ASEAN Journal of Science and Engineering Education

Journal homepage: http://ejournal.upi.edu/index.php/AJSEE/

Teaching Chemical Engineering Thermodynamics using Substituted Blended Learning Techniques

Shafirah Samsuri[1,2*], *Wan Nur Aisyah binti Wan Osman*[1,2]

[1]Department of Chemical Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak, Malaysia
[2]HICoE-Centre for Biofuel and Biochemical Research, Institute of Self-Sustainable Building, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak, Malaysia
*Correspondence: E-mail: shafirah.samsuri@utp.edu.my

ABSTRACT

Blended learning was introduced to ensure students could navigate the complexities of Chemical Engineering Thermodynamics. Assessments in the form of summative, performance-based, and peer-and-self were applied to them. 80% of the students stated successful educators in facilitating blended learning excellently and giving adequate feedback on time. 76% of them mentioned their applicability in applying the knowledge from this course in daily life and industry scale. Furthermore, 72% of them indicated that they have a clear understanding of the aims and goals of this subject and can relate this subject with other subjects that they have learned. Moreover, the educator successfully conducted the course well by creating a conducive learning environment for student-educator interactions. Educators clearly explain all assessments to students very well and provide them with various resources to enhance their learning process. Hence, this blended learning is carefully mapped. The new learning approach in this course has brought positive outcomes toward the student's learning experiences, skills, and understanding.

ARTICLE INFO

Article History:
Submitted/Received 22 May 2023
First Revised 13 Jun 2023
Accepted 09 Aug 2023
First Available online 10 Aug 2023
Publication Date 01 Sep 2024

Keyword:
Blended learning,
Chemical engineering,
Thermodynamics.

1. INTRODUCTION

Chemical Engineering Thermodynamics I am a compulsory subject for First Year Chemical Engineering at UTP (Universiti Teknologi PETRONAS) located in Seri Iskandar, Perak, Malaysia. This course supplies knowledge on the fundamentals of thermodynamic principles and their application on heat, work, and energy transfer within chemical systems. This course's importance is to ensure that the student can analyze the basics of chemical processes and systems, including reactions, phase equilibrium, and energy conversions. In addition, this course aids in the development of thermodynamic models used to represent those used in industry. Moreover, students must learn the utilization of the thermodynamic cycle often used in power plants and industry. This course plays a significant role, especially in shaping engineering students to become capable future engineers.

However, most engineering students are unable to relate to the course and are unable to apply the actual knowledge with the application either in industry or daily life. This is because they would limit themselves when solving complex engineering problems that required practical design thinking and advanced problem-solving skills. Hence, blended learning was introduced to overcome this limitation. Blended learning is an educational approach that provides course content in various delivery formats. This includes offline and online learning. Unlike the conventional learning method where the educators would prepare a related problem statement and guide the students (Tatar & Oktay, 2011). Many studies also highlighted that transformation from those conventional learning is required as it is becoming ineffective (Aziz *et al*., 2013; Lukman *et al*., 2013; Mamat & Mokhtar, 2008).

2. THEORETICAL FRAMEWORK

2.1. Definition and characteristics of blended learning

Blended learning is defined as a hybrid learning method that aims to make learning as impactful as possible. This method offers human contact, practical exercises, and hands-on experience with large-scale accessibility, cost-effectiveness, time efficiency, and a high ability to monitor learning everywhere at any time. It is an innovative concept that combines both conventional learning in the classroom with digital-supported learning mechanisms including offline and online learning (Lalima & Lata Dangwal, 2017). As mentioned in the previous subsection, standalone conventional learning methods such as only lectures become ineffective as students would limit themselves when solving complex engineering problems that required practical design thinking and advanced problem-solving skills. Therefore, blended learning was introduced to overcome this issue and at the same time, enhance the output of learning.

Figure 1 shows the characteristics of blended learning which combined both conventional and digital learning approaches. The conventional learning approach includes formal interaction with educators and non-formal interaction with peers. Face-to-face lectures or known as formal interaction with educators and peers would provide synchronous (real-time) communication where both students and educators can get immediate feedback which is favorable for the learning process (Lalima & Lata Dangwal, 2017). Meanwhile, peer group interaction, or known as non-formal interaction with peers helps students to practice life skills and social values during their free time. Not only that, but it would also encourage the student to develop their confidence by enhancing their communication skill effectively as well as excellent listening skills (Lalima & Lata Dangwal, 2017).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

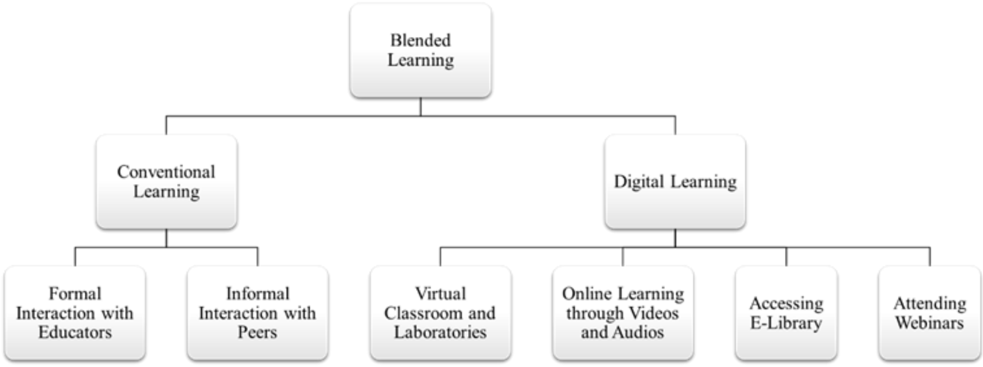

Figure 1. Characteristics of blended learning.

On the other hand, the digital learning approach includes virtual classrooms and laboratories, online learning through videos and audio, accessing e-library as well as attending webinars. Virtual classrooms and laboratories allowed students to learn anywhere at any time and from anyone regardless of the geographical boundaries (Lalima & Lata Dangwal, 2017). Besides, students also can receive help from online learning through videos and audio such as YouTube. Many recordings and animated videos are available online that would ease the learning process especially when it comes to explaining difficult concepts to students (Lalima & Lata Dangwal, 2017). In addition, digital libraries such as E-Library may help students to widen their knowledge as they can access diverse kinds of books related to their learning in various aspects (Lalima & Lata Dangwal, 2017). Also, students may take part in various kinds of webinars for topics relevant to them online. They may get connected with experts in related fields through different software such as Google Meet, Skype, Microsoft Teams, and Zoom (Lalima & Lata Dangwal, 2017).

2.2. Learning theories that support blended learning

Blended learning is supported by variations of learning theories such as listed: collaborative, constructive, and computer-assisted learning (Lalima & Lata Dangwal, 2017) (see **Figure 2**).

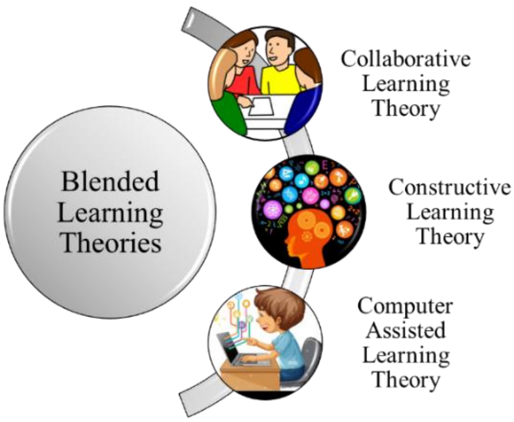

Figure 2. Theories of blended learning

Collaborative learning is an educational approach that requires groups of students to work together in solving a problem, complete a task, or create a product (Laal & Laal, 2012). This theory is supported by studies that claimed it is necessary to shift from individual effort to

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

group work as there is a rise in issues of critical concern which required society to work in a community instead of being independent (Leonard & Leonard, 2001; Welch, 1998). It is a shift away process from a typical lecture-centered concept of classrooms, however, the lecturing process is not entirely removed as it would remain alongside other processes such as group discussion or active learning based on the course material provided. By implementing this theory, a student could enhance their communication and social skills by actively engaging in conversation with peers, exchanging diverse beliefs as well as presenting and defending their ideas (Laal & Laal, 2012).

Meanwhile, constructive learning, or known as constructivism is an educational approach that requires students to engage in activities that require critical thinking, problem-solving, and reflection (Bodner, 1986). This theory encourages the active role of the student as a learner in a learning process, instead of a passive learner (Golder, 2018). Golder (2018) stated that students should construct knowledge from their experiences in which they should apply their prior knowledge, belief, and experiences to the classroom, hence they can make connections between existing knowledge and new information. Besides, this theory also emphasizes that educators play a vital role in the classroom where they should prompt and facilitate a discussion to guide students in developing their conclusions of the learning context or subject (Golder, 2018). Educators should provide a variation of learning materials including raw data, primary sources as well as any interactive course materials that may encourage the students to use them (Golder, 2018). In addition, educators should also help the students to relate the new information with their initial understanding as well as showed them the contradictions if there is any (Golder, 2018). By implementing this theory, students may be able to analyze, synthesize and evaluate that information and able to apply them to real-world context (Bodner, 1986).

On the other hand, computer-assisted learning is an educational approach that facilitated computers in the learning process (Schittek *et al*., 2001). It is an effective way of learning that guides students through variations of learning programs such as integrating text, two-dimensional and three-dimensional images, video, sound as well as animation (Schittek *et al*., 2001). This theory is supported by using the Internet as a tool to gather knowledge as well as share information with others. Moreover, the Internet provides an excellent opportunity for both students and educators especially in searching literature and accessing international resources (Schittek *et al*., 2001). Similar to the collaborative learning theory explained earlier, it is a shift away process from a typical lecture-centered concept of classrooms, but the lecturing process is not entirely removed. By implementing this theory, it would help the student to understand difficult topics as student able to visualize through any learning platform available online (Farooq *et al*., 2017). In addition, it would help the educator to prepare better learning materials that would enhance the student's understanding of the learning context, especially for hardcore subjects (Farooq *et al*., 2017).

2.3. Advantages and challenges of blended learning

There are many advantages gained upon applying blended learning, especially for higher education institutions. This claim was supported by a questionnaire survey for an undergraduate student at the University of Gdansk, Poland in which about 93.2% of students agreed that the blended learning method is an excellent solution to replace the conventional learning method. Data in their study showed that 85.7% of them mentioned that they managed to get better access to learning materials, while 47.6% of them stated that they paid better attention during blended learning compared to the lecture-centered classroom and 48.3% of them indicate a fast and better communication with educators. Their data was

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

summarized in **Figure 3**. Overall, most of them approved that blended learning results in more effective and efficient learning methods where students can master the course outcome during the lecture and examinations as well.

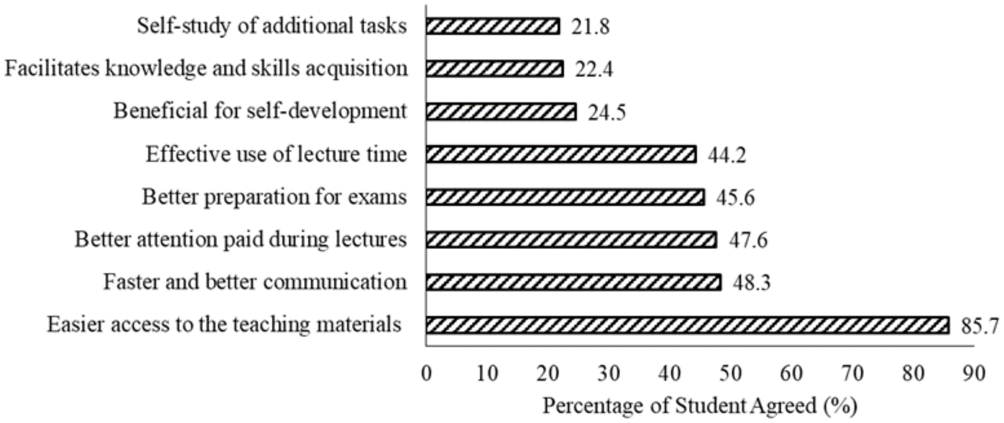

Figure 3. Advantages of blended learning agreed upon by undergraduate students.

Despite the advantages listed, some challenges need to take into consideration upon implementing blended learning. Mukhtaramkhon and Jakhongirovich (2022). (2017) stated that each student has their learning style in which they might not be interested in blended learning. They might prefer a conventional learning style such as a lecture-centered classroom (Mukhtaramkhon & Jakhongirovich, 2017). In addition, high expenses are required for blended learning as there is an increment in the cost of getting a reliable resource (Mukhtaramkhon & Jakhongirovich, 2017). Moreover, a network platform with a low connection may cause negative effects on both educators and students since it might cause navigation loss, thus it is not an effortless operation (Mukhtaramkhon & Jakhongirovich, 2017). Numerous challenges were also listed by the undergraduate students at the University of Gdansk, Poland in their questionnaire survey. Their data showed that about 42.9% of the students mentioned that no solutions were given by their educators for the tests and tasks, meanwhile, 34.0% of them stated that the course materials supplied are not sufficient and 24.9% of them indicate that the system is a user-unfriendly interface, hence cause disturbance to their learning process. Their data was summarized in **Figure 4**. Overall, blended learning is a good approach to enhance the learning method but some limitations need to be overcome.

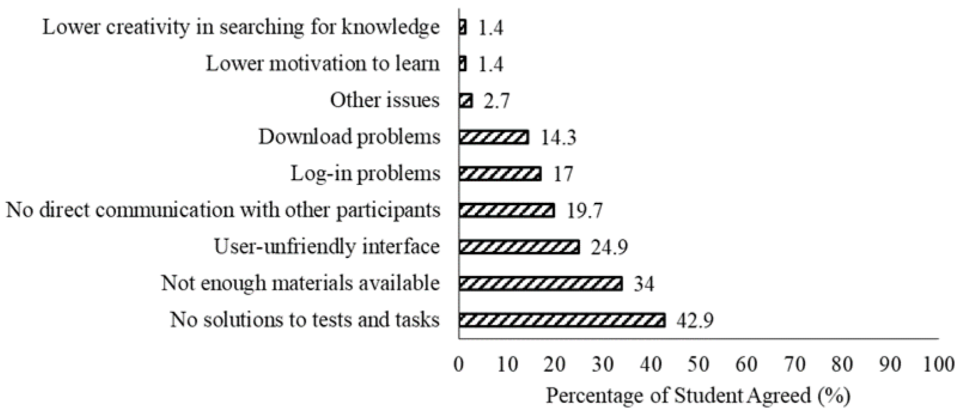

Figure 4. Disadvantages of blended learning agreed by undergraduate students.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

2.3. Summary

The outcomes of this research revealed that approximately 80% (out of 25 students) expressed their affirmation that the educator adeptly facilitated the blended learning approach, coupled with prompt and comprehensive feedback delivery. Additionally, 76% of respondents indicated their ability to effectively apply the knowledge garnered from Chemical Engineering Thermodynamics I to both everyday life scenarios and industrial contexts. Moreover, 72% of participants articulated a keen comprehension of the subject's objectives and aims, further noting their capacity to correlate this course with other previously studied subjects. A further consensus emerged regarding the educator's adept orchestration of the course, evidenced by the creation of an enriching learning environment fostering fruitful student-educator interactions. Furthermore, the educator's aptitude for elucidating assessment methodologies and the provision of diverse resources to bolster the learning journey garnered agreement among the respondents.

3. MATERIALS AND METHOD

3.1. Design and implementation of blended learning for Chemical Engineering Thermodynamics I

3.1.1. Selection of offline and online learning

To design effective and efficient blended learning to be applied to Chemical Engineering Thermodynamics I, a proper selection of online and offline learning is required. It is necessary for educators to first evaluate the course content to decide which aspects need face-to-face sessions (offline learning) and which are suitable to be delivered online (online learning). According to the course syllabus, there are about 10 chapters that need to be covered within 12 weeks (9th January 2023 until 31st March 2023). The selection of offline and online learning for this course is shown in **Table 1**. Offline learning includes direct learning activities like classroom discussions, problem-solving, experiments, hands-on assignments, and quizzes. Offline learning is similar to traditional learning which is lecture-based. Meanwhile, online learning is a learning method that used various digital mediums such as ‘Microsoft Teams’, ‘Zoom’, ‘WhatsApp’, ‘Telegram’ as well as ‘Google Classroom’, and it is not only limited to direct learning alone since any assignments, quizzes, or activities provided by the educator online are considered as online learning (Mohd Basar *et al*., 2021).

Table 1. Selection of offline and online learning based on course content

Week	Topics	Method of Delivery
1	Chapter 1: Introduction Chapter 2: Energy Transfer	Offline learning on lecture
2-3	Chapter 3: Properties of Pure Substance	Online learning on lectures while offline learning for tutorial
4	Chapter 4: Energy Analysis of Closed Systems (First Law of Thermodynamics)	Offline learning on lecture
5-6	Chapter 5: Mass and Energy Analysis of Control Volumes (First Law of Thermodynamics)	Offline learning on lecture
7-8	Chapter 6: The Second Law of Thermodynamics	Online learning in lectures while offline learning for tutorial
9-10	Chapter 7: Entropy	Offline learning on lecture
11	Chapter 9: Gas Power Cycles	Online learning on lectures while offline learning for tutorial
12	Chapter 10: Vapor and Combined Power Cycles	Offline learning on lecture

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

The main online learning platform used for Chemical Engineering Thermodynamics I is known as ULearn (refer to **Figure 5**) where all the course materials including lecture notes, tutorial questions, and video-related topics were uploaded based on semester week and chapters. This was to ease the students in accessing the course materials and enhance the learning process. Upon completing the learning process, students must complete the shelf check activity to review their knowledge and understanding of that topic. This shelf check activity was available for all chapters to ensure that students knew which areas needed further improvement, clarification, and practice. Besides, all topic-related assessments including quizzes and assignments were uploaded at the end of every lecture for educators to review students' progress and identify their strengths and weaknesses. In addition, the activity completion checklist button was also available for each uploaded component as a tool for both educators and students to monitor and manage their progress and facilitate task completion effectively.

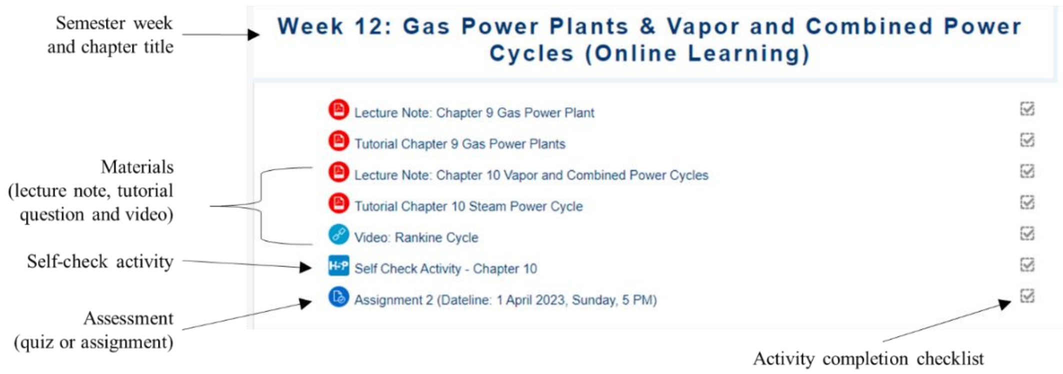

Figure 5. ULearn, an online platform used for Chemical Engineering Thermodynamics I.

There are six components were considered when designing the course content in Chemical Engineering Thermodynamics I. The components are as listed: (1) Learning outcomes; (2) Course overview and introduction; (3) Learning design; (4) Learning activities and learner interaction; (5) Assessment; as well as (6) Course look and feel. **Table 2** showed the elaboration of each component. These components are known as the key to blended learning design and are aligned with UTP's blended learning model. It also considers student learning factors to deliver effective and efficient blended learning for Chemical Engineering Thermodynamics I.

Table 2. A vital component of designing blended learning in Chemical Engineering Thermodynamics I.

List of Components	Descriptions
Learning Outcomes	○ Begin with a verb related to the desired action or performance and end with what the students will know or be able to do by the end of the course ○ Are measurable, student-centered, and achievable ○ Are aligned to the modules'/ topics' resources and activities ○ Are aligned to formative and summative assessments in this course
Course Overview and Introduction	○ The educator's self-introduction is professional and accessible online in which all details about how students can contact the educator if they need assistance are included ○ Contains a message that would make the student feel welcome in the course community

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 2 (continue). A vital component of designing blended learning in Chemical Engineering Thermodynamics I.

List of Components	Descriptions
	○ The course explicitly states the institutional and course policies that the student is expected to follow, or a link to the most recent policies is supplied ○ The course's minimum technological requirements are specified in detail, along with instructions on how to get them ○ Expectations for prior knowledge in the field and/or any necessary competencies are indicated clearly ○ Introductions explain where to find each course component and how to get started ○ Students are asked to introduce themselves to the class in an introductory online forum
Learning Design	○ Uses Substituted Blended Learning (SBL) approach that systematically combines active learning and digital technologies ○ Follows Student Learning Time (SLT) guidelines of the SBL approach. For example, if a course is a 3-credit hour course and it is equivalent to 120 hours of Student Learning Time (SLT), the SBL component of the course ranges from a minimum of 36 hours (30%) to a maximum of 72 hours (60%) ○ Uses the SLT formula 40:40:20 (40% learning materials, 40% learning activities, and 20% assessment) ○ Uses instructional materials that represent up-to-date theory and practice in the discipline Uses a variety of resources in meaningful ways
Learning Activities and Learner Interaction	○ Are relevant to the learning outcomes ○ Are relevant to the course and page topics ○ Are structured to take the course length into account ○ Capture students' interest, intrinsic motivation, and foster enjoyment in learning ○ Enable interaction and social learning among students ○ Enable students to connect concepts authentically to their world ○ Allow students to reflect on their learning ○ Plan for interacting with students during the course and their engagement requirements are clearly stated ○ Provide opportunities for interaction that support active learning Resources in ULearn are appropriate for learning online
Assessments	○ Measure the achievement of the stated learning objectives or competencies ○ Clearly states the grading policy ○ Provides information about specific and descriptive criteria for the evaluation of students' assessments ○ Are sequenced, varied, and suited to the level of the course Provides students with multiple opportunities to track their learning progress with timely feedback
Course Look and Feel	○ ULearn site is appealing and logically sequenced ○ Weekly/topic sections are consistently named and structured using headings and labels ○ Descriptor text is used to indicate the content of a linked file/website instead of just a "click here" text for links ○ Uses relevant and engaging images for icons and thumbnails ○ Links to files and websites are valid ○ Uses tone, instructions, and explanations that are friendly, clear and build rapport with students Is free from grammar/spelling errors

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

3.1.2. Development of course learning outcome

This study employs course learning outcomes (CLO) that are relevant to the course content. CLO is a learning expectation that outlines the standard to achieve in a course. It is very crucial to design CLO since it would be the main indicator of students' achievement such as desirable knowledge, skills, and attitudes. According to (Jenkins, 2015), an effective course is when the learning activities as well as evaluation and assessment are dependent on the CLO.

In Chemical Engineering Thermodynamics I, there are two CLOs that students should be able to apply at the end of this course as listed: (1) Analyze and explain the properties of pure substance using thermodynamics data and relationship; and (2) Perform related calculations and apply them in various thermodynamics systems. To design an effective CLO, it is necessary to make sure that it aligns with the program outcome (PO) (Jenkins, 2015). This is essential to help educators in creating a clear and logical progression of learning throughout the learning process (Jenkins, 2015). Furthermore, it is important to ensure that those individual courses contribute to the overall attainment of program-level goals (Jenkins, 2015). Therefore, each CLO in this course was aligned with a different PO, and the mapping is tabulated in **Table 3**.

Table 3. Mapping of course learning outcome to program outcome.

Program Outcome / **Course Learning Outcome**	**PO1:** Apply knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex chemical engineering problems.	**PO2:** Identify, formulate, research literature, and analyze complex chemical engineering problems reaching substantiated conclusions using the first principles of mathematics, natural sciences, and engineering sciences.
CLO1: Analyse and explain the properties of pure substances using thermodynamics data and relationships.	✓	
CLO2: Perform related calculations and apply them in various thermodynamics systems.		✓

According to both CLOs, students should be able to describe and analyze the fundamental principles and laws of thermodynamics upon completing this course. In addition, they should manage to perform related calculations as well as apply them in various engineering systems and their interrelationship for energy conversion in improving the systems' performance while at the same time, reducing the environmental impact. To achieve this outcome, educators also design the course syllabus according to the CLOs to ensure that the syllabus is aligned with the deliberated learning objectives, thus able to enhance the effectiveness of the course. **Table 4** showed the relationship between course content with the CLOs after proper review by the educator to identify where and how the CLOs are being addressed according to the course syllabus.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 4. Mapping of the course syllabus to course learning outcome.

Course Learning Outcome / Course Syllabus	CLO1: Analyze and explain the properties of pure substances using thermodynamics data and relationship	CLO2: Perform related calculations and apply them in various thermodynamics systems
Chapter 2: Energy Transfer	✓	
Chapter 3: Properties of Pure Substances	✓	
Chapter 4: Energy Analysis of Closed Systems	✓	
Chapter 5: Mass and Energy Analysis of Control Volumes	✓	✓
Chapter 6: The Second Law of Thermodynamics	✓	✓
Chapter 7: Entropy	✓	✓
Chapter 9: Gas Power Cycles		✓
Chapter 10: Vapor and Combined Power Cycles		✓

3.1.3. Pedagogical strategies to support student learning

Applying pedagogical strategies when implementing blended learning, especially for higher education institutions is necessary to create a learning environment that supports students' learning and engagement. In addition, educators can provide active engagement of students in participation, collaboration as well as critical thinking and encourage the students in analyzing the concepts to apply the knowledge to real-world situations, thus promoting a deeper understanding of the subject rather than mere memorization (Jenkins, 2015). Moreover, educators able to cater to the varied needs of students by differentiating instruction based on students' abilities, and this flexibility required a range of pedagogical strategies and approaches to corroborate with the different learning styles of students (Wegner *et al*., 2013).

The pedagogical strategies applied by educators in assessing the student learning outcomes for Chemical Engineering Thermodynamics I are summative, performance-based, and peer-assessment (see **Figure 6**). Summative assessment techniques such as assignments, quizzes, tests, and final examinations would help identify areas where students need additional support and evaluate the student's achievement based on the course outcomes. All assignments must be completed within a week after it is given to the students and the submission was through the ULearn platform. Similar to the quiz where all quizzes were done online through the ULearn platform also. Meanwhile, two tests were conducted in weeks 5 and 10 while the final examination was done according to the UTP's Academic Central Services on the assigned date and it covered all materials presented during the whole semester (12 weeks). On the other hand, performance-based assessment techniques such as integrated projects would allow students to demonstrate their abilities and understanding by applying their knowledge and skills to the real world. Lastly, peer and self-assessment encourage students to reflect on their learning, provide constructive feedback to their peers

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

as well as able to develop critical thinking skills by evaluating their work or the works of their peers based on certain criteria.

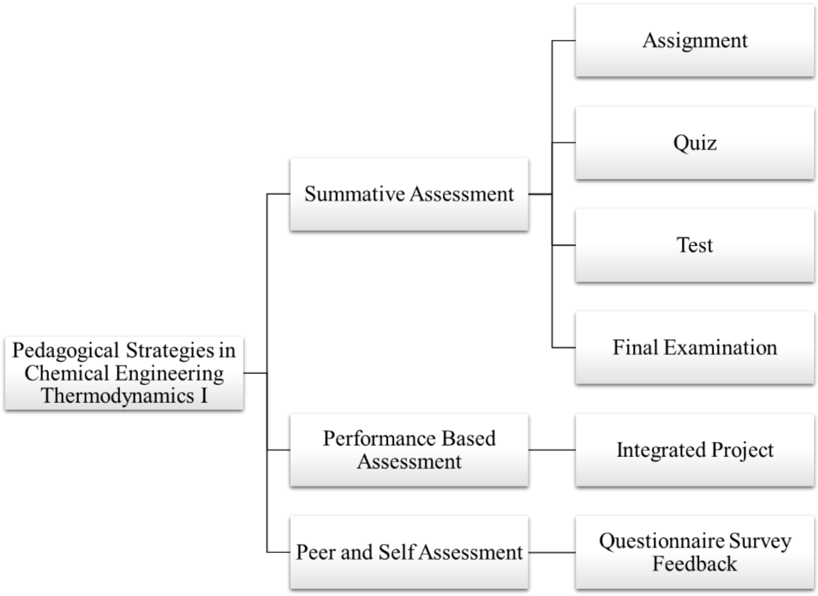

Figure 6. Pedagogical strategies used in Chemical Engineering Thermodynamics I.

3.2. Evaluation of blended learning in Chemical Engineering Thermodynamics I
3.2.1. Methods for evaluating the effectiveness of blended learning

Evaluating the effectiveness of blended learning is particularly important to measure the goals and context of the learning process successfully delivered to students. This evaluation is also crucial for educators to help them in improving their quality of educational experience and instructional practice. Educational experience refers to the overall teaching process involving the interaction between educators and students, interaction among students, and utilization of the learning materials. This is important for the growth, achievement of development of students. Meanwhile, the basis of instructional practice is the techniques applied by educators to conduct an effective and efficient learning process. It includes the selection of appropriate methods, utilization of technology, and classroom management.

Various methods were applied to evaluate the effectiveness of blended learning in Chemical Engineering Thermodynamics I as listed: (1) Learning outcomes assessment; (2) Student feedback surveys and (3) Educator feedback surveys. In learning outcomes assessment, instructors used quizzes, assignments, tests, and projects to evaluate the students in terms of their critical thinking, problem-solving, and knowledge acquisition. On the other hand, educators can know students' perceptions of blended learning implementation by collecting feedback surveys from them. Their feedbacks are important to provide valuable insights as well as guidance for future teaching process. Not only that, but educators' feedback is also crucial as an observation of how students engage with the learning activities by interacting with peers and educators as well as utilizing the technology provided.

3.2.2. Assessment of student learning outcomes

Assessing student learning outcomes involved gathering data and evidence of student performance and what they have learned and achieved from their educational experience. By referring to previous subsection 3.4, there is a variety of assessment tasks provided to students based on the pedagogical strategies applied by educators for Chemical Engineering

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Thermodynamics I. Each of the assessments was evaluated according to **Table 5** and the student's final grade was determined by confirming to **Table 6**.

Table 5. Student's marks contribution based on the assessment task.

Assessment Task	Marks Contribution (%)
Assignments	5
Quizzes	5
Integrated Project	10
Test 1	10
Test 2	10
Final Examination	60
Total	**100**

Table 6. Determination of student's final grade.

Grade	Meaning	Grade Point	Range
A	High Distinction	4.00	85.0 – 100
A-	Distinction	3.75	80.0 – 84.9
B+	High Credit	3.50	75.0 – 79.9
B	Credit	3.00	65.0 – 74.9
C+	High Pass	2.50	55.0 – 64.9
C	Pass	2.00	50.0 – 54.9
D+	Redeemable	1.50	45.0 – 49.9
D	Redeemable	1.00	40.0 – 44.9
F	Fail	0.00	0.0 – 39.9

3.2.3. Feedback from students

A set of questionnaire surveys were carried out among the First Year Chemical Engineering studying Chemical Engineering Thermodynamics I subjects. A total of 25 out of 39 students properly filled out the questionnaires obtained and constituted 64% of the total participants. The survey contained about 8 types of questions which covered different educational themes such as applying knowledge, goals understanding, clear assessment requirements, facilitator facilitating learning, the connection within the curriculum, resources provided, timely feedback, and a conducive learning environment. **Table 7** shows the details of each question based on their theme.

Table 7. Questionnaire survey and students' responses.

No.	Theme	Question
1	Apply knowledge	I can apply the knowledge gained from this course
2	Goals understanding	I had a clear understanding of the aims and goals of this course
3	Clear assessment requirement	The requirements of the assessments assigned were made clear to me
4	Facilitators facilitate learning	The educator was able to facilitate the learning process
5	Connection within curriculum	I can make the connection between this course and other courses that I have learned
6	Resources provided	I was provided with various resources to help me learn
7	Timely feedback	I always received adequate and timely feedback from the educator
8	Conducive learning environment	The way the course was conducted able to create a conducive environment for student-educator interactions

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

4. RESULTS AND DISCUSSION
4.1. Interpretation of the evaluation results

The learning experience gained by the students can be interpreted based on the questionnaire survey done by 25 students (out of 39 students) involved in this Chemical Engineering Thermodynamics I as shown in previous **Table 7** (refer to previous subsection 4.3). Only 39 students were taking this course in January 2023 semester. **Figure 7** summarises the outcome from students whether they were able to apply the knowledge gained from this course in daily life and industrial application. About 76% of students mentioned that they were able to fully apply the knowledge while only 24% of them stated that they are only able to apply the knowledge partially. **Table 8** is for the feedback result for this first question in detail.

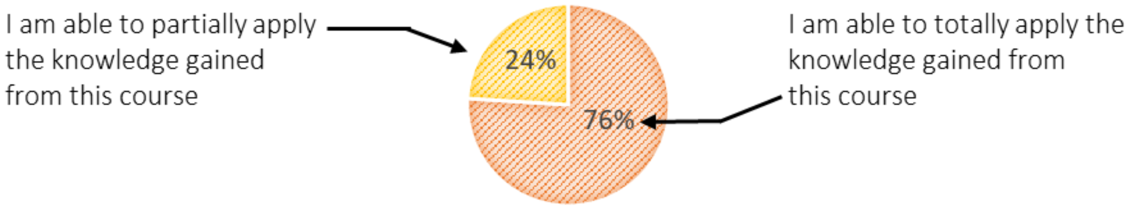

Figure 7. Feedback results in the student's ability to apply the knowledge gained (first question).

Table 8. Student's responses to the first question.

Student's respond	Number of students
I can apply the knowledge gained from this course	19
I can partially apply the knowledge gained from this course	6
I am not sure whether I can apply the knowledge gained from this course or not	0
Total number of students	25

Figure 8 summarises the outcome from students and whether they can understand the aims and goals of this Chemical Engineering Thermodynamics I. About 72% of students claimed that they had a clear understanding of the aims and goals of this course while 24% of them stated that they only understand the aims and goals partially. In addition, only 4% of them mentioned that they are not sure whether they understand the aims and goals of this course or not. **Table 9** is for the feedback result for this second question in detail.

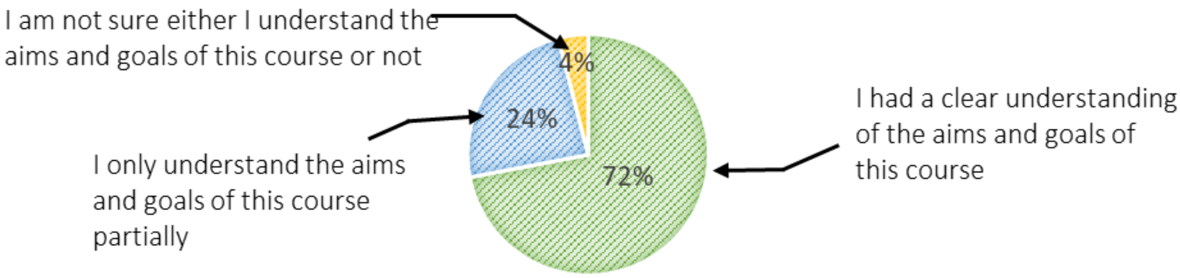

Figure 8. Feedback results in student's ability to understand the course's aims and goals (second question).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 9. Student's respond to the second question.

Student's Respond	Number of Students
I had a clear understanding of the aims and goals of this course	18
I only understand the aims and goals of this course partially	6
I am not sure either I understand the aims and goals of this course or not	1
Total number of students	25

Figure 9 summarises the outcome from student either they are clear with the requirements of the assessments assigned. About 72% of students claimed they clearly understand the requirements of the assessments assigned while 24% of them stated that they only understand the requirements of the assessments partially. Furthermore, only 4% of them mentioned that they are not sure whether they understand the requirements of the assessments assigned or not. **Table 10** is for the feedback result for this third question in detail.

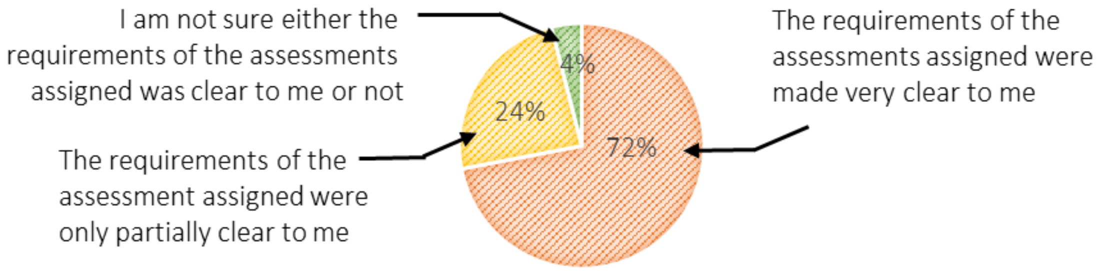

Figure 9. Feedback results on student's understanding of the assessments' requirements (third question).

Table 10. Student's responses to the third question.

Student's Respond	Number of Students
The requirements of the assessments assigned were made very clear to me	18
The requirements of the assessments assigned were only partially clear to me	6
I am not sure whether the requirements of the assessments assigned were clear to me or not	1
Total number of students	25

Figure 10 summarises the outcome from students and whether they agreed that the educator can facilitate the learning process very well. Findings showed that 80% of students agreed with the statement while only 20% of them partially agreed. **Table 11** is for the feedback result for this fourth question in detail.

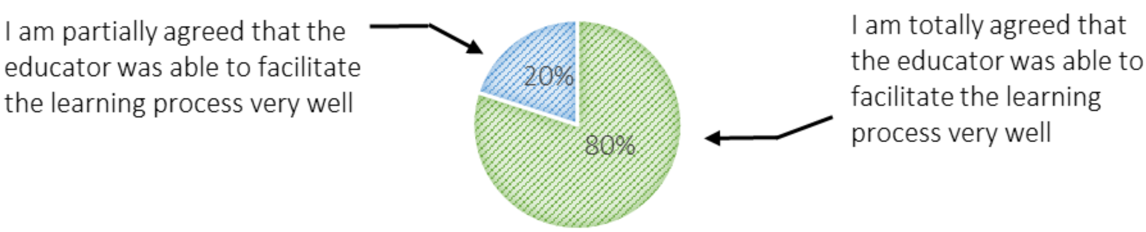

Figure 10. Feedback result on educator's ability to facilitate the learning process (fourth question).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 11. Student's respond to the fourth question.

Student's Respond	Number of Students
I am totally agreed that the educator was able to facilitate the learning process very well	19
I am partially agreed that the educator was able to facilitate the learning process very well	6
I am not sure whether the educator was able to facilitate the learning process or not	0
Total number of students	25

Figure 11 summarises the outcome from students and whether they can make the connection between this Chemical Engineering Thermodynamics I course with other courses that they have learned. Findings showed that 80% of students agreed with the statement while only 20% of them partially agreed. Refer to **Table 12** for the feedback result for this fifth question in detail.

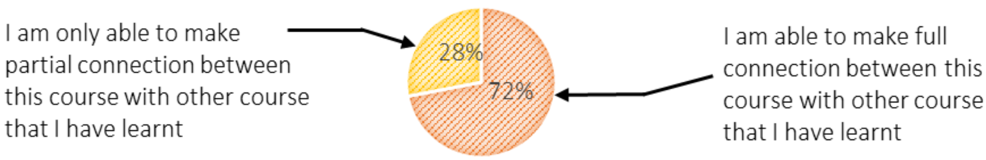

Figure 11. Feedback results in the ability to make connections between this course with other courses (fifth question).

Table 12. Student's responses to the fifth question.

Student's Respond	Number of Students
I can make the full connection between this course with other courses that I have learned	18
I am only able to make partial connection between this course with other courses that I have learned	7
I am not sure either that I can make the connection between this course with other courses that I have learned	0
Total number of students	25

Figure 12 summarises the outcome from students either they are provided with various resources to help them learn. About 72% of students claimed they were provided with full resources while 24% of them stated that they were only provided with partial resources. Moreover, only 4% of them mentioned that they are not sure whether they were provided with various resources to help them learn or not. Refer to **Table 13** for the feedback result for this sixth question in detail.

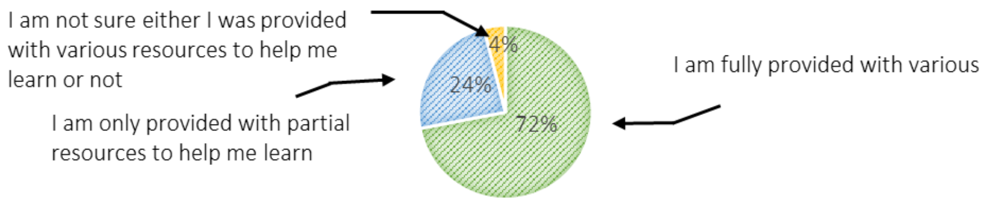

Figure 12. Feedback results on understanding of the assessments' requirements (sixth question).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 13. Student's responses to the sixth question.

Student's Respond	Number of Students
I am fully provided with various resources to help me learn	18
I am only provided with partial resources to help me learn	6
I am not sure whether I was provided with various resources to help me learn or not	1
Total number of students	25

Figure 13 summarises the outcome from student either they received adequate and timely feedback from the educator. About 80% of students mentioned that they always received adequate feedback in timely manner from the educator while only 20% of them stated that they only received adequate and timely feedback from the educator sometimes. Refer to **Table 14** for the feedback result for this seventh question in detail.

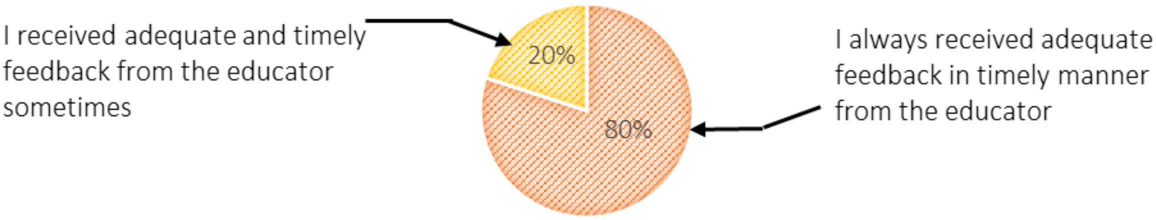

Figure 13. Feedback results in the educator's ability in giving feedback on time (seventh question).

Table 14. Student's responses to the seventh question.

Student's Respond	Number of Students
I always received adequate feedback in a timely manner from the educator	20
I received adequate and timely feedback from the educator sometimes	5
I am not sure whether I received adequate and timely feedback from the educator or not	0
Total number of students	25

Figure 14 summarises the outcome from student either this Chemical Engineering Thermodynamics I was conducted in a conducive environment for student-educator interactions. About 72% of students mentioned that they agreed with the statement while 28% of them partially agreed. Refer to **Table 15** for the feedback result for this eighth question in detail.

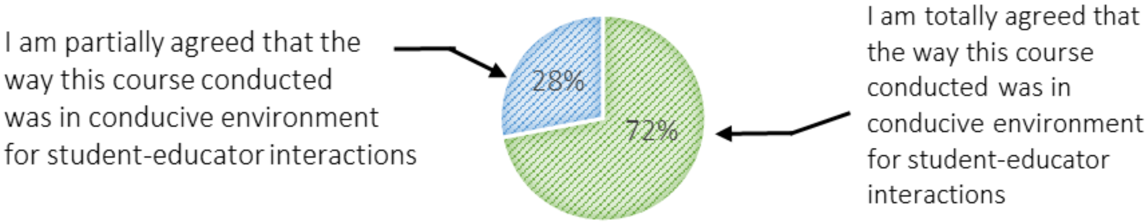

Figure 14. Feedback results in the educator's ability in providing a conducive environment for student-educator interactions (eighth question).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 15. Student's responses to the eighth question.

Student's Respond	Number of Students
I am agreed that the way this course was conducted was in a conducive environment for student-educator interactions	18
I am partially agreed that the way this course conducted was in a conducive environment for student-educator interactions	7
I am not sure whether this course was conducted in a conducive environment for student-educator interactions or nor	0
Total number of students	25

4.2. Feedback from educators

From the educator's point of view, she agreed that blended learning presented a unique opportunity in enhancing student engagement and fostering a better interactive and flexible learning environment. She mentioned that by implementing blended learning, she was able to leverage both in-person and online resources to deliver the course content by focusing on lecturing, facilitating discussions, answering questions as well as providing practical demonstrations during physical classroom while she managed to extend the learning beyond the confines of the classroom through well-designed blended learning where students had access to materials such as lecture recordings and shelf-check activities.

Furthermore, she highlighted that physical classroom sessions helped students to grasp complex thermodynamic concepts more effectively by being able to have direct interaction with educators and peers, hence deeper understanding achieved through immediate feedback. Meanwhile, she also stated online repository of resources offered flexibility for students to review concepts at their own pace, thus reinforcing their understanding and bridging any gaps in knowledge. In addition, the flexibility of accessing the course materials outside of traditional class hours allowed students to balance their academic commitments with other responsibilities which resulted in improved overall time management.

On the other hand, she indicated that the implementation of blended learning for the Chemical Engineering Thermodynamics I course was a success as she was able to witness the growth and enthusiasm of her students throughout the learning process. She believed that embracing innovative learning approaches like blended learning able to enhance teaching and learning experiences in the field of thermodynamics and beyond. This is because blended learning creates a dynamic and student-centered environment that promotes active participation and deepens students' understanding. In the future, she intended to build upon this success and further refined the blended learning approach by incorporating more interactive online activities as well as continuously improving the accessibility and reliability of the technological infrastructure.

4.3. Lessons learned and areas for improvement

Implementation of blended learning offered valuable lessons learned in teaching and learning that would improve future learning processes such as the importance of flexibility and adaptability from both educators and students. Blended learning emphasizes the need for educators to be responsive to student needs, technological challenges, and instructional strategy evolution. In addition, it is important to select proper technology tools as well as provide technical support to ensure that the technology aligns with the course outcome. Moreover, it is vital to create clear communication between educators and students to provide clear guidance, especially on class activities and assessment criteria. Furthermore, it

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

is necessary to provide ongoing support and professional development for educators to train them in instructional design, technology integration as well as effective online facilitation, thus it would help the educator to stay updated with the best practices and adapt to the evolution of blended learning. Lastly, it is essential to conduct continuous evaluation such as gathering feedback from students and reflecting it on instructional practice as this could assist in identifying areas for improvement, refining instructional strategies as well as enhancing the overall blended learning experience.

4.4. Implications for future use of blended learning in Chemical Engineering Thermodynamics

Chemical Engineering Thermodynamics I am a challenging subject that involves various applications of thermodynamic principles and equations that require students to develop critical thinking skills. Nevertheless, with the proper implementation of blended learning, students can successfully navigate this subject's complexities, thus gaining a strong grasp of thermodynamic concepts and principles. Therefore, the future use of blended learning in this subject offer opportunity in creating adaptable learning environments that may cater to individual student needs and promote personalized learning. Personalized learning can be supported via adjustment of course outcomes and activities based on individual student needs and performance (Jenkins, 2015). In addition, blended learning provides students with direct access to various range of learning resources that may help them to explore different concepts and foster deeper understanding, especially on complex concepts, hence reinforcing their theoretical knowledge. Moreover, online tools and software when applying blended learning for this subject ensure that students can develop skills in visualization and data analysis for the application of thermodynamic principles to real-life situations. Furthermore, blended learning enhanced communication skills among students via group work, peer-to-peer interaction, and knowledge sharing, consequently increasing students' engagement during the learning process.

4.5. Recommendations for Educators and institutions

Despite the implementation of blended learning for the Chemical Engineering Thermodynamics I course being a success, some recommendations should be taken into consideration to improve the blended learning style for this subject. First, educators should explore new pedagogical strategies by incorporating emerging technologies while experimenting with diverse online and offline learning activities (Jenkins, 2015). This could aspire educators to design more creative learning styles that may go beyond traditional classroom methods. Next, educators should strategically plan on how to integrate online and offline components to leverage the benefits of both modes. This could help educators in enriching educational experiences that would optimize the learning outcomes. In addition, educators should always assess the effectiveness of blended learning implementation by collecting the students' feedback and analyzing the data to reflect on the teaching methods, make adjustments and share the best practices. Lastly, educators should consider the needs of diverse learners by supporting students with different abilities, backgrounds, and learning styles.

On the other hand, institutions should provide ongoing professional workshops such as training programs, unlimited resources, and mentorship opportunities to make sure that educators are well-equipped with the necessary skills and knowledge in designing, implementing, and assessing blended learning experiences effectively. It is an innovative idea to collaborate with educational technologists, curriculum specialists, or instructional

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

designers to guide educators in assessment strategies, analysis techniques, and data collection methods (Jenkins, 2015). Moreover, the institution could also provide full access to various technology infrastructure and tools including reliable internet connection, software applications, and hardware resources to support the educators throughout their learning process. High-quality learning resources and content for blended learning such as digital textbooks, interactive multimedia materials, simulations, and online databases are highly recommended to ensure educators could deliver the course at their best level (Jenkins, 2015). Furthermore, institutions should also provide funding opportunities, recognition, and incentives to well-performed educators to acknowledge their efforts and achievements in blended learning. At the same time, institutions can motivate them while inspiring other educators to enhance their practices.

5. CONCLUSION

In conclusion, implementing blended learning in Chemical Engineering Thermodynamics I for First Year Chemical Engineering in UTP has brought positive outcomes in navigating this course's complexities. This claim was supported by the analysis of students' feedback survey where 80% (20 out of 25 students) stated that the educator was able to facilitate blended learning in an excellent way as well as able to give adequate feedback on time. On the other hand, 76% (19 out of 25 students) mentioned that they can apply the knowledge that they gained from this course in daily life as well as industry scale. Besides, 72% (18 out of 25 students) indicated that they have a clear understanding of the aims and goals of this subject and can relate this subject with other subjects that they have learned. In addition, they agreed that the educator had successfully conducted the course well by creating a conducive learning environment for student-educator interactions as well as the educator was able to clearly explain all assessments to students very well and provide them with various resources to enhance their learning process. This study's findings provide empirical evidence to substantiate the assertion that the implementation of a new learning approach using blended learning is conducive to the enhancement of students' skills and comprehension in the respective subjects.

6. ACKNOWLEDGMENT

The authors would like to express their appreciation to the Chemical Engineering Department, UTP, for their support. The authors also would like to thank the students who had taken part in this study.

7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

8. REFERENCES

Aziz, A. A., Yusof, K. M., Udin, A., and Yatim, J. M. (2013). Development of students' knowledge-behavioural changes in relation to sustainability through a case study. *Procedia - Social and Behavioral Sciences, 102*, 568–576.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*(10), 873.

Farooq, M., Kawoosa, H. S., and Muttoo, M. A. (2017). CAL: Computer Assisted Learning. *International Journal of Computer Science and Mobile Computing, 6*(6), 254-258.

Golder, J. (2018). Constructivism: A paradigm for teaching and learning. *International Journal of Research and Analytical Reviews, 5*(3), 678-686.

Jenkins, D. M. (2015). Integrated course design: A facelift for college courses. *Journal of Management Education, 39*(3), 427-432.

Laal, M., and Laal, M. (2012). Collaborative learning: What is it? Procedia. *Social and Behavioral Sciences, 31*, 491–495.

Lalima, Dr., and Lata Dangwal, K. (2017). Blended learning: An Innovative Approach. *Universal Journal of Educational Research, 5*(1), 129–136.

Leonard, P. E., and Leonard, L. J. (2001). The collaborative prescription: Remedy or reverie? *International Journal of Leadership in Education, 4*(4), 383–399.

Lukman, R., Lozano, R., Vamberger, T., and Krajnc, M. (2013). Addressing the attitudinal gap towards improving the environment: A case study from a primary school in Slovenia. *Journal of Cleaner Production, 48*, 93–100.

Mamat, M., and Mokhtar, F. (2008). Effective instructional design for value dominant education in Malaysian public universities. *Social and Management Research Journal, 5*, 61.

Mohd Basar, Z., Mansor, A. N., Jamaludin, K. A., and Alias, B. S. (2021). The effectiveness and challenges of online learning for secondary school students – a case study. *Asian Journal of University Education, 17*(3), 119.

Mukhtaramkhon, K., and Jakhongirovich, E. J. (2022). Advantages and disadvantages of blended learning in higher education. *Journal of Pedagogical Inventions and Practices, 9*, 14-18.

Schittek, M., Mattheos, N., Lyon, H. C., and Attström, R. (2001). Computer assisted learning, a Review: Computer assisted learning. *European Journal of Dental Education, 5(*3), 93–100.

Tatar, E., and Oktay, M. (2011). The effectiveness of problem-based learning on teaching the first law of thermodynamics. *Research in Science and Technological Education, 29*(3), 315–332.

Wegner, C., Minnaert, L., and Strehlke, F. (2013). The importance of learning strategies and how the project 'Kolumbus-Kids' promotes them successfully. *European Journal of Science and Mathematics Education, 1*(3), 137–143.

Welch, M. (1998). Collaboration: Staying on the Bandwagon. *Journal of Teacher Education, 49*(1), 26–37.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815