monitoring and evaluating their work (86.8%) and seeking help from friends when needed (91.5%). We postulate that this can be due to the close similarities in the tasks given in the two sessions (P2 or practical 2 is the first session, and P3 or practical 3 is the second session) which allowed students to replicate the process fairly easily. Indeed, the following quotes from two students are quite typical of the responses obtained:

> *"After doing P2, I think I am able to do P3 really fast as they are similar experiments so I don't need more guidance and support."*

> *"As P2 was very much similar to P3, thus when I fully understand P2 which I have already carried out. I would then be able to understand P3 much better and would be able to carry out the experiment more smoothly."*

We are encouraged to find our attempt for lecturers to model SDL through verbalisation of the thought process using questions appeared to help students understand and apply SDL skills to tasks, at least for these two sessions. The second session also gave students another opportunity to reproduce the behaviour of a self-directed learner. Some students shared that:

> *"The rundown on how the model was used was crucial in bridging the gap between understanding and using it practically."*

"There were a lot of questions in P2 which were guiding us and explaining in detail what each step is actually about, allowing me to understand more about SDL and I am then able to apply it to P3."

"there were alot (sic) of questions to be filled up asking about my metacognition and thinking. and i could model the approach of being self directed in p3 by thinking and reflecting by referring back to what i wrote and reflected on what went wrong"

"… … Reflecting on the data and how it was derived helped to push me to research more on the variables that have to be taken note in an experiment. This meant that future calculation would be more accurate."

"In practical 2, whenever I'm in doubt I will ask my group members. However in practical 3 I have learnt to ask myself questions and think in-depth to the question before asking my group members"

On the other hand, we still have students who wanted more guidance:

"I still need help thinking deeply on why is this the case etc."

"We wish we knew more about the theory behind the procedure because at hat (sic) point we have not learned anything about it yet."

More than half the students surveyed indicated that they were unable to manage their emotions. 52.8% agree or strongly agree that they get frustrated easily when they were unable to find the information needed or answer the questions.

Our findings may be due to the students' grasp of domain knowledge (academic ability) which may have a correlation to their readiness to be self-directed, and how much they can relate their own competence level to the model's (the lecturer).

Students who are academically stronger will naturally be more ready to take control of their own learning as they will struggle less to make sense of what they are learning, and therefore more confident to perform the learning task (Van Woezik, et al., 2019; Weimer, 2015). Since learning through modelling requires one to observe, follow through the process and make sense what is to be learnt, this approach can be challenging for learners if the model is unable to "break down" the information to the learner's level of competency while modelling. When that happens, the traditional direct instructional approach where one simply needs to do what they have been told may be more beneficial to these learners. This observation is echoed by Gronenendijk, et al (2013), Braaksma, et al (2002) and Zimmerman & Kitsantas (2002). Gronenendijk, et al (2013) found that students who were naturally creative benefitted more from observing and self-verbalising the designing process and products compared to students with lower creativity levels. Braaksma, et al (2002) reported in their study of learners learning to write that writers who were weaker learn more from a writer model who was not as competent in writing while the converse is true for stronger writers. Similarly, Zimmerman & Kitsantas (2002) found college students performed better when they learn from a model who improved over time compared to a model who was fully competent at the beginning.

To our students, the lecturer is considered a mastery model. Therefore, students who seemed to have learnt more effectively to be self-directed, as shown from their responses, could have been those that are stronger academically. Academically weaker students may have found the lecturer's thought process challenging to follow and rationalise due to insufficient underpinning knowledge. As such, use of differentiated questions while modelling how to be self-directed or personalise guidance during learning may be one way to provide support to all students to learn to be self-directed. To do so, we will need to find out the students' academic abilities, and their baseline SDL-readiness levels. The former can be determined based on their grade point average (GPA) while the latter requires the use of a measurement instrument such as Personal Responsibility Orientation Self-Directed Learning Scale (PRO-SDLS) (Stockdale, 2003) to measure students' SDL readiness.

We are also mindful that these results, being all self-reported responses, may not provide a complete picture of whether students had become more self-directed since there is a likelihood for learners to to misjudge their own skill levels (Saks & Leijen, 2013). However, since self-reporting measures is still the dominant approach to evaluate self-directedness of learners in the literature, we will continue to use it and will triangulate with other evidence sources, such as knowledge transfer to perform tasks in other non-skill based modules.

Finally, we ourselves are not perfect as models. Models should be technically competent in knowledge and skills in their domain area but also adept and passionate in transferring this knowledge and skills to all students (Cruess, et al, 2008). Our teaching team may not yet have sufficient expertise to be able to effectively teach SDL through teacher modelling, and some of them may be in fact not comfortable doing so. There is henceforth a need for professional development in modelling SDL (CDIO Standard 9 Enhancement of Faculty Competence) as well as in designing integrated learning experiences and/or active learning lessons using workbook (CDIO Standard 10 Enhancement of Faculty Teaching Competence).

CONCLUSION

The overt teaching and intentional integration of SDL into a curriculum is a promising way to develop self-directed learners - findings from our 3-year longitudinal study indicated that students are able to attain SDL competency, but to varying levels. To further improve the teaching of SDL, we turned to the use of teacher modelling. In this pilot study, we found that most students seemed able to understand and independently replicate the modelled behaviour when asked to in a new yet similar context, but there are still some who requested for more guidance. In view of this, we plan to enhance the teaching of SDL via modelling by providing differentiated instructions during the modelling process based on their comprehension of domain knowledge required for the task, and readiness to be self-directed.

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