TRANSFER OF SELF-DIRECTED LEARNING COMPETENCY

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ABSTRACT

In this new disrupted world, it is important for students to be self-directed learners and equipped with the ability to purposefully transfer their learning from one context to another. The Diploma in Chemical Engineering (DCHE) aims to develop self-directed learning (SDL) in students, and their ability to transfer learning by integrating SDL activities into different core modules of its 3-year curriculum. In this manner, students will develop SDL skills alongside other skills specified in those core modules. The general approach taken to integrate SDL into the DCHE curriculum, and how SDL was introduced in a Year 1, Semester 2 practical-based module through an explicit instructional process using the DCHE SDL Model supported by good thinking heuristics have been shared earlier. This paper continues with that study and determines if the same cohort of students, who had learnt SDL skills in Year 1, were able to apply them in later years of study to different contexts, specifically to a project-based module in Year 2, followed by internship at local companies in Year 3. Practical-based modules generally consist of structured workshop sessions with activities where application of SDL may not be so obvious or intuitive to students. Conversely, project-based modules, being less structured and often ambiguous, will naturally lead students to realise that SDL is necessary to complete their projects. This paper highlights the differences when embedding SDL into the different types of modules, then discusses the process of infusing SDL activities into the Year 2 project-based, chemical product design module by referring to the SP-customised CDIO syllabus. Simple surveys were conducted on the students to evaluate their ability to transfer the SDL skills learnt from the structured practical-based module in Year 1 and apply them to the project-based module in Year 2. The findings indicate that the students find the DCHE SDL Model useful in helping them learn systematically as they progress through the curriculum. There is also evidence of SDL transferability and application across the two years of studies and the different learning contexts. When a representative number of students from the same cohort were surveyed in Year 3 during their internship, findings show that they were also able to use the SDL skills acquired in school in the real-life work environment. The paper concludes by outlining areas of improvements to enhance transferability of SDL in DCHE students.

KEYWORDS

Chemical Engineering, Self-Directed Learning, Skills Transferability, Standards: 1, 2, 3, 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 a as "faculty" in the universities.

INTRODUCTION

A key approach towards lifelong learning is to be self-directed (Candy, 1991; Alexander, et al., 2004; Tunney and Bell, 2011; Weimer, 2015). A self-directed learner is able to identify one's own learning needs, set learning goals, manage his/her own learning, evaluate and fine-tune the learning process and subsequently extend (or transfer) his/her learning to different contexts and situations (Loyens, et al., 2008). Transfer of learning, as defined by Brandsford, et al. (1999) is "the ability to extend what has been learned in one context to a new context". As contexts progress from being similarly related to remotely related to each other, transfer of learning will also shift from one being instinctive and requiring minimal effort, to one that requires purposeful abstraction of concepts, effort to connect and apply to the different situations and reflective thinking (Dewitz and Graves, 2014). Transfer of learning is thus a complex process that is difficult to attain (Bereiter, 1995; Dewitz and Graves, 2014; Perkins and Salomon, 1988) particularly for more dissimilarly related contexts, but could be facilitated through the development of metacognitive skills (Belmont, et al., 1982; Billing, 2007).

The Singapore Government launched the SkillsFuture Initiative in 2015 to help Singapore manufacturers remain competitive globally. A key thrust of the Initiative is to foster a lifelong learning culture. Singapore Polytechnic (SP) as an institute of higher learning, also recognises the importance of lifelong learning. A focus area of SP's new Educational Model is to prepare students to be lifelong learners by having self-directedness and the ability to transfer their learning so that they may be ready for uncertainties and challenges that await them.

THE SPIRAL CURRICULUM AND SELF-DIRECTED LEARNING IN DCHE

The Diploma in Chemical Engineering (DCHE) introduced its spiral curriculum course structure in 2018 (Cheah and Yang, 2018), which allows students to progressively develop the desired knowledge, skills and attitudes.

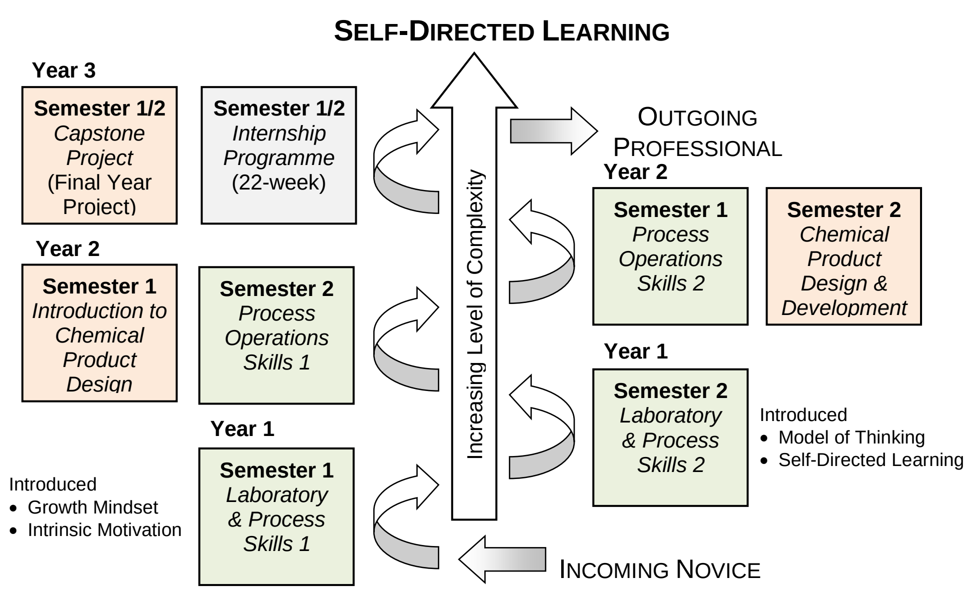
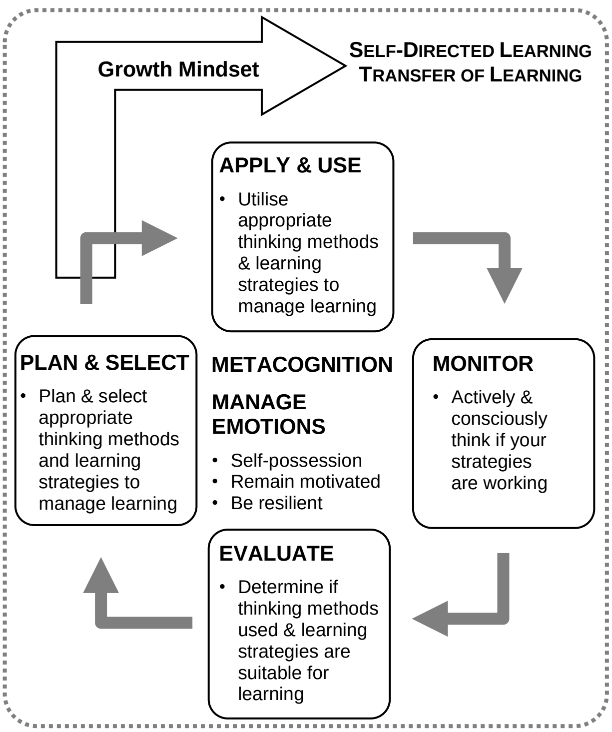


Figure 1. Progressive Development and Transfer of SDL Competency in DCHE

Self-directed learning (SDL) is integrated into the DCHE spiral curriculum through practical-based modules (Laboratory & Process Skills 1 and 2), as well as project-based modules (Introduction to Chemical Product Design, Chemical Product Design & Development and Capstone Project) as shown in Figure 1 (Cheah, et al., 2019; Cheah and Chua, 2019). The intent is to gradually develop students' SDL competency in Year 3 to Advanced level, as defined in the lifelong learning generic skills and competencies under the SkillsFuture Initiative (Cheah, 2020), alongside other skills such as core technical skills.

To help students better understand the skills and attitudes of a self-directed learner, the DCHE SDL Model (Cheah and Chua, 2019) (Figure 2, left) was introduced to teach students the key steps in the SDL process in the Year 1, Semester 2 module, Laboratory & Process Skills 2 (Figure 1), with learning of metacognition supplemented through teaching of thinking heuristics using Sale's Model of Thinking (Sale, 2015) (Figure 2, right).



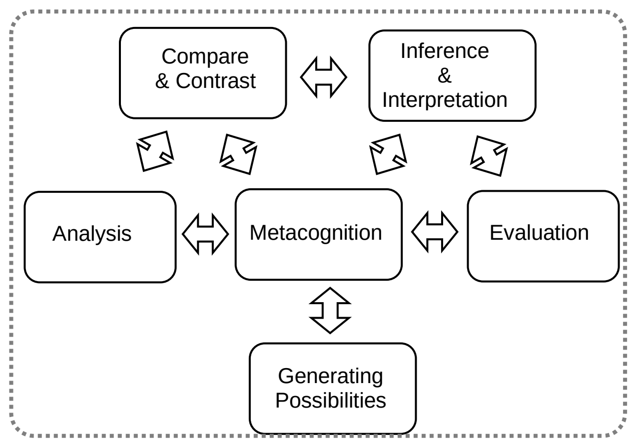


Figure 2. DCHE SDL Model (left) and Sale's Model of Thinking (right)

SDL scaffoldings and lecturer guidance are gradually reduced as students go through the curriculum, to progressively allow shifting of control and responsibility for learning to the students themselves, which, according to Azevedo et al. (2004) and Schunk and Rice (1993), is a truer hallmark of self-directedness and a more effective way for students to gain SDL skills. At the same time, they gain technical domain knowledge which increases their confidence to direct their own learning (Bolhuis, 2003; Grow, 1991). Growth mindset and metacognition, both important concepts in facilitating development of self-directedness and learning transfer, were incorporated into the DCHE SDL Model. Since continuous communication is one critical factor affecting transfer of learning (Cheng and Ho, 2001; Rossett, 1997), the rationale, purpose and benefits of the DCHE spiral curriculum and the various learning models embedded within, e.g. SDL, etc., were shared with students to help them understand and increase their acceptance and use of these learning models beyond the curriculum.

Evaluation of SDL in DCHE: A Longitudinal Study

Year 1 students in Academic Year 2018-2019 (AY1819) is the first cohort of students introduced to SDL. SDL is embedded in practical-based modules (Laboratory & Process Skills 1 and 2) in the context of laboratory investigative and process plant operation skills while SDL is incorporated in project-based modules (Introduction to Chemical Product Design and Chemical Product Design & Development) in relation to product design & development and C-D-I-O skills (Table 1).

Table 1. Development and Evaluation of SDL Skills in DCHE Students

Development of SDL Skills in DCHE							
DCHE Spiral Curriculum	**Academic Year**	**Year 1 Sequential**		**Year 2 Sequential**		**Year 3 Swapping**	
		Semester 1	**Semester 2**	**Semester 1**	**Semester 2**	**Semester 1/2**	**Semester 1/2**
	Module Name	**Laboratory & Process Skills 1**	**Laboratory & Process Skills 2**	**Introduction to Chemical Product Design**	**Chemical Product Design & Development**	**Capstone Project/ Internship**	**Internship/ Capstone Project**
Types of skills that are developed together with SDL Skills	Laboratory Investigative Skills (Bench-top)	✓	✓	N.A.	N.A.	✓	✓
	Process Plant Operation Skills (Pilot Plants)	N.A.	✓	N.A.	N.A.	N.A.	✓
	Product Design & Development C-D-I-O Skills	N.A.	N.A.	✓	✓	✓	✓
Evaluation of Student Experience in SDL							
SDL Implementation		**In-Campus**	**In-Campus**	**In-Campus**	**In-Campus**	**HBL (Circuit Breaker)***	**Mostly in-Campus**
Cohort AY1819 Pilot run to evaluate if students are able to transfer SDL skills learnt in one context to another		Students briefly introduced to Growth Mindset and SDL model	1st Survey on Experience in using SDL completed	2nd Survey on Experience in using SDL completed	1st Survey on Transfer to New Context completed	1st survey on experience & transfer during Internship completed	To survey on experience & transfer during Capstone Project

*Circuit Breaker (7 April 2020 – 1 June 2020) was a period where the Singapore Government implemented closure of non-essential workplaces and full home-based learning for schools to minimise the spread of COVID-19.

We conducted a 3-year longitudinal study to follow their progress for the entire duration of their study in the diploma to ascertain the effectiveness of the teaching of SDL, and to determine if they were able to demonstrate assimilation of knowledge and transfer it to new applications. More specifically, we were interested to find out if students were able to apply the SDL skills acquired in *one context* through the practical-based module, Laboratory & Process Skills 2, in Year 1 Semester 2, to a *different context* in the project-based module, Chemical Product Design & Development in Year 2 Semester 2 with progressively less scaffolding and guidance, and finally transfer and independently use the SDL skills in a real-world environment during their 22-week internship at a local company (in Year 3).

In Year 1 Semester 1, students were introduced to growth mindset in an activity in a practical-based module, Laboratory & Process Skills 1. In Year 1 Semester 2, students were taught the DCHE SDL model (Cheah, et al., 2019) and Sale's Model of Thinking. Subsequently, they applied SDL in a series of workshops and some practical activities and performed reflective thinking to identify learning gaps that can be addressed by the SDL model. Most students found that the SDL Model was useful in helping them apply SDL (Cheah, et al., 2019).

When the students progressed to Year 2 Semester 1, they revisited the Sale's Model of Thinking, DCHE SDL Model and growth mindset through three learning activities where they performed their needs analysis, ideation and preliminary design specifications for their chemical product in a project team setting in the Introduction to Chemical Product Design project-based module (Cheah and Chua, 2019). Since students were given full autonomy to decide on their chemical product idea, this translated to about 30 unique chemical product projects for the cohort. In Year 2 Semester 2, they continued to work on their chemical product ideas in another project-based module, Chemical Product Design & Development. In the same project team, they had to manage the construction and testing of their chemical product prototype, and communicate the work done, the design approach, design process and prototype testing results, through a design portfolio to the facilitator.

We referred to the SP-customised CDIO syllabus, specifically sections 2.4.5 *Demonstrate Metacognition and Knowledge Integration,* 2.4.6 *Engage in Lifelong learning (Self-directed Learning)* and 2.4.7 *Manage Time and Resources* to guide us in designing SDL-infused learning activities related to the management of their chemical product projects so that students could apply SDL skills learnt earlier in structured learning activities to this new, ambiguous context of managing a project. Infusing SDL activities into project management also allowed these activities to be done by all students regardless of the type of project they had. We also reduced the amount of scaffolding and provided only the DCHE SDL model and limited guidance questions to students for them to apply the SDL model when they create a Gantt Chart to manage their project (Table 2). Compared to the two Year 1 practical-based modules, Laboratory & Process Skills 1 and 2, and the project-based module in Year 2 Semester 1, Introduction to Chemical Product Design, the guidance questions on metacognition and managing emotions were embedded in all 4 SDL stages as students were expected to think about their own thinking, and manage their emotions throughout at this juncture.

Table 2. Examples of SDL Guidance Questions in Chemical Product Design & Development

Stages of SDL		**Examples of Guidance Questions**
Metacognition Manage Emotions	Plan & Select	What is the importance of project management? What are the deliverables of the Project Management activity? Are we doing Project Management activity only to get the marks? By when must we complete Project Management activity - Is the time given sufficient, if not, what can we do? What are the project management tools at our disposal? Do I know how to apply the project management tools - if I am not sure, what help or resources can I fall back on? How detailed or broken down should the list of project tasks be to be reasonably practicable? Should the team discuss it or seek advices from the facilitator or both?
	Apply & Use	For the purchases of materials to construct a prototype, do we give a slightly longer duration in anticipation of delays in deliveries? Perhaps even a longer duration if we buy from an overseas supplier? Our team is given 3 weeks to construct and test our product prototype - how should we schedule the work? To ensure the schedule feasibility, what are the tasks that can be carried out concurrently to save time but carrying out tasks concurrently also means manpower will be split, do we have the bandwidth to operate? How do we do the tasks distribution to achieve fairness and manage emotions of all team members?
	Monitor & Evaluate	Is the information contained in the Activity Logic Table correct and practical? Is the information in the Activity Logic Table correctly transposed to Network Diagram, and then the Gantt chart? Have we examined the work thoroughly? Did we leave out anything important? We can probably exchange views with other teams - they may see things that we do not? Does the project meet the schedule feasibility – if not, what can we do? How regular should the Gantt chart be updated? Who is responsible for updating it?

After two years of practising SDL in the school curriculum, students moved onto their internship in Year 3 in a real-world work place environment where they would have to deal with unfamiliar processes with little or no supervision from their lecturers. Although students were allocated a company supervisor for the duration of the internship, level of supervision provided will vary based on factors such as company culture and the supervisor's personality. Students would also have to complete an individual project on top of their daily work tasks at the workplace. Internship was therefore the most opportune time for them to independently apply their technical knowledge and use the SDL skills acquired to help them overcome challenges faced.

We report on the students' SDL learning experience in Year 2 and their experience in using SDL during their internship in Year 3 in the next section. We surveyed the students' experience in using the DCHE SDL Model when they were in Year 2 to see if there was a difference when the learning context changed from practical-based activities and workshops to project-based chemical product design. We also surveyed the students on their learning experiences in Year 2 Semester 2 in the Chemical Product Design & Development module itself, and also in Year 3 during their internship and Capstone Project to check for evidence of transferability. The cohort of students was split in Year 3. In Semester 1, half of them went on internship and the other half remained on campus for their Capstone Project. The students will then do a swap in Semester 2. The findings on the students' experience in using SDL during the Capstone Project in Year 3 is not within the scope of this paper and will not be discussed here.

RESULTS AND DISCUSSION

Student's Experience in using DCHE SDL Model

Students continued to find the DCHE SDL Model useful in helping them learn systematically as they progressed through the curriculum, from Year 1 to Year 2 (Figure 3).

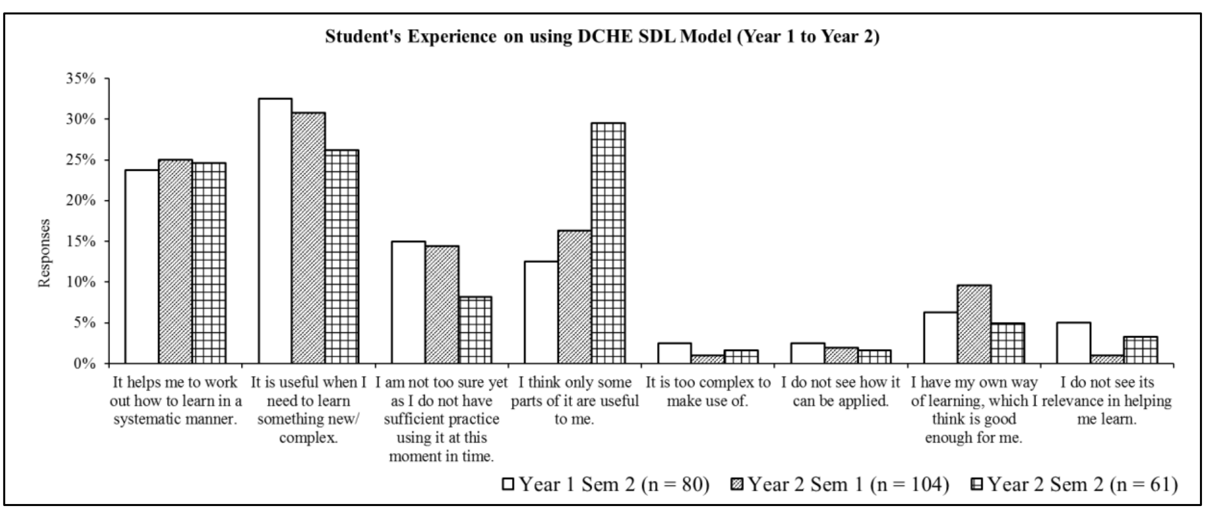


Figure 3. Students' Experience on using the DCHE SDL Model

It is also worth noting that students found the DCHE SDL Model useful when they needed to learn something new and complex. Gureckis and Markant (2012) opined that SDL helps optimise one's learning experience, allowing the student to focus on useful information that he/she does not already possess and exposing him/her to information that he/she does not have access to through passive observation. This content curation and analytical skill is important when one is learning something new or complex, and the DCHE SDL Model and Sale's Model of Thinking offer that. As they gained more practice in using SDL, they become more familiarised with SDL, similar to the observation made by Van Woezik, et al. (2019) who found that students need to be given time to familiarise themselves with a new mode of learning. Furthermore, when students apply SDL, he/she also gets to learn other important skills such as time management, self-assessment and goal setting. These are important skills that can be applied anywhere, across contexts.

Transferability of SDL – Chemical Product Design Project

When students worked on their chemical product design project in Year 2 Semester 2, they were expected to run their own project by managing critical project tasks, from creating and refining a bill of materials for a chemical product prototype, procuring materials needed, conducting a risk assessment on prototyping activities, to constructing and testing the chemical product prototype, preparing a design portfolio and monitoring project progress using a Gantt chart. All these naturally requires students to be self-directed. As such, we believe project management is a good platform to allow students to apply and reinforce their SDL skills, consistent with what was reported by Eggermont, et al. (2015).

In the management of the chemical product design project, students were given less scaffolding to guide them in applying SDL in a context different from what they had encountered before. This progressive withdrawal of scaffolding is consistent with the model proposed by English and Kitsantas (2013), in which teachers begin with a high-level of teacher directions and then gradually remove the scaffolds so that students will increasingly take ownership of their learning.

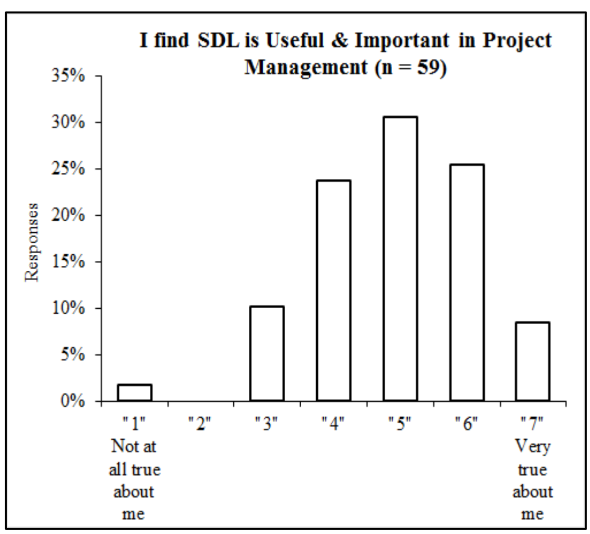


Figure 4. Students' Responses on Usefulness & Importance of SDL in Project Management

64.4% (only favourable responses were considered, i.e. those of "5", "6" and "7") of the students (Figure 4) found that SDL was useful and important in managing a project although they had only previously applied SDL to structured learning activities. This observation is shared by Johnson, et al. (2015), who wrote about the usefulness of project-based learning in teaching students SDL skills.

When polled, nearly 50% of the students expressed that they did make use of the set of curated SDL guidance questions in managing their chemical product design project (Table 2), suggesting that the guidance questions remained relevant and useful, similar to that reported by Perkins and Salmon (1988) who suggested that explicit instructions would be helpful for students to transfer their learning from the original context to a new context. A third of the students however confessed that they did not use the guidance questions. This could mean that the students either did not require scaffolding for SDL as they already had 3 semesters of prior experiences and practice, similar to that observed by others (Azevedo, et al., 2004; Schunk and Rice, 1993), or they were not able to apply SDL to project management. One possible reason for students not being able to apply SDL could be related to their level of readiness. Stewart (2007) shows that SDL readiness is a key enabler for achieving learning outcomes from project-based learning, which is often open-ended, ambiguous and requires knowledge beyond the curriculum. If students are not ready to take control and responsibility for their own learning, they most probably will not learn SDL and apply it (Brockett and Hiemstra, 1991; Candy, 1991), or will resist its use.

Perkins and Salomon (1988) reported that transfer of learning requires one to be able to refer back to the context where the learning had taken place originally and find similarities to connect the learning to the new context where the learning has to be transferred. This process becomes increasingly more difficult and requires more metacognition and motivation as the new context becomes increasingly dissimilar to the original context where learning had occurred.

Therefore, when slightly more than half of the students (53.3%) found their prior SDL experiences useful when they had to apply SDL in a new context to manage their chemical product design project, this suggests these students were able to transfer their learning from the practical-based module, Laboratory and Process Skills 2 to the project-based module, Chemical Product Design and Development.

Transferability of SDL – Internship

When students progress to Year 3, the cohort will be split, with half the cohort undergoing a 22-week internship at a local company and the other half remaining on campus to complete their capstone project first, after which they will swap (see Figure 1 and Table 1).

Students on internship have to complete the individual graded internship project whilst fulfilling their daily work requirements at the company. Compared to the student-initiated, group-based chemical product design project done in Year 2, students on internship had little to no autonomy to decide on the type and scope of their projects, and the project methodology as these were predominantly specified by the companies. Outcomes from the chemical product design project also only contributed to the wider knowledge base while that from the internship projects had specific value to the company and often had to be solutions to real-life problems faced by the company. Since the internship project is company-specific, and our students are placed in companies whose nature range from manufacturing, testing, to research and development, their projects will reflect this varied nature of placement and the 3-year curriculum will not likely cover the needs of all companies that our students intern at. Students are thus expected to use SDL skills to manage and at the same time learn the new materials needed to complete their internship projects.

Application of SDL was evident when we surveyed the same students who completed their local internship in Year 3. For half the cohort who did their internship in Semester 1, 16 out of 30 respondents (53.3%) expressed that they had to learn new materials for work on their own.

This is similar to the other half of the cohort who completed their internship in Semester 2. 23 out of 38 respondents (60.5%) indicated that they too had to learn new materials independently. Although there exists external factors, such as limited supervision, that will inadvertently led students to be more self-directed during their internship than compared to when they were in the school environment, all students except for one student, who had to learn new materials independently during internship agreed that SDL skills acquired in school were useful for their internship. The respondent who disagreed stated that he/she did not know how to use the skills during internship as he/she did not remember the steps to do so. Interestingly, a follow up question posed to that respondent revealed that he/she had actually applied the SDL skills acquired in school during internship; he/she had planned his/her own work, identified gaps and the resources needed to bridge the gaps in his/her knowledge to achieve his/her goal.

Students who have already been thinking about their own thinking, essentially the application of metacognition, will find it easier to make the transfer successfully (Belmont, et al., 1982; Billing, 2007). Since these students were also taught metacognition through the Sale's Model of Thinking, they would find it easier to make the transfer, as evidenced by the students' responses when they were asked about their learning and applying new things at the work place in Year 3 (Figure 5, n = 16 (Semester 1), n = 23 (Semester 2) for students who had to learn new things on their own). The questions asked are as indicated in Figure 5. It is worthwhile to note that the data in Figure 5 may not be representative given the small sample sizes.

Most students indicated they were able to identify their own learning needs, plan, monitor and evaluate their own learning while managing their emotions at work. They essentially displayed characteristics of a self-directed learner who had transferred what they learnt about SDL, from structured activities to projects in the school, and eventually to real-world work places. This shows that the students were able to transfer SDL competency successfully during their internship in Year 3.

Overall Discussion

One of the challenges that arose during this process to develop DCHE students into self-directed learners through the infusion of SDL into the DCHE curriculum is to balance the amount of guidance and feedback students receive and the level of independence students can be given over what they learn so that they can become self-directed learners. This is a similar observation made by others (Shanley, 2007; Dorna, et al. 2007). Our students come from diverse socioeconomic backgrounds, and to a certain extent, possess varied academic abilities and different levels of interest in the course. Being new to the course, they will not have the technical domain knowledge hence may lack confidence in their own abilities to complete new learning tasks in Year 1. They are also used to be passive learners as moulded by the traditional education methods prior to entering SP. As such, they will hesitate to take control and responsibility for their learning, preferring instead for their lecturers to do so (Van Woezik, et al., 2019). Having different levels of interest in the course will also influence their emotional and mental investments in learning tasks. This in turn will affect the extent to which they will explore and eventually adopt the use of SDL in their learning (Maiese, 2017) and to transfer it to an entirely different context. There is a need to calibrate the level of lecturer guidance and feedback to give students just enough support so that they will be encouraged to persevere in using SDL, and eventually gain confidence to take control and responsibility for their own learning.

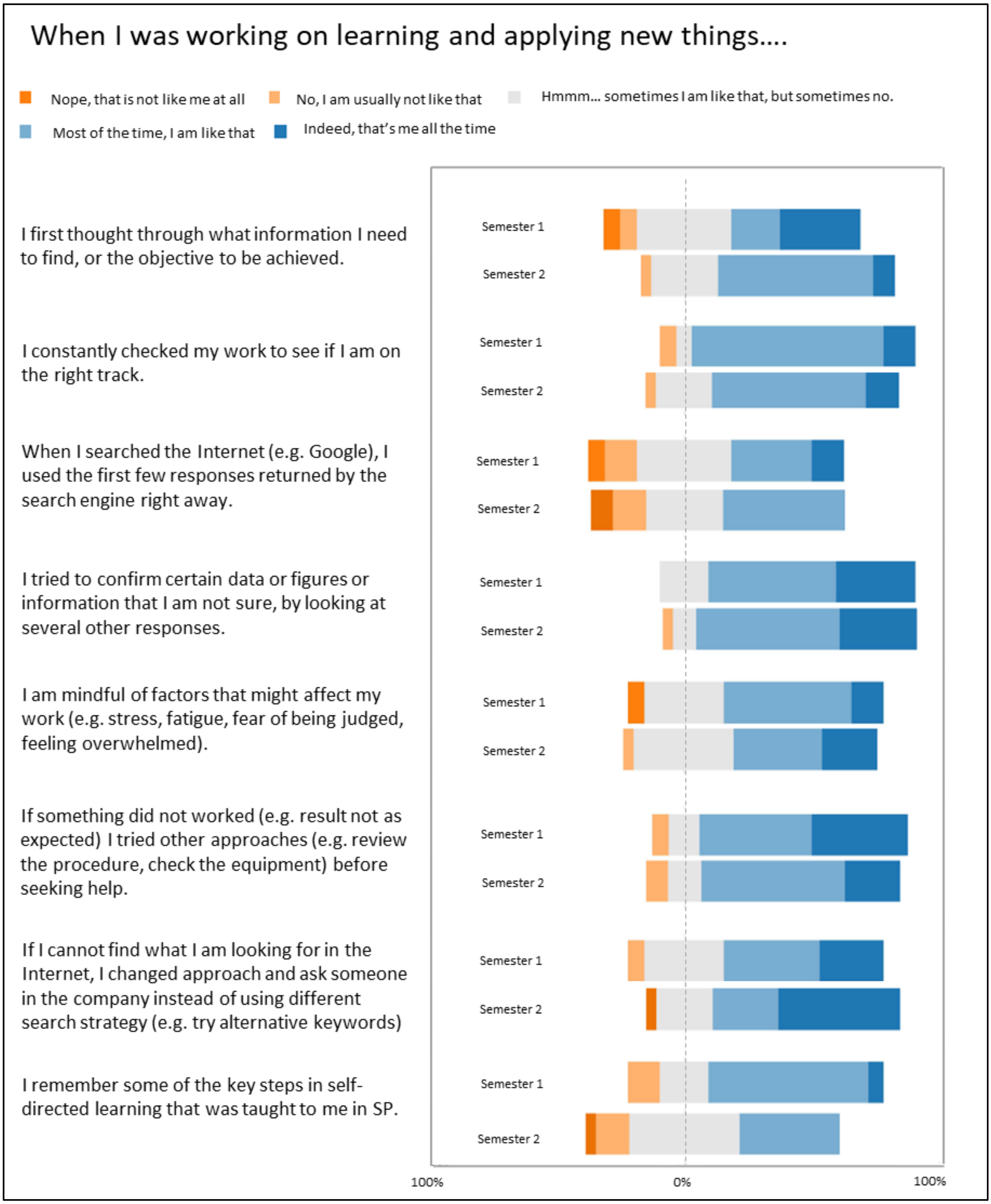


Figure 5. Students' Responses when Learning and Applying New Things during Internship

Based on the results obtained so far, we are encouraged that students seemed able to practise and use the SDL skills taught in Year 1, Semester 1 in different contexts in the familiar school environment where guidance from lecturers was still available. They also seemed to have developed into self-directed learners during their internship at a real-world work environment, after two years of practising SDL and gaining familiarity with its use in different contexts.

CONCLUSION

This paper reported the work done for only one cohort of students, which did not allow for statistical analyses. The results show that the students were able to transfer SDL skills learnt in one module and one context to another as they progress through the DCHE spiral curriculum, and then to the real-world work environment during their internship. Moving ahead, we have plans to convert some Year 1 practical-based modules to e-versions and continue to study how to develop SDL and enhance its transferability in DCHE students.

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