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Integrated Assessment for Introduction to Engineering, Industrial Seminar and Profession and Introduction to Computer Programming Courses

Zaki Yamani Zakaria[1*], Aziatul Niza Sadikin[2], Mimi Haryani Hassim[3], Nor Alafiza Yunos[4], Aishah Rosli[5], Siti Hajjar Che Man[6], Hasrinah Hasbullah[7], Khairiyah Mohd Yusof[8]

[1,2,3,4,5,6,7,8] Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

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A B S T R A K

Penelitian ini menyoroti tantangan yang dihadapi dalam pengintegrasian mata kuliah tahun pertama teknik kimia, yaitu pengantar teknik, Seminar Industri dan Profesi, serta Pengantar Pemrograman Komputer. Tantangan utama terletak pada penilaian terintegrasi yang efektif, terutama dalam memastikan bahwa siswa memahami keterkaitan antara berbagai disiplin ilmu dan penerapannya dalam konteks dunia nyata. Penelitian bertujuan untuk mengembangkan model penilaian terintegrasi yang efektif berbasis constructive alignment untuk mendukung pembelajaran siswa di ketiga mata kuliah tersebut, dengan fokus pada pemecahan masalah autentik terkait keberlanjutan. Mata kuliah tersebut dirancang dengan pendekatan penilaian terintegrasi melalui laporan proyek, pameran, jurnal refleksi, dan portofolio pembelajaran. Masalah dunia nyata yang relevan dengan keberlanjutan digunakan sebagai tema utama, dan penilaian dilakukan secara formatif dan sumatif untuk mengukur keberhasilan pembelajaran. Penilaian terintegrasi ini berhasil meningkatkan keterampilan siswa dalam berpikir kritis, komunikasi, serta kemampuan teknis. Umpan balik positif dari siswa dan panel ahli menunjukkan bahwa model penilaian ini efektif dalam menghubungkan berbagai disiplin ilmu dan menyiapkan siswa untuk tantangan dunia kerja yang sebenarnya.

A B S T R A C T

This study highlights the challenges faced in integrating first-year chemical engineering courses, namely Introduction to Engineering, Industrial and Professional Seminar, and Introduction to Computer Programming. The main challenge lies in effective integrated assessment, especially in ensuring that students understand the interrelationships between the various disciplines and their applications in real-world contexts. The study aims to develop an effective integrated assessment model based on constructive alignment to support student learning in the three courses, with a focus on solving authentic problems related to sustainability. The courses are designed with an integrated assessment approach through project reports, exhibitions, reflection journals, and learning portfolios. Real-world problems relevant to sustainability are used as the main theme, and assessments are conducted both formatively and summatively to measure learning success. This integrated assessment has succeeded in improving students' skills in critical thinking, communication, and technical abilities. Positive feedback from students and expert panels indicates that this assessment model is effective in connecting the various disciplines and preparing students for real-world challenges.

1. INTRODUCTION

Growing emphasis on interdisciplinary engineering education curricula requires engineering educators to build links between various distinct disciplines. Integrated curricula in engineering education started to trigger interest to assist learners develop connections between topics (Utami & Wutsqa, 2017; Virvou et al., 2005). Integrated curricula could enable the establishment of networks to a larger learning community, which help learners to build interdisciplinary understanding and connections. Before such integrated curricula can be executed, a smaller scale implementation that integrates several courses in a particular curriculum, could be perform (Ng, 2019; Zarouk et al., 2020). There are many advantages of integrating different courses in a curriculum. It is easier to design the integration for two to three courses (micro-scale) compared to a more complicated program curricula (macro-scale), which means there is a point to start easily and swifter rather than to start big in a more complex manner. Student would be able to see the connection between different courses and

* *Corresponding Author: Zaki Yamani Zakaria: zakiyamani@utm.my*

how they are interrelated (Abdurrahmansyah et al., 2022; Sadaf & Johnson, 2017). In addition, the integration can also reduce students' workload for similar project or common 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 (Khasanah et al., 2021; Sari & Hidayat, 2019). As good as it sounds, one challenge remains in between the integrated courses and student's achievement, that is integrated assessment. Integrated assessment is important when it involved more than two courses that are integrated together to achieve certain learning outcome. Often it is tough to focus or oblige on a common integrated assessment. Even if an integrated assessment is formulated, it could be less effective. Educators need to continuously improved their integrated assessment model to create one that is duly effective for a successful integrated assessment (Hidayat et al., 2019; Shalatska et al., 2020).

The purpose of this paper is to highlight integrated assessment underpinned by constructive alignment theory implemented in Introduction to Engineering (ITE), Industrial Seminar and Profession (ISP) and Introduction to Computer Programming (ICP) courses for the first-year chemical engineering student in the School of Chemical and Energy Engineering. Since its early implementation, ISP has been designed to support the incorporation of Sustainable Development (SD) in the ITE course. In the year 2020, ICP had been integrated with ITE and ISP for the first time (Jubaerudin et al., 2021). The synergy continues with the Safety and Health Campaign was chosen as the sustainability theme (Semester 2021/2022) for the implementation of Cooperative Problem-Based Learning approach in those courses.

The aim of constructivist learning theory is to promote comprehensive learning and teaching. Previous study describes constructive learning as deep learning, where the student moves beyond learning facts and develops a sense of the larger picture (Alkhudiry, 2022; Pande & Bharathi, 2020). Constructive alignment refers to the ability of students to construct meaning through appropriate learning activities. This includes the assessment that embodies the students' overall understanding as well as self and peer assessment, not only the obvious assessment like final examinations, objective test or standard assignment (Alias et al., 2015; Carless & Boud, 2018). Conventionally, implementation of each course of a curriculum was conducted independently, hence, students had difficulty to see the relation and interdependence of each course. For example, when a chemical engineering student learns to solve algebraic problems in mathematics class, he may not realize that the same theory and understanding are heavily applied in mass balance class especially for assessment. This is because traditional class was usually conducted to be very focused on the specific topic and isolated and like a filtering process for students to advance for the following year of the programme (Hartman et al., 2019; Hashemifardnia et al., 2018). Hence, students are not able to identify the link between courses in the curriculum.

The graduates of engineering programmes are expected to be able to work in various industries, job scopes and positions. They can be entry level engineers, marketing personnel, logistic supervisor and even work in the human resource department of related science, technology and engineering industries (MacLeod & van der Veen, 2020; Thannimalai & Raman, 2018). In later years, they may be in management positions or migrate to other industries for higher positions. So, preparing them for that venture and ability to utilize all the knowledge and skills that they have acquired should happen during their learning process. Integrated assessment that includes knowledge from various courses, shall prepare them for the various working challenges which is the real-life test. Some schools in Vietnam had started to employ integrated assessment actively based on CDIO (Conceive-Design-Implement-Operate) methodology to ensure the graduates will meet the country's integrated industrial needs (Boyd & Darragh, 2020; Marouchou, 2012).

At present, integrating two or more courses in engineering curriculum has become wide-spread interest in developing high quality engineering graduates (Ali et al., 2020; Sriadhi et al., 2021). Previous study present the integration of INEN 401 Engineering Statistics II by vertically integrating it with ENGR 120 Engineering Program Solving I (Heri Suryaman et al., 2020; Jubaerudin et al., 2021). INEN 401 basically learns how to apply the statistical quality control method to monitor product quality while ENGR 120 works in team to fabricate a product (this time it was a small centrifugal pump). It was proved that with the integration of both courses, the new pump developed resulted in better pump efficiency. Previous study reported the design of chemical engineering 1st year integrated courses based on constructive alignment (Tse et al., 2021). The impact of these integrated courses led to enhancement on students' interpersonal skills and technical knowledge which were evidenced through students' reflection journal.

Whilst the benefits of the course integration are exceptional, the challenges in the implementation are real. Among the challenges is the assessment for the integrated courses. Assessment in CPBL can be seen as an important part of the developmental process of learning rather than fail or pass (Monica et al., 2019; Suastra et al., 2019). Implementation of assessment integration was reported to be accomplished in four approaches; 1) initiating a structured process with involvement of all stakeholders; 2) Provide related assessment education course/seminar for staff and faculty; 3) establishment of assessment toolbox to measure the intended outcomes; and finally 4) the assessment and continuous improvement to be embedded in the educational environment to ensure rewarding effort by the faculty member (Akhmad et al., 2018; Takrouni & Assalahi, 2022). Assessment in group or team has been widely debated in cooperative problem-based learning. Issues such as representative of marks between individuals and groups are among the highlights. Previous study reported the adoption of constructive alignment in the assessment of group work in the Mental Health Nursing 1 module as part of the BSc (Hons) Nursing programme (Hussin et al., 2018). Group work presentation and individual reflective online log were the two units of assessment for this module that underwent review.

Previous study reported on the Drone Innovator Program that was described as an integrated STEM curriculum (Minsih et al., 2019). To ensure all knowledge was properly assessed, each group had a Drone Innovators Mission Book that reported steps of the Drone process and rubric as their guide. For formative assessment, they were graded on every section reported and received feedback for further observation. Upon completion of the project, the Mission book was graded according to the rubric. In addition to this, the summative assessment also included an Output Card in which they had to report on a specific product in the drone industry. Hence, this curriculum was designed with integrated learning and assessment of various STEM fields (ie: engineering, environmental science, geophysics etc.), entrepreneurship, as well as governance and law (Garza & Travis, 2019; Saripudin et al., 2021). Furthermore, perseverance and strategic thinking were cultivated in preparing the students for careers in STEM. Hence, integrated learning and assessment would promote transition of the typical four-year undergraduate programme of producing trained engineers to emerging professionals with knowledge base and intellectual capability for career-long learning (Kearney & Maher, 2019; Zakaria et al., 2022).

Electronic portfolio has been reported to be one of the assessments in course integration (Balaban et al., 2013; Mohamadi, 2018). Electronic portfolio, which is also known as ePortfolio, is a digital learning platform, which documents students' learning development. E-portfolio provides many opportunities to integrate all of the student's work on the course and to connect new ideas with the student's existing knowledge and context. Collections can be the work of an individual, or assembled and shared by a group. The activities in e-portfolio such as reflection are able to increase the learner's ability to make sense of concrete experience (Alajmi, 2019; Beckers et al., 2016). Besides that, the integrating effects possessed by e-portfolio are in agreement and meet the requirement for authentic assessment to ensure student's learning and growth. The aims of this study is to develop an effective integrated assessment model based on constructive alignment to support student learning in the three courses, with a focus on solving authentic problems related to sustainability. Novelty of this study is introduces an innovative method of integrating three distinct courses. By aligning the learning objectives, content, and assessments constructively across these courses, the research demonstrates how students can build interdisciplinary connections, which enhances their understanding of real-world engineering challenges.

2. METHOD

This study uses a constructive alignment-based research design, which integrates three first-year courses in the Chemical Engineering Department, namely Introduction to Engineering (ITE), Industrial and Professional Seminar (ISP), and Introduction to Computer Programming (ICP) (Beneroso & Robinson, 2022). This design is designed to support interdisciplinary learning by emphasizing the relationship between various disciplines through integrated assessments centered on authentic problem solving. Each course is strategically aligned to achieve the expected learning outcomes, both in the realm of technical knowledge and professional skills. Data were collected through several instruments, including project reports divided into several stages, reflective journals compiled periodically throughout the semester, and learning portfolios that summarize students' learning experiences during the course. In addition, project exhibitions accompanied by videos and presentations were used as part of the summative evaluation. Questionnaires were also distributed to students at the end of the semester to collect feedback on their learning experiences and the assessments applied. Assessment rubric for exhibition of the sustainability related project is show in Table 1.

Table 1. Assessment Rubric for Exhibition of the Sustainability Related Project

Item Assessed	Poor	Acceptable	Excellent
MATLAB program	No explicit objective or purpose of the program. No apparent direction in the design of the program.	Provide acceptable objective and purpose of the program that is somewhat related to the problem. Overall program designed towards fulfilling the objective.	Clear objective and purpose of the program related to the problem. Overall program designed clearly shown to be well-thought towards fulfilling the objective.

Item Assessed	Poor	Acceptable	Excellent
Solution for SD problem	Impractical and non-innovative engineering solution without acceptable justification. Both manufacturing and disposal solution is simplistic.	Practical and somewhat innovative engineering solution with acceptable justification and engineering/ scientific principles and related to SD for both manufacturing and disposal solutions.	Practical and highly innovative engineering solution with sound justification and engineering/scientific principles, related to the source of the problem, suitable for the appropriate target group of users. Provide both manufacturing and disposal innovative solutions.
Video Presentation	Video has no original thinking. Video is not well planned and has poor edits. Sound is of poor quality. Many sound and visual elements distract from the video's message.	Video has some original thought and is moderately creative. Video was somewhat planned. Transitions and edits are rudimentary. Sound is reasonably balanced. Some sound and visual elements are distracting.	Video is original, creative and unique. Video is well planned with smooth transitions and edits. Sound is expertly balanced and easy to hear. All sound and visual elements coincide with the video's message.
Communication skills & team participation	No eye contact, low confidence level, views not convincing, timid voice, no flow of idea, only 1 person explaining	Some eye contact, shows confidence, views not so convincing, at times unclear speech, some jumbled ideas, 1 or 2 members did not participate in the discussion, not all members show deep understanding	Good eye contact and body language, high confidence level, voice is clear and fluent and passionate presentation, ALL team members participated in discussion and illustrate deep understanding of subject matter

Data analysis was conducted using qualitative and quantitative approaches. Project reports and reflection journals were analyzed qualitatively using a predetermined assessment rubric to measure students' level of understanding and critical thinking skills. Quantitative data were obtained from the results of questionnaires filled out by students, where simple statistical analysis was used to identify trends in feedback related to the effectiveness of integrated assessments. The results from these various instruments were combined to provide a comprehensive picture of student learning outcomes.

3. RESULT AND DISCUSSION

Result

The challenges in designing an integrated course do not lie on the content's development and deliverable aspects only. While these two aspects drive the progress of the integrated courses, the real hurdle comes from the assessment part; that is, how the students' performances are gauged when the learning involves several different courses, which all this while, were conducted separately. The ITE course (3 credits) has been integrated with the ISP course (1 credit) for several years now, but only very recently did these two courses were also integrated with the ICP course (3 credits). The aim of integrating these three courses is none other but to further enhance students' learning by training them starting from their first semester out of a total of eight to complete their chemical engineering undergraduate studies. The strength of integrating these three courses is the opportunity to integrate different disciplines of knowledge in solving sustainability related problems given to them in the ITE class. As such, it is desired for students to recognize the relation between different disciplines of knowledge and for students to be able to construct knowledge on different disciplines and various sustainability issues so that they may apply the knowledge and skills gained from one course in a problem posed by another course. Assessment is one of the deciding indicators of successful integration of different courses. Therefore, in order to measure the success of the integration of these three courses in achieving the aforementioned aims, suitable assessment methods need to be designed.

The assessment for integrated courses can be tricky, as each course have various means in assessing students' understanding and overall performance, which were designed into activities or outputs expected from each syllabus of the course. The ITE class has many topics in the syllabus to cover including introduction to roles of engineers, engineering ethics, engineering calculations, among others. While ISP provides scaffolding to the ITE course and to some extent, the ICP course, the ICP course has to cover vastly different topics, such as MATLAB Environment, arithmetic and logical operators, arrays operations, algorithm and flowcharts and structured programming. Regardless, the main part of the ITE course is the sustainability related project. Each year students are given a realistic case study related to various sustainability issues such as river pollution, food wastes, and energy consumption. This project is the only element of the ITE course that was designed to be integrated with both the ISP and ICP courses.

In the first stage, students are tasked to conduct an extensive literature study, perform critical review on the collected information and figures (from the published statistics, for example), and design a detailed research methodology focusing on the conduction of real data collection. The collection of data, typically conducted among the students and their families, and subsequent organization of data, are carried out in the second stage of the project. Students' reports were graded using formative and summative assessments based on clearly constructed rubrics. At these stages, the reports were graded for assessment of the ITE course only.

In the final stage of the project, students need to make use of the well-analyzed data from Stage 2 to identify the most pressing issue and subsequently propose the most appropriate engineering-based solution for the identified issue. It is at this stage that the programming knowledge and skills obtained from the ICP course is utilized. In this stage, students are required to design a MATLAB program that is user-friendly and capable of receiving input then converting it into a meaningful output. The developed MATLAB program is used as a decision making tool, where the output pinpoints the issue that the students need to address in their engineering-based solution. The solutions need to be innovative, more environmentally friendly compared to the existing item or condition, as well as cost effective. Here, the report is assessed for both the ITE and ICP courses the students have to come up with ways to apply computer programming (ICP) as part of the methodologies towards designing the solutions.

In addition to the report, students also need to prepare a video of maximum 5 minutes' duration to showcase their overall project. The videos are judged by several panels including those appointed from other universities as well as from relevant industries. Similar to the reports, there is a well described rubric to guide the panels in assessing the videos. After the video presentation, students are tested for their understanding on the project they presented during the Q&A session by the appointed panels. This ensures that the students' understanding, knowledge and application are objectively assessed by various experts relevant to the courses. All these are done in one special dedicated event, called the Exhibition Day, which was done using online platform during the pandemic. Before the pandemic, students would set up physical booth with posters and prototypes of their proposed solution. The panels would visit the booths assigned to them for the face-to-face presentation and Q&A session. The presentations and ability of the students to defend and justify their work are graded for both ITE and ICP courses. The whole exhibition, which is very demanding to organize due to the massive number of students involved (averagely 120-160 students per batch) is typically coordinated by the ISP lecturers.

Throughout the semester, students need to write down their reflections on the courses in roughly three weeks' intervals. This is to help them to construct the knowledge they have gained and experiences they have gone through and turn them into effective learning to prepare them to be excellent engineers. At the end of the semester, they need to write a meta reflection documenting their experience from the beginning of the semester to the end, which trains them to do deeper reflection on their thinking process throughout the semester. The journals were graded using formative assessment for the ISP course.

A new assessment tool, the learning portfolio, has been added in the latest semester. Students are required to submit three learning portfolios following the learning process at the current time of the semester, and an overall learning portfolio depicting their learning process, knowledge and skills obtained throughout the semester, and future goals. While the learning portfolio assessment contributes only to the ITE course, it allows valuable qualitative input from the students regarding all three courses, as the learning portfolio aims to identify the knowledge and skills obtained from the courses, track and reflect the personal progress and growth through the processes that the students have undergone throughout the semester, provide evidence of knowledge and abilities for prospective employers and/or scholarship providers, and recognize areas for possible future growth and endeavors. By reflecting upon their learning process, identifying weakness and potential room for improvement, and setting clear future goals, it is expected that students will be motivated to continuously learn, develop, and improve.

Discussion

This paper discusses the assessment practice performed for engineering students during CPBL implementation. The integrated assessment administered within the three courses was viewed as an integral component of the learning process. CPBL in ITE course emphasizes conceptual learning and attempts to promote deep learning. Therefore, it is essential that this learning technique be supported by continuous formative and summative assessment processes. Continuous formative assessment is an important part of the development and learning cycle, whereas summative evaluations are based on the performance at the end of the course (Bhagat & Spector, 2017; Jacques et al., 2020). The assessment tasks in the ITE, ICP and ISP courses were built on essential activities underpinning the problem, including working in a team, writing reports, presenting the projects, keeping a learning portfolio and reflecting on the project processes. The student performances and experience are a key indicator since it has a direct impact on meeting the learning outcomes of all three courses (Chetty et al., 2019; Konchiab & Munpanya, 2021). Therefore, an electronic survey was distributed to all students who completed the integrated project at the end of the semester in order to gather the students' perceptions of the integrated project and the value of the integrated assessment (Asbari et al., 2019; Melović et al., 2020). 137 pupils out of a total of 168 responded to the request. The percentage of students who responded is 82%. The survey consisted of biographical information and questions addressing students' perspectives on the project and assessments. In the ITE course, the final report is the final integrated form of assessment for the CPBL learning. The final report must be a demonstration of the outcomes of the ITE course, as well as an integration of the ICP course. The ITE learning outcome focuses on aspects related to sustainability issues, while the ICP focuses on MATLAB programming that could help to solve the problems (Huang & Chang, 2019; Niraula, 2021). Students commented that documenting their solution in the final report would help them develop their written communication and critical thinking skills. Below is an example of student responses on final report writing.

In order to prepare future ready engineering students, they must not only have a solid foundation in technical knowledge, but also be competent in critical thinking and written communication. Critical thinking and writing skills are compatible, synergistic processes (Jubaerudin et al., 2021; Ratama et al., 2021). By acquiring knowledge from the three classes, students were able to identify and solve sustainability issues. They were able to analyze data, propose engineering solutions and write a comprehensive final report. The instructors' observations of student performance in the CPBL activities from Stage 1 and Stage 2 reports offer formative feedback to help students to improve. Stage 1 and stage 2 reports are types of assessments that offer insights into how well the students are learning and are consistent with learning outcomes. Students in these courses received regular, detailed feedback and had opportunities to discuss and act on it (Chust et al., 2013; Sarker et al., 2019). This encouraged students to include feedback into subsequent report submissions. Students develop not just their communication skills but also their abilities to think critically and analytically as they go through the process of revising their written reports and considering the comments of both their instructors and their peers (Huisman et al., 2019; Jensen-Doss et al., 2018). At the end of the semester, the exhibition generates excitement for the students. In response to the epidemic, the exhibition has been shifted to an online meeting platform, and it was discovered that many components performed unexpectedly well even in a remote environment. Exhibition is an assessment approach that allows students to integrate skill, information, and concepts at both the theoretical and practical levels. Below is an example of a response that demonstrates a student's ability to integrate knowledge from all three courses.

Through a CPBL exhibition, students were able to demonstrate the integration of knowledge and skills developed across the three courses. Additionally, student exhibitions promote student engagement. Students take ownership of their work since they know it will be viewed by more than just their peers and instructors (Hendarwati et al., 2021; Silalahi et al., 2021). When presenting the project, students were needed to consider their audience and build presentations accordingly. Students get the opportunity to demonstrate their skills in leadership, accountability, and creativity, as well as develop effective communication skills, during the exhibition. A Google document with all of the links for each showcase project has been created and will be available during the exhibition. Google forms were integrated into each student's project to allow internal and external judges to submit feedback on the project. The judges have given positive feedback on the project's addressing of real-world sustainability issues (Cookson & Stirk, 2019; Vartiainen et al., 2016). The judges found that incorporation of real-world problem-based learning to be exciting and a worthy challenge. The project was able to capture students' accomplishment of addressing sustainability issues and exposed to them what everyday real-world problems may entail. Examples of judge comments on the CPBL project are provided below.

Even though assessment of the reflection journals only counts towards the ISP course, the reflection journals are very important means of assessment. While the other assessments show the outcomes of the students' learning process, the reflection journals are the only form of assessment that collects students' direct feedback on the running of the courses (Ho, 2015; Papanthymou & Darra, 2019). This allows instructors to clearly gauge the success of integrating these three courses. Additionally, from the reflection journals, students become more aware and mindful of their own learning and thinking process. It has been proven that reflection has offered valuable insights on students' thoughts on the course (Papanthymou & Darra, 2019; Rahmani, 2020). Various insights can be obtained from the reflection journals, and from some of the reflection journals, it is evident that the integration of the courses through the sustainability related project is successful in motivating students to seek additional knowledge to fortify the knowledge and skills that they have gained in class, as well as to find possible solutions to a problem. One of the students stated:

In addition to reflection, learning portfolios have been implemented as a form of assessment because it can measure the progress and achievement of student learning. Students were required to document the project's processes and their views on learning activities in a learning portfolio. Students were instructed to determine what worked, what didn't, and what could be improved upon as they reflected on the project's activities. With the help of portfolio assessments, students can reflect on their actual performance, identify their areas of strength and weakness, track their progress throughout the learning process, and be motivated to take ownership of their learning (Abdullah et al., 2016; Suwaed, 2018).

The integrated assessment model allows students to develop both technical and professional skills simultaneously, preparing them better for the real-world industry demands. This approach promotes critical thinking, problem-solving, and adaptability, which are key competencies in engineering and programming fields. By integrating assessments across courses, students are exposed to interdisciplinary learning, encouraging them to connect concepts from various domains such as engineering principles, professional ethics, and programming logic. This can enhance overall learning outcomes, fostering a deeper understanding of how different knowledge areas interact in practice. Not all students may benefit equally from integrated assessments, as some may find it difficult to manage the cognitive load of synthesizing knowledge from different subjects. This can result in uneven engagement and learning outcomes among students.

4. CONCLUSION

Three courses under chemical engineering degree in Universiti Teknologi Malaysia were integrated since 2020 for the 1st year program, namely ITE, ISP and ICP and an effective integrated assessment was successfully designed and implemented for them. The integrated assessment which surrounds a chosen authentic problem was carried out via reports, exhibition (that include presentation), reflection journals and learning portfolios. Outcome from this was positive as the educators manage to create a reasonably effective integrated assessment. Feedback from students and invited expert panels (for exhibition) were evidence that the integrated assessment was qualitatively good.

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