DESIGNING BLENDED-TYPE INTEGRATED LEARNING EXPERIENCE USING CORE PRINCIPLES OF LEARNING

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ABSTRACT

This paper shares the experience in designing a blended learning to provide an integrated learning experience (CDIO Standard 7) for students to develop a core competency required in the workplace. The integrated learning experience is designed using a set of core principles of learning. Specifically, the integrated learning experience is contextualized to develop the required skills and desired attitude in carrying out line-tracing in the chemical process industries. The students are from the Diploma in Chemical Engineering, who spent about 4 hours per week on the learning tasks, for a total of 3 weeks. In blended learning approach, students first learn how to read an engineering drawing known as the piping and instrumentation diagram (P&ID), a blueprint for a chemical plant. This is achieved through an e-learning package developed by the author. Students then learn about skills in conducting line-tracing, based on a pilot plant in the workshop. They are then given the opportunity to practice line-tracing using the same pilot plant. Lastly, they are required to sketch their own P&ID for other pilot plants that they will later use in subsequent activities. The paper first provides a brief background of line-tracing and P&ID, to set the context (CDIO Standard 1) for designing the integrated learning experience, and the key desired learning outcomes (CDIO Standard 2) are explained. The paper then gives a quick overview of core principles of learning and proceeds to provide detailed explanation of how the integrated learning task is designed. The paper then elaborates on the choice of collaborative learning as key pedagogy, and the design leveraged on students' prior learning in chemical plant operation, teamworking and self-directed learning (CDIO Standard 3). The paper also addresses the assessment of student learning (CDIO Standard 11). High effect size strategies to scaffold student learning (such as workbook, feedback and reflective practice) and promote collaboration, as well as measures to evaluate effectiveness of teamworking are also shared. The latter requires students to carry out self and peer assessment using an online platform, which automatically calculates the Self and Peer Assessment (SPA) factor and the Self-Assessment to Peer Assessment (SAPA) factor. Lastly, as part of continual improvement (CDIO Standard 12), the paper concludes with findings of student learning experience via a survey, the author's own reflection and suggestions to further enhanced the learning from such an endeavour.

KEYWORDS

Core Principles of Learning, Blended Learning, Standards: 1, 2, 3, 7, 11, 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

A key area of employment for student graduating from the Diploma in Chemical Engineering (DCHE), Singapore Polytechnic is in the chemical processing industries, taking on positions as process technicians or engineering executives. One key competency in this job role is the ability of reading a blueprint of the chemical plant known as the piping and instrumentation diagram or P&ID in short. The importance of the P&ID cannot be understated: it provides key information about the plant including all equipment, instruments, valves, pipes and piping components, as well as key process parameters (temperature, pressure, flow rate, etc) and material (feed, intermediate, product, by-product, utilities, waste, etc) and energy flows in the plant. There are represented by symbols with suitable abbreviations and nomenclature. The process technician familiarise himself or herself by walking with the chemical plant using the P&IDs. The P&IDs are also referenced every time any modification is to be made to the plant; and updated after the modifications were made. One main challenge is that, despite the availability of international standards, the use of different symbols, abbreviations and nomenclature are prevalent among chemical companies' own in-house system, plant design contractors and plant design software vendors. A chemical company can easily end up with different P&ID systems, much to the frustration of its engineers and process technicians.

P&ID reading and line-tracing are taught to DCHE students in Year 1, Semester 2, in a module entitled *Laboratory & Process Skills 2*. This module aims to impart in students various laboratory skills and process skills, chief among the latter are the P&ID reading and line tracing. The module is non-examinable, and assessment is based fully on report submissions; whereby students need to complete 10 learning tasks and an assignment over a 15-week period (Table 1). The first 3 learning tasks (P01 to P03) are continuation of laboratory skills that was started in another module, *Laboratory & Process Skills 1* taught in Year 1, Semester 1. The integrated learning experiences on P&ID reading and line tracing (P04, P05 and P06) are covered in 3 Parts in the following 3 weeks. These tasks are meant to prepare students for 4 subsequent activities in plant operations (P07 to P10).

Table 1. Schedule of Activities for *Laboratory & Process Skills 2*

Week	Activity Number and Name / Description		Comments
1	P00	Safety Briefing, Teamwork Exercise, Mini-Workshops on Thinking & Self-Directed Learning (SDL)	Student complete teamworking sheet (same as Semester 1), self-assessment of SDL skills
2	P01	Investigation on Parameters that affect Leaching	Lab skills on Design of Experiments
3	P02	Study on Sensible and Latent Heats – Part 1	Lab skills in planning experiments using SDL + Survey 1 after P03
4	P03	Study on Sensible and Latent Heats – Part 2	
5	P05	P&ID Reading and Line-Tracing Part 1 (e-Learning)	Feedback on Reports for P01-P03 (during P04) Process skills + SDL in chemical plant operation, and chemical process safety Debrief P05 (during P06) Teamwork Measurement 1
6	P04	P&ID Reading and Line-Tracing Part 2, including Process Hazards Analysis	
7	P06	P&ID Reading and Line-tracing Part 3, sketching of P07-P10 P&IDs	
8	-	Mid-Semester Test (Not applicable for this module)	Survey 2
9-11	-	Semester Break	Assignment on P&ID Reading
12	P07	Fluid Flow Pilot Plant & Utility Systems	Weeks 12-15: Process skills in plant operation (Rotation, 1 pilot plant per group per week)
13	P08	Shell-and-Tube Heat Exchanger Operation	
14	P09	Multiple Pump Test Rig	
15	P10	Double-Pipe Heat Exchanger Operation	
16	-	Debrief & Wrap-Up	

			Week 16: Survey 3 + Teamwork Measurement 2, Briefing on preparing for next stage (Sem 1 Year 2)
17	-	Spare week for any make-up class	NIL

BLENDED LEARNING APPROACH TO INTEGRATED LEARNING EXPERIENCES

There are various definitions of blended learning, and the purpose of this paper, it is suffice to use one offered in the Oxford Dictionary: a style of education in which students learn via electronic and online media as well as traditional face-to-face teaching.

As can be seen in Table 1, the integrated learning experiences of interest in this paper is the one on P&ID reading and line tracing, imparted to students over a 3-week period. It starts with Part 1 (in P05) which is delivered fully online in an asynchronous manner, as part of e-learning. A series of 11 short videos were created using PowerPoint with narratives and posted to YouTubes for students to access and watch on their own time. Parts 2 and 3 are carried out face-to-face in the laboratory, where Part 2 (in P04) continues to build on P&ID reading skills developed in Part 1 to developed line-tracing skills; and lastly Part 3 (in P06) requires students to apply the skills to trace the lines and sketch P&IDs for various pilot plants.

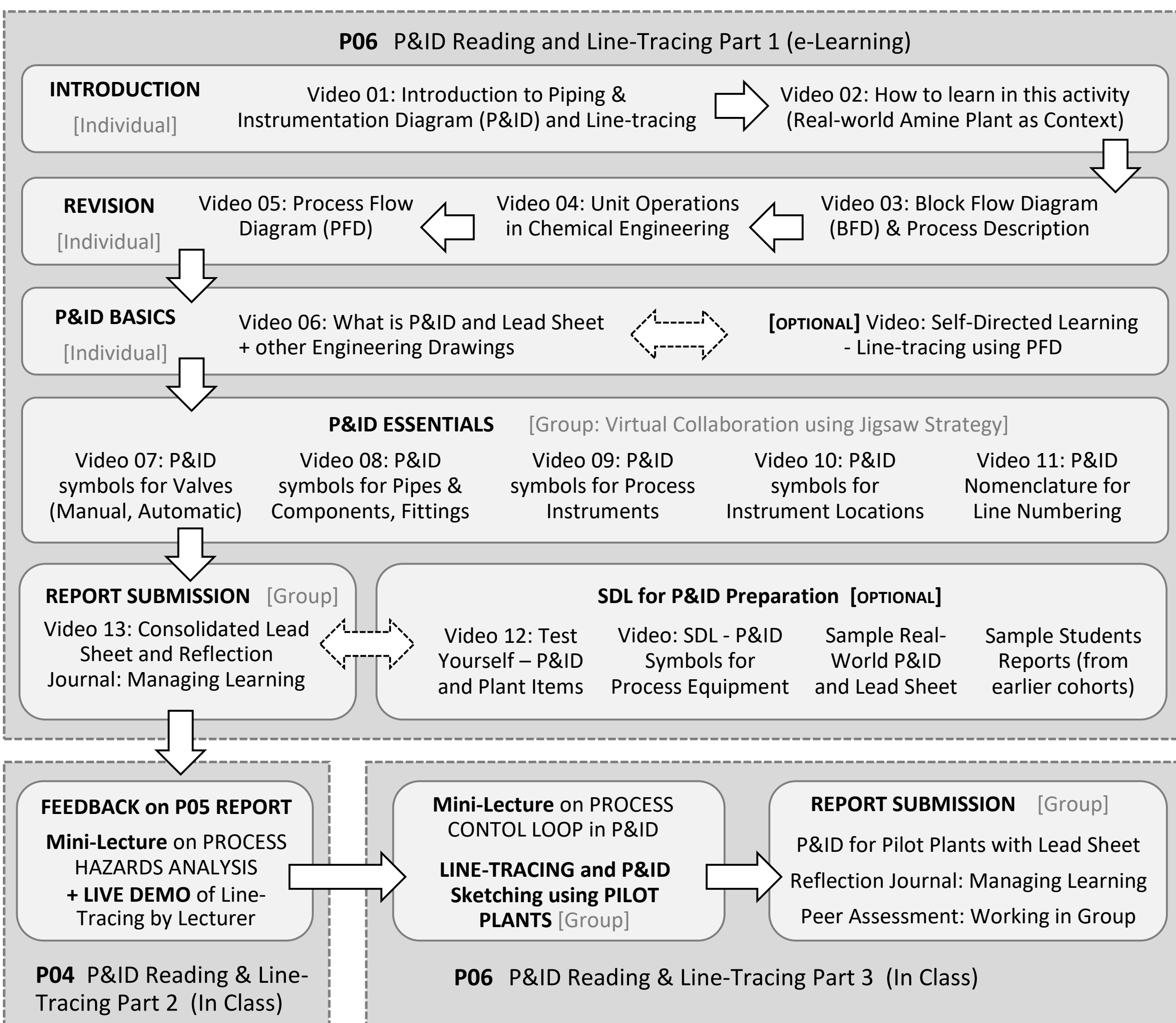

Figure 1. Blended Learning for P&ID Reading and Line-Tracing

The blended learning aims to simultaneously develop the technical knowledge in P&ID reading and line-tracing, as well as skills and attitudes in preparing a P&ID (which is a form of graphical communication for chemical engineers), self-directed learning skills in learning about P&ID symbols, and teamwork in completing the various assignments, which was deliberately designed to the very challenging for any one student to complete on his/her own.
The context for learning (CDIO Standard 1) is clearly explained to students, which is based on the job role for process technician as spelt out in the Energy and Chemicals Skills Framework (Cheah, et al; 2019). The technical aspects of the learning outcomes (CDIO Standard 2) are:

(a) Interpret piping and instrumentation diagram (P&ID) of a given process.
- Able to apply prior knowledge in Block Flow Diagram (BFD) and Process Flow Diagram (PFD), to explain operation of a chemical plant using its Process Description
- Able to explain simple Process Control Loops shown in a PFD, and the relationship between process variables
- Able to understand symbols shown in a Piping & Instrumentation Diagram (P&ID) in terms of the item (equipment, instrument, valves and other piping elements) that the symbol represents and how it is connected to other items
- Able to explain information (size, class, material, etc) contained in a line number as explained in the P&ID's Lead Sheet

(b) Perform line tracing of pilot plants.
- Able to trace a given line (process or utility), locate and identify all items (equipment, instrument, valves, other piping elements) contained in the given line using the P&ID
- Produce a PI&D sketch (including lead sheets) of a given pilot plant
- Able to obtain additional details about an Item from various sources, e.g. from name plate attached to the item, information stamped on the item, tags or labels secured to the item, as well as data sheets and vendor catalogues

In addition, students are informed that there will be 2 touchpoints where teamwork measurement exercise will be carried out (Table 1) where they are required to do self- and peer evaluation based on them working together in teams.

DESIGNING INTEGRATED LEARNING EXPERIENCES USING CORE PRINCIPLES OF LEARNING

Sale's 10 Core Principles of Learning (Sale, 2015), as shown below, are used to guide the design of integrated learning experiences which is then delivered using the blended learning approach:

CP01 Learning goals, objectives and proficiency expectations are clearly visible to learners
CP02 Learners prior knowledge is activated and connected to new learning
CP03 Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject
CP04 Good thinking promotes the building of understanding
CP05 Instructional methods and presentation mediums engage the range of human of senses
CP06 Motivational strategies are incorporated into the design of learning experiences
CP07 Learning design takes into account the working of memory systems
CP08 The development of expertise requires deliberate practice
CP09 A psychological climate is created which is both success-orientated and fun

CP10 Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback

These principles are based on his extensive review of the literature on human learning and studies on effective teaching professionals in a range of educational contexts. They are not exhaustive or summative as new knowledge and insights will continually enhance our understanding of human learning and the implications for how we teach. Furthermore, just as combining high effect methods can have a powerful overall impact on learner attainment, as captured in Hattie's (2009) analogy of 'Russian Dolls', the same applies to the thoughtful and creative application of core principles of learning.

The use of these Core Principles of Learning in the design of integrated learning experiences (CDIO Standard 7) is further illustrated below, using the design of Integrated Learning Experiences for activities in P05, which as noted earlier is delivered via e-learning, as shown in Figure 1 earlier. In the sections that follow, other relevant CDIO Standards impacted are also highlighted, to illustrate the inter-dependence of these standards.

<u>CP01: Learning goals, objectives and proficiency expectations are clearly visible to learners</u>

The learning context and learning outcomes were spelt out at the beginning, and repeated at suitable intervals, and emphasized again in Report Submission section. Explicitly taught on Week 1 (Table 1) are Sale's Model of Thinking (Sale, 2015) and SP's Model of Self-Directed Learning (SDL) (Cheah, et al, 2019). These are repeated multiple times in various e-learning narratives and in-class PowerPoint slides.

<u>CP02: Learners prior knowledge is activated and connected to new learning</u>

As shown in Table 1 and Figure 1, the learning tasks are sequenced to take place over a 3-week period to allow sufficient time for students to grasp the contents and make meaningful connections in the learning. The activity starts with Part 1 (P05) that introduces students to P&ID reading, by building on their earlier knowledge of other engineering diagrams, namely the BFD and PFD; and fundamental knowledge of typical equipment and processes in a chemical plant, as well as the importance of various process variables such as temperature, flow rate, composition, level and pressure (Figure 1: Videos 01, 03, 04 and 05). Students learnt these topics in the module *Introduction to Chemical Engineering* in previous semester. Students are then introduced to P&ID in Video 06.

The above also serves to illustrate how curriculum integration of technical content is being carried out in DCHE (CDIO Standard 3). In CDIO, curriculum integration emphasizes the infusion of skills and attitudes alongside the technical content. Students are reminded to maintain a growth mindset and to use the teamworking skills they learnt in another module *Laboratory & Process Skills 1* in the previous semester (Week 1, in Table 1). In addition, students are required to exercise SDL skills imparted in earlier activities (covered in P02 and P03 in Weeks 2 and 3, Table 1, for laboratory skills) in the context of P&ID Reading (Cheah, 2020). To give them an idea of what the line tracing process entails and how SDL can be used, an optional video demonstrating how a simplified process can be done using the PFD, a document that they are already familiar with.

<u>CP03: Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject</u>

Content is organized around understanding the P&ID of an amine processing plant, commonly found in the chemical processing industries. The P&IDs of the plant is derived from a real-work operating unit that the author worked on, in his previous place of employment prior to joining the academia. Students are therefore exposed to the actual complexity of a chemical plant. In Part 1 (P05), students are taken through the structure of a plant P&ID, emphasizing a master reference section known as the Lead Sheets, which is like a pictorial dictionary comprising all the symbols, abbreviations and nomenclature for various plant items organized into different categories of equipment, valves, instruments, pipes and piping component, etc. These are offered as "P&ID essentials" in the form of Videos 07 to 11 (Figure 1). The technical outcome of P05 is to prepare a Lead Sheet comprising all the P&ID symbols for the different categories of plant items. One of the key requirements from students is to reconcile the differences, and at times conflicting, symbols used by different parties; for example, a plant item with 2 or more different symbols from different vendors or contractors, or the same symbol used by 2 different vendors and assigned to 2 different plant items. This requirement adds realism to the learning experience, as this is indeed how the real world is liked.

Part 2 (P04) then built of the learning from Part 1 (P05), where students are now introduced to techniques of line-tracing and identifying process hazards. Then Part 3 (P06) built on the learning from Part 1 (P05) and Part 2 (P04) whereby students sketch their own P&IDs for assigned pilot plants based on the line-tracing that they conducted.

<u>CP04: Good thinking promotes the building of understanding</u>

and featured regularly in various topics covered, as illustration on how to use it, as well as reminder for students to use it. Cutaway views of plant items in particular various types of valves, or piping components. In the video for line-tracing using PFD, guiding questions or prompts are used to guide students in the thinking process. Techniques of breaking down a seemingly complex problem into its constituent parts – itself an application of good thinking – are taught to students, for example to start with the familiar, look for similarities or repeat occurrence of same symbols, logical deduction, are covered.

<u>CP05: Instructional methods and presentation mediums engage the range of human of senses</u>

In the blended learning used in P05, real world pictures of plant items are used, alongside with vendor drawings, YouTube videos, animations curated from vendors, etc are used. 2 set of learning documents – one Instruction Manual, and one Workbook – are made available to students. In the face-to-face sessions for P04 and P06, students get to touch and feel actual cutaway models of various types of valves when they are working in the laboratory; and in P06 they get to walk around various pilot plants to complete the line-tracing process and carry out process hazards analysis with real plant items, albeit on pilot plant scale.

<u>CP06: Motivational strategies are incorporated into the design of learning experiences</u>

Various scaffolds and supports are made available. One main item is the use of Workbook to help student keep track of their progress during the e-learning of P05. This approach has been shown to be effective in engaging students in their learning (Nathan, 2010). There are also short, self-test learning tasks embedded in each video to help students assess their own learning. Hints are given as appropriate. Also made available (see Figure 1) are: (1) rubrics for preparing Lead Sheets, customized to preparing lead sheet and line tracing, so that students are aware of the expected performance standard; (2) samples of not-so-good reports from earlier cohorts that did not meet desired expectations; (3) interactive web-based SDL for line-tracing, with guidance questions for each step of the process; and (4) a comprehensive 40-question self-evaluation that can be taken at the end of the e-learning process (Video 12 in Figure 1).

CP07: Learning design takes into account the working of memory systems

The entire learning journey is split into 3 sessions, with P05 being conducted via e-learning whereas P04 and P06 are face-to-face, where each session lasts 4 hours. The learning progression in P05 is structured to engage students in understanding P&ID symbols in bite sizes. Each major topic is segmented into short sections, punctuated with small activities to reinforce the content covered and group exercises before moving on to the next topic. Summary of tasks covered are included just before instructions for report writing, to remind students of the topics learnt and follow-up needed in report submission. Students were also briefed on how they should approach the learning task in P05 (Video 02).

CP08: The development of expertise requires deliberate practice

Besides the self-test learning tasks embedded in each video in P05, there is also a separate. non-assessed set of 42 questions (Video 12) at the end of P05 for students to test their understanding. These questions cover the full range of topics in P05 covered earlier. Many of these questions require students to use knowledge from different topics, thereby creating an awareness among students on how they should integrate their learning from the various topics covered. In P04, students carried out line-tracing on their own after watching the lecturer demonstrated the process. In P06, they carried out more line tracing and P&ID sketching on their own.

CP09: A psychological climate is created which is both success-orientated and fun

The questions posed at the end of each topic are relatively easy, and presence of Model of Thinking prompts students to use certain thinking heuristics make the task achievable. Lecturer serving as facilitator also model the desired behaviour. Sharing of personal experience and near-miss stories also helped. Many of the learning tasks are made bite-size by having each team member being responsible for one section of the task; whereby they then collectively piece together all members' answers to address the question raised. To this end, students were taught how to use the jigsaw approach in collaborative learning.

CP10: Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback

Most assessments are formative in nature, introduced at the end of each short topics in the case of P05, which is conducted via e-learning format. For P04, interactive question and answer format (active learning) is used in class as the lecturer take the class through the step-by-step line tracing and thinking process, based on a selected section of a plant's operating manual. Emphasis is made on understanding the rationale for carrying out a prescribed step and potential consequence of failure to adhere to the procedures; instead of merely following what is prescribed in the manual. For P06, students are given time in class to work on more activities, again using collaborative learning. Feedback is largely given in real-time based on work done by students. Reports (summative assessment) are marked and promptly returned to students within a week, with detailed comments, and they are given the opportunity to improve their P&ID lead sheet.

EVALUATION OF STUDENT LEARNING AND TEAMWORKING EXPERIENCES

Two instruments were used: one was a survey questionnaire for the blended learning approach for learning P&ID; and another was an online tool for teamwork measurement. For the survey questionnaire, details are not included in this paper due to constraint in the number of pages. Suffice to note that the survey is rather exhaustive and we had the liberty to craft probing questions to elicit responses specific to the learning tasks in P04, P05 and P06.

For measuring teamwork, we used the online assessment tool that computed two factors namely SPA (Self and Peer Assessment) and SAPA (Self-Assessment to Peer Assessment) based on student responses to a feedback form (Willey & Gardner, 2007; Freeman & Willey, 2006). In our adaption of the method, each student is required to complete the feedback based on 7 questions. The first 5 questions require each student to rate himself/herself and his/her team members on 5 dimensions – Competency, Team Contribution, Interaction with Team Members, Keeping Team On-Track, and Quality Work – using the Likert 5-point scale ("1 – Never", "2 – Rarely", "3 – Occasionally", "4 – Usually" and '5 – Always"). The other 2 questions are open-ended: and each student is to provide input on what one appreciates about one's team member, and a request from one's team member.
The first factor calculated, SPA, provides feedback about a student's performance compared to the average performance of all members in the team. It can be used as a weighting factor to change a team mark for a project (stage) into an individual mark. For example, if a team's project mark was 80 out of 100 and a team member receives a SPA factor of 0.9, he/she would receive an individual mark of 72 to reflect a lower-than-average team contribution as perceived by a combination of the team member and his/her peers. Alternatively, if not used to moderate summative assessment the SPA factor can be used formatively to assist in student development (CDIO Standard 11).

The second factor calculated, SAPA, is the ratio of a student's own rating of himself/herself as compared to the average rating of contribution by his/her peers. This has strong feedback value for future development e.g. using self-critical reflection. It provides students with feedback how the student perceives his/her own contribution relative to how his/her team perceive his/her contribution. For example, a SAPA factor greater than 1 means that a student has rated their own team performance higher than they were rated by their team peers. Conversely, a SAPA factor less than 1 means that a student has rated their own performance lower than they were rated by their peers. The possible combinations are shown in Table 2.

Table 2. Teamwork Measurement: SPA and SAPA Factors

	SPA < 1.0	**SPA = 1.0**	**SPA > 1.0**
SAPA < 1.0	1. Your performance is below expectation and your self-assessment is too low.	2. Your performance met expectation, but your self-assessment is too low.	3. Your performance exceeds expectation, but your self-assessment is too low.
SAPA = 1.0	4. Your performance is below expectation and your self-assessment is about right.	5. Your performance met expectation and your self-assessment is about right.	6. Your performance exceeds expectation, and your self-assessment is about right.
SAPA > 1.0	7. Your performance is below expectation and your self-assessment is too high.	8. Your performance met expectation, but your self-assessment is too high.	9. Your performance exceeds expectation, but your self-assessment is too high.

Results for both SPA and SAPA in the range of 0.95 to1.00 is considered Acceptable Teamwork, and in the range of 1.00 to 1.05 as Good Teamwork.

DISCUSSIONS ON FINDINGS

For the survey questionnaire, a total of 87 students participated, out of 7 classes totalling about 140 students, i.e. a response rate of about 62%. The key findings are shown in Table 3. Overall, majority of students find the blended learning approach either useful or very useful in helping them learn about P&ID reading and line tracing. However, comparing P05 (Statement 1) which is e-learning, with P04 (Statement 2) and P06 (Statement 3) which is face-to-face, it can be seen that students tend to value more face-to-face interactions. This may be due to the lack of interactions between students and facilitator for P05, as not all avail themselves to students during e-learning. And perhaps not too surprising, majority of students (Statement 4) are still not so sure of their ability to handle similar tasks for more complex plants in the real world. We see this as positive sign that most of them possess the growth mindset that was instilled in them since Semester 1 of Year 1. Other findings include the usefulness of instruction manual and workbook used to guide the learning process (69.0% Strongly Agree or Agree; 27.6% Somewhat Neutral), and the somewhat lukewarm on the use of Reflective Journal (49.4% Strongly Agree or Agree; 32.2% Somewhat Neutral). The rest of the findings identified various areas that proved challenging to students in reading or using P&ID, and 5 students (or 2.3% of respondents) who claimed that they still do not know how to conduct a line tracing.

Table 3. Selected Key Findings from Survey Questionnaire

Statement (Each statement had 5 possible answers, and each answer has a detailed description, that is for the purpose of this paper, had been broadly grouped into 3 categories of "Strongly Agree/Agree', 'Somewhat Neutral', and 'Strongly Disagree/Disagree')	Percentage of Responses		
	Strongly Agree or Agree	Somewhat Neutral	Strongly Disagree or Disagree
1. Do you find the activities in P05 sufficient put across the understanding of importance of self-directed learning (SDL), to help you make sense of a Piping & Instrumentation Diagram (P&ID) and the Lead Sheet?	58.6	36.8	4.5
2. Does the table-top line-tracing in P04 using a given P&ID and set of operating procedures, equipped you with the knowledge to prepare yourself for the actual work in the pilot plant itself?	75.9	23.0	1.1
3. Are you able to apply the skills in P&ID reading (covered in P05) and line-tracing (covered in P04) to the activities in P06 (i.e. line-tracing and sketching of P&ID pilot plant to be used in P7 to P10)?	81.6	18.4	0.0
4. Please rate how confident you are, envisioning in the near future, if you are in a new plant environment (for example during internship in Year 3) in your ability to read a P&ID of a chemical plant that is **new to you**; based on the skills acquired from P05 on P&ID Reading and Lead Sheet Symbols.	32.1	59.8	8.0
5. Do you think good teamwork (division of work, cross-teaching one another P&ID symbols for different categories of plant items, review of work done by each member, checking for completion of report before submission, etc) was practiced in the completion of the	79.3	12.6	8.0

assignments required for P05 on P&ID Reading and Lead Sheet Symbols?			
6. Do you think good teamwork was practiced in the completion of the assignments required for P06 on sketching of P&IDs for the assigned pilot plants – those to be used in later activities, namely P07 to P10?	71.2	23.0	5.7

On the other hand, for SPA/SAPA teamwork measurement, due to this being the pilot year the initiative is introduced, we have very limited data to work on. For DCHE, the Course Management Team decided to pilot this with one module per semester, starting with Semester 1 of Year 1, with 2 selected classes only. In fact, it was the author's initiative to carry out the teamwork measurement for this blended learning activity, i.e. not part of the DCHE pilot run. He tested this with the one class (in Semester 2 or Year 1) where he served as the facilitator. Although ALL students in this class completed the SPA/SAPA assessment, only 11 of them completed the survey questionnaire. The findings are shown in Table 4.

Table 4. Sample Scoring for Teamwork Measurement

Class 1B/0X	Group A		Group B		Group C		Group D	
	SPA	SAPA	SPA	SAPA	SPA	SAPA	SPA	SAPA
Student 1	0.99	1.00	0.93	1.02	1.08	0.92	1.05	0.94
Student 2	1.00	1.03	1.10	0.92	0.98	1.13	0.97	0.96
Student 3	1.00	0.89	1.10	1.05	1.00	0.90	1.00	1.11
Student 4	0.98	0.99	0.93	0.94	1.08	0.99	0.98	1.06
Student 5	1.03	1.01	0.99	0.95	0.85	0.80	1.00	1.00

Despite the small sample size, we are able to make some inferences on the findings. Comparing the figures in Table 4 with that in Table 2, it would appear that with the exception of several outliers, most students in the class are quite 'on target' in terms of how they evaluate themselves and their team members. This can be compared with the findings from the survey questionnaire, namely student responses to Statements 5 and 6 (Table 3). Students generally reported good or very good teamworking in both activities that require then to work effectively in teams (P05: learning P&ID symbols and preparing lead sheets), and P06 (line tracing of selected pilot plants, and sketching the P&IDs). Interestingly, there was higher satisfaction with teamwork in P05 (32.2% Strongly Agree, 47.1% Agree) which came before P06 (28.7% Strongly Agree, 42.5% Agree). This could be due to the explicit instructions given to students in P05 (including how to use the jigsaw strategy), but we are largely silent on teamwork in P06. However, not being able to identify specific students who contributed to the survey questionnaire, which was conducted anonymously, we were not able to further link the negative findings from P05 (2.3% Strongly Disagree, 5.7% Disagree) and P06 (0.0% Strongly Disagree, 5.7% Disagree) with specific suggestions each student gave to team members in the 2 open-ended questions in the SPA/SAPA measurement.

The one challenge that we faced, in trying to discern the contributing factors that leads to the outliers, in particulars scores lower than 0.95, which can be sign of loafing or free-riding, is that students tended to be more 'conservative' when providing open-ended answers for their team members to improve, as compared to giving a score using Likert scales.

Lastly, it is to be noted that since not the entire 2 classes used the SPA/SAPA measurement to evaluate teamwork for this blended learning activity, we do not use the SPA scores for any mark adjustments.

REFLECTION ON THE LEARNING TASKS AND AREAS OF IMPROVEMENT

One of the main challenges that we tried to overcome using the blended learning approach is to provide students with realistic and immersive learning experience otherwise not available to them. Due to the large number of students (140 in total for Year 1), it is logistically not possible to arrange for visits to chemical plants. Even when visits are possible, the is a cap on the maximum number of students permitted on site, for example, a petrochemical company once restrict the trip to its premises to only 30 students. Even when a visit is possible, the trip is limited to a bus tour following prescribed lanes inside the chemical plant compound. There is in fact a legislation that all personnel must take a 1-day safety orientation course and pass its examination before one is permitted to enter *any* chemical plant. Therefore, there is no opportunities for students to get “up close” to a piece of plant equipment. Timing is also a factor, as a company can only host a visit for a duration of about 3 to 4 hours as the maximum.

With the Covid-19 pandemic, we faced additional challenges: first, the campus is closed for extended periods of time, and we need to convert as many experiments as possible to the “online” version. This unfortunately is not easily done for us in the chemical engineering discipline, as efforts are needed to create digital versions of pilot plants – both in terms of technical know-how to use the software and also the financial cost of doing so, in addition to the long development time. Second, even with the eventual opening of campus, and students are allowed back to the laboratory, the necessity of maintaining safe distance among students also imposed a constraint on how many of them can work in a given pilot plant. The Covid-19 pandemic had somewhat altered our plans on how to improve the student learning experience (CDIO Standard 12).

Moving ahead, the author is working on converting the activities in P04 and P06 (see Figure 1) into the e-learning version as well. It is envisioned that the design of P04 will use a combination of pre-recorded video of the Neutralizing Reactor Pilot Plant which is used for the activity; and pre-recorded, narrated PowerPoint slides. The Core Principles of Learning will once again the used, leveraging on learning acquired from P05 covered in this paper. In the author’s opinion, it is acceptable that this activity be fully e-learning, because the overriding consideration is to maintain safe distancing around a single pilot plant.

Lastly, is P06, for which the challenges students identified can best be addressed. Ironically, this is still be achieved with real presence in the pilot plant. Considerations for e-learning version of P06 however, is also more challenging in that this activity is meant to lead on to later activities, namely P07 to P10; which decidedly still requires physical presence at site working on the pilot plants. It is not expected that fully online versions of these activities will be available anytime in the near future. It is therefore decided to create a learning task based on Interactive Video for one of the four pilot plants for P07 to P10, namely the Shell-and-Tube Heat Exchanger Unit. Interactive video is a type of digital video that supports user interaction. These videos play like regular video files; but include clickable areas or "hotspots" that perform an action when you click on them. For example, when you click on a hotspot, a multiple-choice question may appear that require student response, or to display information about the object clicked on via a pop-up box, or to jump to a different part of the video, etc. The choice is made in order to retain some elements of interactivity that requires facilitation from the lecturer, to ensure that important learning points are covered, or highlight key features that may get glossed over by students, if they were left to complete the activity on their own.

While one can debate about the relative merits of going fully e-learning versus blended learning, notably in terms of full e-learning not being able to deliver certain desired learning outcomes that can only be developed or acquired via hands-on experience. This is especially the case for the chemical processing industries, where one also learns from the senses: sight, sound and smell; especially the latter that is hard to duplicate in the even with advanced technologies such as digital twin. Case in point is the radiant heat of a furnace, or the odour of fugitive emissions. The lesson of Covid-19 had in a way forced a decision on what matters most, in terms of continuity of some form of education via e-learning as compared to no learning at all due to campus closure. It had become more acceptable for lecturers to accept the fact that some learning outcomes need to be forfeited and replaced with less effective ones, e.g. verbal description or graphical depiction of unpleasantness of exposure to radiant heat or foul-smelling discharges.

All in all, it can be said that based on reports submitted by students (in terms of lead sheets, and sketched P&ID of various pilot plants), there had been improvements compared to previous cohort that learnt entirely through the face-to-face interactions. However, the author is hesitant to conclude from these observations alone, on effectiveness of blended learning, as there had been other improvements in the learning tasks implemented for this cohort with blended learning, such as the use workbook, or simply better design or presentation of the learning materials.

Lastly, on the teamwork measurement, as we ride on the institution-wide initiative for our own evaluation, we were not able to add additional questions to the standard template. This in the author's opinion, had somewhat limited the usefulness of the findings. Fortunately, he was able to build into the separate survey questionnaires, 2 questions that ask students for responses on their perception of teamwork when completing the blended learning activities (P05, P04 and P06) that enabled him to cross-check some of the findings reported by the SPA/SAPA calculations. Another point is that some authors highlighted on the needs for moderation of students' SPA/SAPA scores to account for possible biases among team members, or that some may try to game the results. The results obtained from this pilot run seemed to indicate that this is not a concern as far as the class is concerned. We need more trials with this way of measuring teamwork before a more affirmative decision can be made.

CONCLUSION

This paper shared the design of a blended format of integrated learning experiences for developing competency in P&ID reading using the Core Principles of Learning. Examples of how each of the ten core principles are explained and examples provided. Findings from students experience on the learning process showed that thoughtful design of such learning activities can benefit student learning. Preliminary results from the use of SPA and SAPA scores looked promising as a tool to assess teamwork, but more trials need to be used with more classes. Areas for improvement for the blended learning activities had been described, which pointed to the way for more online components to reflect the needs for continued delivery of education in the event of pandemic such as Covid-19.

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