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Integrated Sustainable Development Project for First Year Chemical Engineering Students

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ABSTRACT

In view of the need to equip students with 21st century attributes, for the past 15 years, first year chemical engineering students undergo specially crafted sustainable problem under the Introduction to Engineering (ITE) and Industrial Seminar and Profession Course (ISP) courses. Recently, in order to improve and create more challenging sustainable problems, the development and execution of the sustainable problem has been integrated with the Introduction to Computer Programming (ICP) course. Under the Smart Consumerism Campaign 2020 (SCC2020), students were given tasks to comprehend, calculate and formulate carbon footprints of normal daily used products. This requires students to grasp the concepts of sustainability and sustainable development, among others, and challenged their critical thinking to come out with an app that could calculate carbon footprint. The integrated effort from three compulsory courses (ITE, ISP and ICP) have helped students develop important engineering skills. It represents an innovative collaboration between courses to develop students' 21st century attributes and skills. Encouraging feedbacks from students were extracted and analysed from their reflection journals. Thus, the positive impact of course integration has validated the effectiveness and suitability of the established authentic problem based CPBL model for typical engineering courses.

1. Introduction

United Nation has outlined 17 Sustainable Development Goals (SDG) [1] that aims to put an end to poverty, achieve prosperity, and preserve the planet for everyone by 2030. The integration of the sustainable development (SD) element into existing curriculum or courses in institutions of higher learning falls under SDG 4, with the objective to ensure quality education that is equal and inclusive, as well as to advocate lifelong learning opportunities for everyone. For the accreditation of engineering programs under the Washington Accord, sustainable development must be embedded

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in the curricula to ensure future engineers who are aware of their roles in providing sustainable solutions for the betterment of the world [2].

The need to firmly incorporate SD into engineering education has led to the implementation of various pedagogical approaches. In Singapore Polytechnic, the integration of SD was made through the Chemical Reaction Engineering course in their Diploma of Chemical Engineering curriculum, which was developed through the Conceive Design Implement Operate (CDIO) concept [3]. They focused on implementing chemical engineering principles to SD, incorporating design and management of SD, as well as environmental and social impacts and restrictions. Langara College in Vancouver, Canada developed and integrated sustainability, project management and research into a team and project-based first year engineering course, APSC 1010: Engineering and Technology in Society. Other than the traditional lectures and class discussions, the instructional methods include expert appearances [4]. Blottnitz *et al.,* [5] presented a case in the University of Cape Town, South Africa, where curriculum reforms were made in the chemical engineering curriculum, to incorporate a new introductory course highlighting sustainable development. The course is divided into three main parts starting with seminars like natural foundations theory, followed by practice to develop engineering skills where students will write about sustainability and finally the water reuse or desalination project, which is used as a means to tie the theory and skills developed.

There are many advantages of integrating different courses in a curriculum. Student would be able to see the connection between different courses and how they are interrelated. In addition, the integration can also reduce the workload of the students as the same project or assignment can be provided for all courses. Students are also expected to be more responsible and sensitive towards the issue highlighted in the tasks and able to improve critical thinking and problem-solving skills, in addition to providing more structured argument in their tasks [6,7].

In the Chemical Engineering program in Universiti Teknologi Malaysia, since 2005, the Introduction to Engineering (ITE) course had been designed to embed a sustainable development-based problem through the Cooperative Problem-Based Learning (CPBL) approach [8]. This course aims to motivate and prepare first year students for learning engineering while instilling them in sustainable development [9]. Student-centred learning (SCL) approaches are implemented, and real problems based on sustainability related issues are designed with input and cooperation with industries or related agencies. In 2010, to provide additional support for the students, the ITE course was integrated with the Industrial Seminar and Profession (ISP) course to include stakeholders into the curriculum by inviting them to share their experiences and knowledge. Since the Introduction to Computer Programming course taken by the first-year students has an end-of semester project, in the 2020/2021-1 session, we made the effort to integrate the project with the final part of the problem in the ITE course. The integration will hopefully provide context for the programming project and motivate the students to be more aware of their future role in attaining sustainable development for the nation and community.

In this paper, we describe the implementation of the sustainable development project integrated between the three courses. Since students were at home amidst pandemic (for the 2020/2021 session), the focus for the problem this semester on consumerism was designed relevant to them. In Smart Consumerism Campaign (SCC), students investigated consumer behaviour to guide themselves and their families' purchases towards lowering their carbon footprint. For the final solution of SCC, students were asked to formulate a computer program for calculating carbon footprint based on different modes of purchase.

There are many literatures discussing the integration of SD at different levels in education, including national, regional, institutional, program/curriculum and integration directly at the course level itself. Anand *et al.,* [10] from the Université de Sherbrooke, Canada discussed the incorporation

of SD at the regional level in Quebec, Canada through two universities and five colleges. They did not merely look at the integration itself but also in terms of the pedagogical approach. The reason for this regional approach is so that the learners can be inspired and later inspire the local community around them to adopt sustainability in their lives. Through a regional initiative called Partnership, Learning, Collaboration and Transfer in Sustainable Development Education (PACTE 2D), three strategies were used; to provide aid and support for professors, to integrate SD at the curriculum level and to develop a global approach to integrate sustainable development at the institutional level. Holgaard *et al.,* [11] discussed the integration activities of SD in two universities (Aalborg University and the Royal Melbourne Institute of Technology) in two different countries – Denmark and Australia. After systematically comparing the two different scenarios based on the external and internal activities, entities, and resources, they came out with a conceptual framework that is able to point out the potential change strategies, in which activities are linked to entities and resources at both university and national levels.

Interest to address sustainable development in higher education have resulted in several review papers. Byrne *et al.,* [12] have made a comprehensive review on this global issue where there have been positive developments in many declarations, action plans, policies, code of ethics and accreditation guidelines. Ramos *et al.,* [13] have looked at the bird's eye point of view on the implementation of SD in institutions of higher education by reviewing 33 papers discussing the SD, participation and engagement of stakeholders, campus operations, sustainability reporting and curriculum design, development, and delivery. The review concludes that a better integration of SD in curriculum, research, and most importantly holistically into the institutions of higher education's system may be needed. Another review article by Thurer *et al.,* [14] made a systematic review of 247 literatures highlighting the integration of SD in the curriculum. They analysed the papers by asking questions on the new practices, the subjects and objects on whom the new practices are applied on, influence of other stakeholders and the outcomes of applying the new practices. From the analysis, based on the initial questions, the authors came out with twelve future research questions which if adequately answered, will enhance the integration and subsequently produce graduates ready to face the 21st Century Challenges. Handayani [15] in her review on the integration of SD in higher institutions in many countries concluded that there are three integration models that have been used which include a multidisciplinary approach, interdisciplinary approach, and transdisciplinary approach. Roure *et al.,* [16] presented the integration of SD in civil engineering curriculum through a developed framework. There are five steps in the framework which include mapping of the curriculum, setting learning targets, developing, and implementing an action plan for the assessed program and final performance assessment. In the integration, environmental life cycle assessment and life cycle costing are some of the utilized tools.

At the course level, there are many examples that can be found in the literatures. In Monash University, Australia, the sustainability element was embedded into a first-year engineering curriculum through the creation of a web portal [17]. Professors can use the resources in the portal to provide lectures and use it as a resource to prepare case studies and assignments. The portal is also available for the first-year students to support their learning. Montanes *et al.,* [18] on the other hand, integrated SD in the chemical engineering curriculum, specifically in their teaching laboratories by implementing an environmental management system. The reason for this is that the facility in the laboratories resembles the industrial setting closely and the set-up can be used to provide better exposure for the students to understand SD and how it can be implemented later in the real working environment.

Next is to highlight the integration of computer programming in the curriculum. Computer programming is widely used as a problem-solving tool to solve many different engineering problems

which would be a suitable integration with the existing ITE-ISP pair. Normally, the basics of computer programming is introduced at the early stage of the curriculum which sometimes pose certain drawbacks as the students' knowledge in core chemical engineering disciplines such as reaction engineering, thermodynamics, transport phenomena, and unit operations has not been well developed yet. Therefore, the application of the programming would be only to solve mathematical problems encountered in engineering mathematics instead. In order to solve that issue, Santos *et al.,* [19] developed an elective course on advance programming so that student will have the opportunity to implement their programming knowledge to solve pure chemical engineering problems. Therefore, through the integration of ICP with ITE-ISP that we have made, we can provide a context for the students to apply the programming knowledge which in this case was to develop a carbon footprint calculator.

Cress *et al.,* [20] on the other hand, have developed a MATLAB tool which contains modules from all the courses offered in the first year Chemical Engineering curriculum which include Engineering Computation, Engineering Biology, Chemical Engineering Concepts, Electrical Engineering, and Calculus for Engineering. This method has helped improve the students' problem-solving skills and encourage them to better integrate the concepts learnt in each course. In the work by Wang and Hwang [21], they have highlighted a problem posing-based strategy in facilitating the development of students' programming skills in a team-based learning (TBL). They agreed that TBL is a good way to learn programming where students can be creative, systematic, and communicate and collaborate effectively with their teammates. However, the students need to be engaged through a certain approach where they could actively build knowledge from each other while receiving assistance if needed. Through the CPBL problem in the ITE-ISP-ICP integration, the students are also assigned to work in teams. Ballesteros *et al.,* [22] applied PBL to the unit operations and modelling and simulation course using a joint project involving design, assembly, and characterization of a centrifugal pump which was later analysed through experiments and using mathematical models. This paper will further describe the design and implementation of the new integrated PBL activities between the ITE, ISP and ICP courses.

2. Methodology

The design of the problem is underpinned by constructive alignment [23] and the How People Learn (HPL) Framework [24]. The outcomes of each of the three courses were considered to ensure that the teaching and learning activities as well as assessment tasks are appropriate and aligned. The four lenses of the HPL, Knowledge, Learner, Assessment and Community centeredness are considered in designing an effective learning environment for students to undergo in reaching the intended learning outcomes. The integrated SD project is intended to consolidate three departmental courses taught in the first semester of the Chemical Engineering Program: Introduction to Engineering (ITE), Introduction to Computer Programming (ICP), and Industrial Seminar and Profession (ISP). It is a project that incorporates both theory and application from the three courses. It is a group project that focuses on a real-world sustainable development issue and an open solution that fosters student creativity.

ITE is a three-credit hour course with classes of 30 – 40 students. There are many sections, each is facilitated by two instructors. Students were divided into groups of three or four for this activity. A Cooperative Problem-Based Learning (CPBL) cycle guided student by assisting them in systematically identifying the problem, constructing new knowledge, and providing a solution [25]. As illustrated in Table 1, the complex problem presented in the ITE course is situated in a real-world environment with the involvement of stakeholders and is designed to incorporate the three pillars of sustainable

development. The 2020/2021 session focuses on consumerism activities and the environmental impact of human behaviours and lifestyles. The problem is divided into three phases to gradually increase the complexity for the students. Each level brings the student closer to the final objective, which involves documenting the final version of the problem solution. While these stages are consecutive, feedback occurs between them, providing students with the support that is needed to scaffold their learning.

Table 1
Schedule of Project Implementation

Week	ITE	ISP	ICP
3	SCC Stage 1 Learning Activity: as part of the CPBL cycle, search for information and learn about SD at local and global stages, then present critical analysis of findings. Learning Outcome: Able to explain SD, discuss current world scenario and benchmark current endeavours in Malaysia compared to other nations around the world by analysing collected data.	Understanding Consumer Behaviour: Toward a Greener Economy	Understanding MATLAB Environment and General commands
4		Understanding Carbon Footprint Calculation	Understanding MATLAB pre-defined functions, Arithmetic Operators and logical operators, and Arrays
5			
6		Introduction to Microsoft Excel and Basic Engineering Calculations	Developing script and function file in MATLAB
7	SCC Stage 2 Learning Activity: as part of the CPBL cycle, plan and collect necessary data at homes, then analyse the data to determine pattern for bench-marking. Use outcomes of data collection and analysis to justify problems that needs to be the focus of proposed solutions. Learning Outcome: Data collection to be taken from students and their family's needs to be designed to estimate and determine behavioural pattern. Then refine collected data and analyse for benchmarking against local and global information to propose possible solutions.	Sustainable Development: Between Opportunity and Challenges	
8			Understand Input-Output function
9		Sustainable and Ethical Consumer: Minimizing Our Impact to the Environment	Writing Structured Programming using Conditional Statements
10		Problem solving using TRIZ (The Theory of Inventive Problem Solving)	
11		Developing computer program for specific users	Writing structured programming for Loops
12	SCC Stage 3		
13	Learning Activity: as part of the CPBL cycle, design an innovative solution with sound justifications and receive feedback from stakeholders.	MATLAB Coding: A Practical Guide for Engineers	
14	Learning Outcome: Propose engineering solutions to a specific problem, receive feedback on problem and possible solutions from stakeholders and focus on the design of proposed solution		Propose an Apps for Carbon Footprint Generated for Consumerism Activity
15	Exhibition (Smart Consumer Campaign 2020)		

Stage 1 focuses on learning of SD, gathering information about the current global situation, and benchmarking. Students are required to conduct an initial investigation into SD initiatives in Malaysia

and throughout the world. Information must be collected from credible sources then analysed to decide on the definition of SD, the current state of sustainability efforts, Malaysian consumerism activities in comparison to those at the international level, and the impact on sustainable development that can be used for benchmarking.

Stage 2 focuses on a specific aspect of SD, data collection and subsequent analysis of the spending habits of students and their families, as well as how their purchasing and shopping habits have affected the environment thus far. The task requires students to analyse the impact of consumerism on the lives of a student and a Malaysian family. Additionally, a thorough audit of all goods purchased must be conducted. This requires tracking and recording the carbon footprint of all purchases. Students must analyse the data that has been collected and calculated, as well as compare it to data from Malaysia and other countries.

In Stage 3, students propose an engineering solution for a more environmentally friendly manufacturing and disposal process that is related to the consumer behaviour of a typical Malaysian student or family. The solution should be able to persuade users of the product's carbon footprint and how it affects their purchasing behaviour.

A series of seminars as shown in Table 1 were also organized for the students to help them solve the problem and acquire the skills needed for both the ITE and ICP courses. A talk on carbon footprint was held to introduce students to various aspects of carbon footprint, such as reliable database sources, data filtration and normalization, and, most importantly, the carbon footprint calculation itself. Additionally, there was a seminar on Introduction to Microsoft Excel, during which students learned advanced skills for using Excel in order to get the most out of it and apply it during data analysis for their case study project. Additionally, students learned about the Theory of Inventive Problem Solving (TRIZ). This is a well-known and effective technique for problem solving. Seminars on How to do Programming were also offered with the purpose of educating students on the basics of the subject. As a whole, the seminar is significant since it provides reinforcement for what students have learned in the ITE and ICP classes.

For the final part of the problem in the ITE course from week 10 to week 15, students were tasked with the development of a computer program using MATLAB to calculate the carbon footprint generated by a student and a Malaysian family's consumerism activities. This part is conducted in collaboration with the lecturers in the Introduction to Programming course, allowing students to get more support and in-depth context since they have been involved with the problem in both the ITE and ISP courses from the beginning of the semester. Carbon footprint and standard carbon emission factors should be calculated by the program. The program is expected to produce the following outputs: purchasing mode and distance, product list, packing, quantities, total price, and carbon footprint. Then, students are required to create an application that calculates the carbon footprint caused by any consumer activity. The input must be user-friendly, and the output must be visually appealing. Along with measuring the carbon footprint, the developed application should be able to compare several purchasing methods and propose the one with the lowest carbon footprint to assist the user in making informed shopping decisions.

The Smart Consumer Campaign Online Video Competition (Figure 1) was organized in week 15 to educate students about the alarming subject of climate change and the influence of human behaviours and lifestyles on the environment, as well as to encourage them to do their part for a cleaner, more sustainable future. Each team is required to create a video highlighting the developed applications and innovations included in the solution. External committees comprised of representatives from industry and other universities were also asked to assess the students' projects.

Fig. 1. Poster for the exhibition of CPBL project

Reflection journals were used to collect qualitative information so that the efficacy of the integrated project can be determined. Students were instructed on how to write reflective journals in which they may reflect on their learning experience. In order to analyse the journals, a thematic analysis method was used in the research study. The course instructors spent a large amount of time researching and developing coding during the course's duration. The codes were analysed, and then they were put together to form themes. A number of other researchers were involved in the process, which helped to validate the themes that were developed and boost the dependability of the results. The journals were meticulously examined to determine the overall trend of the students' learning experiences.

3. Results

A group of 156 first year chemical engineering students who were enrolled in the 'Introduction to Engineering' course were the subjects of this study. A teaching and learning approach that utilized CPBL was used on a problem related to sustainability, as explained earlier. In previous years, ISP and ICP courses have been conducted in parallel, thus the integration of these two courses [26] did not undergo much change. While there were some additional challenges of conducting the courses online due to the COVID-19 pandemic, CPBL was implemented in a similar style that it has been conducted before. A current sustainability issue was identified prior to the beginning of the semester and designed as a real problem for students to solve in the ITE course, with the input and support of stakeholders from the industries and related agencies in the ISP course. However, this is the first time that ICP, a programming course has been integrated into the ITE and ISP courses. Therefore, the effects of the integration on the students' quality of learning, achieving the outcomes of the program and courses, as well as students' knowledge and performance according to the observations done by

the ICP lecturers need to be observed. In the third cycle of CPBL, Smart Consumer Campaign Online Video Competition (Figure 1) was held for the students to present the outputs of the CPBL problem that they have worked on the entire semester. The students presented to panels from different universities, countries, as well as the industry experts/stake holders. Panels gave precious and diverse feedbacks to students' effort as well as the exhibition program itself. Awards and prizes were offered as an extra incentive. The primary data source is the written Reflection Journals, as the contents would reflect the learning experiences of the respective students regarding the ITE, ISP and ICP courses. From our previous work [26], it is evident that writing reflection journals is effective in educating students in acknowledging their thinking and learning processes based on Gibb's reflective cycle [27]. Students were given the opportunity to learn through seminars hosted every week in the ISP course. Students were able to relate the seminars held during ISP course as scaffolding support to the CPBL problem introduced in the ITE course [26]. Throughout the semester, each student needs to write four reflection journals to summarize what they have learnt and went through in each stage of the case study. The first cycle of case study ended at Week 6, which was when the first reflection journal was written. They were briefed on the reflection journal format that would require them to reflect their learning through CPBL. After the second cycle of CPBL at Week 10, the next reflection journal was collected and then finally the last one was collected in Week 13. At the end of the semester, the students were asked to write a Meta-reflection journal so that they can reflect on their learning experience throughout the whole semester. The submission of the reflection journals was done online through the e-learning system in the interest of internalizing their learning process as well as the concept of sustainability. Through e-learning, the lecturers can access the submitted documents and provide feedback and support.

Table 2 contains analysis focused on the assessment of the perception of students on the integrated activities in ITE course and programming course. The analyses of the reflection journals show that ITE project integrated with ICP and ISP courses gives student an insight to how engineering can directly benefit the masses. Through the reflection journals, it is clear that the students were able to correlate the impact of their actions and their ability to affect the situation, especially after the ISP seminars in Weeks 8 and 9. During these two weeks, three seminars focusing on consumers and the impact of consumerism were given by experienced speakers, one of which is a zero-waste practitioner who champions mindful consumerism and recycling for the sustainability of the environment. Moreover, the ITE project, which requires the students to tackle a real-world issue, in addition to ISP seminars given by stakeholders working in the field, had shown the students a view of engineering applications in the real world. This direct correlation between lectures and reality is helpful in emphasizing the importance of engineering fundamentals, engineering ethics, among other things.

Table 2
Examples of quotations on students' perception in ITE, ISP, and ICP courses

Code	Examples of quotations
Sustainable Development Awareness	Student 1: There are so many new things I learned from this campaign like carbon footprint, consumer behaviour, sustainability development, and climate change. From this project, I also learned some skills like how to do data analysis, how to calculate carbon footprint, how to do audit, and how to handle a data collection
	Student 2: This case study had opened my eyes to worldwide views and had made me to become a mature person in coping with engineering-based problems. From the first stage of this case study, my knowledge on sustainable development, climate change, and carbon footprint had been fully enhanced. I finally understand how they relate to each other and their consequences.

	Student 3: I learned we as a consumer have the power to make the earth greener. I learned the activities like manufacturing, packaging, event, and transportation will contribute to carbon emissions. In calculations of carbon footprint, we must take a big account in transportation because it emits a lot of carbon and easier to compute compared with others.
	Student 4: As a consumer, the word 'sustainability' is in fact relatively new to me. The thoughts that I put in before purchasing a product habitually entails whether it is cheaper, does the quality live up to its price and such. I was taught that there were far more pressing concerns that I was simply unaware of, e.g. does the product that I buy contribute to the degradation of our already critical condition of our environment?
	Student 5: Through the case study campaign, it fosters the importance of sustainable development goals of environment and engineering ethics towards the welfare of human beings.
Exhibition	Student 6: The "Exhibition Day" was both exciting and nerve-wrecking. It was an opportunity that I value greatly as I was able to experience presenting a project that was worked on for a long period of time with much effort and receiving feedback on it. I was also able to experience the joy and nerves of watching other group's – in which were my competitors, work. It was a day filled with various emotions but the most prominent of it all was satisfaction, contentment and proudness.
	Student 7: During the exhibition, I felt very happy as our presentation video got praised by all judges. Also, during the Q&A session, the questions asked by all the judges are good as sometimes the problems are not identified by our group. So, this is also testing our critical thinking skill to solve all uncertain situation around us.
MATLAB Programming	Student 8: We also need to develop computer program using MATLAB for calculating the generated carbon footprint for consumerism activities. With the seminar on MATLAB coding, our group can develop a user-friendly program and make comparison between purchasing methods to recommend the approach that will result in the lowest carbon footprint to assist the user in making a wise decision before buying products
	Student 9: Other than that, we learnt how to build our own program using MATLAB as our platform. It was a very helpful sessions as it gave us the inspiration on how to create database for our program. I found it very useful for our stage 3 programming task
	Student 10: These kinds of skills and software really make our life easier and convenient. Also, we have learnt the basic of MATLAB Coding that will assist us to comprehend the knowledge of coding better for becoming an engineer. It really helped me for doing the MATLAB program of SCC Stage 3.
	Student 11: The skill that I had acquired is to apply the knowledge of computer programming in developing the program to calculate the carbon footprint generated by using the MATLAB software.
Course Integration of ITE, ISP and ICP	Student 12: The seminar (ICP) today was very informative because all the content was necessary for our final stage (ITE) and computer programming project (ISP).
	Student 13: With the help of lecturers in this seminar, I can get some ideas for Stage 3 computer program and I can build a stronger relationship between ITE and ICP. In my opinion, this seminar is very useful for me because I can understand more about ICP and gain extra information that lecturer does not deliver in the class. In addition, I like the collaboration between ITE and ICP which I can apply my knowledge about ICP in my ITE assignment.
	Student 14: I am happy we were able to get this Industrial seminar and Profession as it helped a lot of us in understanding the MATLAB coding and programming.

The codes selected in Table 1 are aligned with both the course learning outcomes (CLO) and program learning outcomes (PLO). For example, the code Sustainable Development Awareness is in line with CLO 3 of the ITE course, which calls for "ability to analyse sustainability related problem and recommend engineering-based solutions to overcome the problem based on the three pillars of sustainability development using Cooperative Problem-Based Learning." Based on student's individual reflection, the CPBL introduced by the ITE course and integrated with the ICP and ISP courses has successfully exposed the students to sustainable development. Being a consumer is something that the students may have taken for granted prior to these courses, but with the Smart Consumer Campaign, the students are aware of the consequences of their actions and their influence as members of society and engineers on sustainable development. Individually, the students were made aware of their own responsibilities to ensure sustainability. As engineers, the students become conscious of their position to affect large-scale and sustainable change through the development of engineering-based solution to a problem. Moreover, the codes in MATLAB Programming and Professional Skills are connected to CLO 4 and CLO 5 of the ICP course, which corresponds to "work in a team to accomplish the computational assignments" and "initiate self-improvement through continuous professional development and life-long learning".

While lectures impart knowledge and skills to the students, often the students do not practice them thoroughly enough. Unfortunately, by the time the students need to recall these skills or knowledge, for example, in a few years' time when they are working, they would have forgotten most, if not all, that they have gained from these courses. However, by integrating all three courses, the students are given the opportunity to utilize directly and immediately the information given to them, especially from the ISP and ICP courses, into the ITE project and ICP assignments. This instils deep learning [28], with a higher likelihood that the students will be able to remember and employ the skills and knowledge whenever they need it in the future. A clear instance of this is the seminar held in weeks 6 and 7, which taught the students presentation, public speaking, and Microsoft Excel skills. From the reflection journals, it is apparent that students had greatly benefitted from these three seminars. Lecturers were also able to see the results of these seminars directly in the ITE project and assignments, where the students were required to use Microsoft Excel skills. Moreover, applying a common authentic problem from the ITE course across all the three integrated courses allowed the students to focus all the knowledge and skills they have gained throughout the three courses on one complex, realistic problem. This is not only helpful in relating these different courses with one another, but it also makes it easier for the students to collect resources and seek help from more lecturers in all three courses instead of relying on the help of only one lecturer per course.

The inclusion of ICP course in the previously integrated ITE and ISP courses brings a newly added value to all three courses. With the development of various technologies and complex issues nowadays, collaboration and integration between different disciplines has become a necessary part of resolving problems. This necessity and advantages of multidisciplinary knowledge was perfectly highlighted through the collaboration between these courses, where programming knowledge is essential in completing the ITE project. Students were able to observe this as well, citing that programming knowledge from ICP lectures and ISP seminars was the crux in developing the program, which is the main output of the ITE project. The reflection journals under code of integration are proof that students were able to relate and highlight the beauty of this integration between ITE, ISP and ICP courses without being asked to do so. They acknowledged that the integration of these courses helped them to understand more of that subject. For example, the information gained in ISP helped them to better understand the project given in the ICP and ITE courses which can be seen written by a first-year student in the reflection journal.

The integration of these three courses has also shown valuable improvement for the ICP course, just as the integration of the ITE and ISP courses have augmented these two courses [26]. The ICP lecturers took note in the differences before and after the ICP course were integrated with the ITE and ICP courses. After the integration, when there is a need to apply programming knowledge, students became more creative and able to explore beyond the classroom. With a basic introduction to MATLAB from ICP lecturers, students were able to develop their unique program as the output of the ITE and ICP project. It can be observed that the MATLAB programming coding produced by students were extensively designed and structured to achieve the aim of the project. During the project demonstration, most of the teams successfully executed their programs with no error in the coding. Only some teams experienced problems during the demonstration, however, they managed to rectify the errors and solve the issues. It also proves that the students have the capability to debug errors in a program, which is a crucial skill in programming.

Additionally, the integration of the ICP course with the ITE and ISP courses brought a very essential benefit to the ICP course, which is the application of programming in solving an authentic problem. The unfortunate yet inevitable issue with offering the ICP course in the students' first semester of the Chemical Engineering program is that the students have yet to learn the core Chemical Engineering courses, where they can possibly apply their knowledge of programming. Hence, the lecturers of the ICP course can only pose basic mathematical problems for the students. This diminishes the impact of the course, as students are unable to relate the necessity of programming as engineers. However, by necessitating the use of programming to solve the CPBL problem introduced in the ITE course, the students were able to utilize their knowledge of programming to produce a program that could contribute to alleviating an authentic sustainability problem. One of the most significant advantages of posing an authentic problem to the students is that the students are triggered to think in a more inventive manner and plan their own unique programming algorithm, which is a computer procedure to solve the problem and produce the targeted outputs. Authentic problem allows students to learn constructively, thus enhancing students' creativity, critical thinking, and decision-making skills. The effects of presenting an authentic problem on the students are evident from the developed MATLAB program. One of the teams presented a program with 2,254 lines of commands, which is quite extensive for first-year students. By requiring students to solve an authentic problem instead of a simple one, students needed to design not only the programming algorithm to achieve the desired outcomes, but they also had to come up with solutions to circumvent multiple programming errors, such as syntax errors, logic errors, and arithmetic errors. To achieve this, the students sought MATLAB coding beyond the knowledge they had been taught in the ICP and ISP lectures and seminars. The ICP lecturers observed that the students used functions that were not discussed in class but were useful in completing their project to produce a program that is more extensive and user-friendly. This might have stemmed from their desire to develop a program that is close to applications that they are used to using in their daily lives, as the problem called for a program to be used by the public. The ICP lecturers were able to see the obvious achievements of the students after the ICP course was integrated with the ITE and ISP courses compared to the previous year, as the students this semester were able to create interesting and interactive programs with pop-up menu rather than conventional input-output methods.

While the ITE and ISP courses experienced some challenges due to the online mode of teaching this semester, it did not significantly affect the students' participation and performance. Unfortunately, the ICP course saw a slight decline in the overall results this semester, with only 75% of the students managing to score A in the course compared to 94% the previous year. However, this was due to the online mode of teaching and issues with the MATLAB license that caused a delay in

teaching in the beginning of the semester, not because of the integration of courses. These issues resulted in some students experiencing trouble in installing the software and were forced to rely on remote access to the university's computer laboratory. The remote access restricted the students to limited access to the MATLAB software and only gave them the opportunity to access the MATLAB software only during class. Additionally, the international students were further hindered by the time difference since the university's computer lab only operates during office hours in local time. Therefore, a close observation on the effects on the integration of these three courses needs to be done once it is possible to conduct physical classes again, especially for the ICP course, to properly observe the effects of integration of the three courses on students' performance in the ICP course.

Despite the challenges, the transfer of knowledge and application between courses was effective in training students to relate knowledge and skills obtained from one source to a different field. While being assigned to different teams for the ICP and ITE courses can be challenging for the students, indirectly it was able to foster better teamwork, enhance creativity and improve communication skills among students. Being forced to work with various people pushed students out of their comfort zone, which allowed them to broaden their minds and way of thinking. These are some of the valuable 21st-century skills that cannot be taught through traditional teaching methods.

4. Conclusions

SCC2020 has successfully been integrated within ITE-ISP-ICP courses as a CPBL theme for 1st year chemical engineering students. It represents an innovative collaboration between courses to develop students' 21st century attributes and skills. Encouraging feedbacks from students were extracted and analysed from their reflection journals. Thus, the positive impact of course integration can now be unleashed using an authentic problem based CPBL model suitable for typical engineering courses.

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