Assessing the Usability and Effectiveness of Chemical Engineering Capstone Design Project Teaching and Learning Model

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Abstract

In recent years, industry leaders, academicians, and ABET standards have expressed renewed interest in teaching engineers to solve real-world and open-ended problems. In chemical engineering program, a capstone design project is a course that allows students to deal with these problems whilst using the knowledge they have acquired from previous courses offered in the curriculum. The course represents all the Accreditation Board for Engineering Education (ABET) program outcomes required for accreditation. To enhance students' learning and meet the program outcomes requirements, we present this work focusing on the evaluation phase of an effective teaching and learning model. This model is specifically designed for chemical engineering capstone projects and aligns with the intended program outcomes. Additionally, it allows us to assess the model's effectiveness and its impact on student learning. This study aims to assess the usability and effectiveness of the designed survey questionnaires in investigating the suitability of conducting a capstone design project via this approach method. The research methodology centered on creating and validating a survey questionnaire to evaluate the suitability of the capstone design project approach. The population of this study was final-year students of the chemical engineering degree program, Faculty of Chemical Engineering & Technology, Universiti Malaysia Perlis (UniMAP), Malaysia, enrolment 2020/2021. To ensure the reliability and validity of the survey instrument, a pilot test was conducted with a minimum of thirty respondents, employing Cronbach Alpha (CA) and Principal Component Analysis (PCA). The analysis results indicate the survey questionnaires are reliable and valid, with a CA value of 0.891 and Kaiser-Meyer-Olkin (KMO) index of 0.690. The evaluation results show improved students' understanding of program outcomes and also their perceptions that the capstone design course helped their professional growth. Also, the detailed assessment and feedback given to students via this teaching and learning model made the course more valuable for preparing them for industry careers. This work resulted in better ways to teach, manage, and assess the technical and non-technical course outcomes. Indirectly, it can improve the current practices used by instructors.

Keywords: capstone design project, chemical engineering design, capstone design teaching and learning model, survey questionnaire assessment.

Introduction

The development of a capstone design course is an effort to bring the practical side of engineering back to the engineering curriculum (Scholes, 2021). Additionally, it has been influenced by many sources including the ABET, engineering educators, and numerous industrial companies. In the chemical engineering curriculum, the capstone design project is a key component of undergraduate engineering education that reflects the knowledge gained in the preparatory years, in which students apply and integrate all their knowledge from years one through the final year. The capstone design project represents the culmination of what they have learned.

The main objective of the capstone design project is to provide students with a multidisciplinary experience. It enables them to integrate knowledge gained from core, intermediate, and advanced courses in chemical engineering. The seniors in the fourth-year program will apply the skills and knowledge gained through their culminating design experience to demonstrate their readiness for engineering practice. According to Ocampo-López et al., (2022), various authors discuss the development of capstone design projects with applications to laboratories or process control courses which involve design, instrumentation, simulation, and control.

In the engineering curriculum setting, complex engineering problems are embedded in the capstone

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design project. Unfortunately, students often face well-constrained problems but are expected to graduate with the ability to solve complex problems. On the other hand, studies show that learning through solving real-world problems can provide context, thus it promotes deep and meaningful learning, in addition to enabling students to retain and transfer or use knowledge in other situations (Kamaruzaman et al., 2018). Therefore, it is important to ensure that the university's graduates meet current industry demands and are equipped with real-life engineering skills, enabling them to transition seamlessly into the workforce after graduation.

Although some research focuses on capstone design as the primary sample course, future studies could explore how students in lower-year engineering courses perceive and approach complex engineering problems, particularly in courses involving design (Alexa Ray Fernando, 2022). A successful teaching process relies on the development of appropriate and effective teaching methods, techniques, and strategies. For example, McHenry et al. (2005) introduced constructivism as a learning theory that fosters the development of engineering students' competencies, preparing them for engineering practice and graduate education. In the context of undergraduate engineering education, the teaching and learning approach emphasizes the development of factual knowledge, which, when intellectually combined, enables students to understand engineering principles, scientific laws, and mathematical applications. This foundation is critical for conceptualizing and executing solutions to real-world problems, with a particular focus on design. Importantly, these skills must be developed progressively, starting from the first year and continuing through the final year of study.

To immediately address this instructional approach, a study was conducted among final-year Chemical Engineering students at the Faculty of Chemical Engineering & Technology at the Universiti Malaysia Perlis, Perlis, Malaysia to improve their understanding of the PO. In this study, the capstone design teaching and learning model aims to enhance students' understanding. Throughout the approach, the students' acceptance of this new technique is evaluated. This model can be viewed as a teaching method that includes elements such as objectives, content or program outcomes (POs), teaching and learning strategies (pedagogy), activities, student-centered assessment, and the practice of soft skills.

Consequently, survey questionnaires were employed for data collection in this study. Survey questionnaire is one of the means of collecting standardized quantitative primary data that are consistent and coherent for analysis (Satya & Roopa, 2017). Close-ended questions were used, allowing respondents to select from predetermined responses, which makes the process easier and faster, though it may limit the depth of information gathered. A common example of close-ended questions is those constructed using the Likert scale, which provides a structured way to measure responses (Taghinejad et al., 2023). (Taghinejad et al., 2023).

Methods

The study was conducted in three stages. In stage one, the survey questionnaire was designed according to the purpose of the study. Then in stage two, the set questionnaires were distributed to the target population for pilot testing where the reliability of the survey questionnaires was analyzed using CA. Stage three is where the usability and the effectiveness of the capstone design teaching and learning model were assessed using the survey questionnaires. All the above analyses were done by deploying the Statistical Package for the Social Sciences (SPSS 27) software.

Stage 1: Design of the Questionnaires

For the usability assessment in this study, three main domains were investigated: i) usability of the model, ii) satisfaction, and iii) ease of use (USE). Table 1 presents the three main domains and the set of questions for the investigation.

Table 2 presents the set of questionnaires consisting of 12 PO statements. Two types of close-ended question structures were adopted for this part of the study and the former was set with a 5-Likert scale quantification measurement. The survey questionnaires were created using an online Google form.

Stage 2: Pilot Test and Reliability Test

The pilot study began by distributing a survey questionnaire to 30 students registered for the Chemical Plant Design course. A previous study suggests that a sufficient pilot test sample size can be as minimum as 12 or 30 respondents (Sarmah & Bora Hazarika, 2012). Another study affirms that a minimum of 10 respondents per instrument is recommended (Laura & Stephanie, 2011).

The pilot test was conducted as a preliminary step prior to the actual data collection to ensure the quality and effectiveness of the survey questionnaire. This process helped identify and address potential issues related to the questionnaire's theme, content, grammar, sentence structure, and layout format (van Teijlingen & Hundley, 2002). During the pilot test, respondents' feedback and recommendations were closely monitored and incorporated to improve the questionnaire.

In addition, data cleaning of the survey responses was carried out at this stage to eliminate duplications, incomplete responses, and other errors, ensuring the data's accuracy and reliability. As the data collected is considered prime data, this step is crucial for maintaining the integrity of the dataset prior to further analysis (Mullat, 2011). Data cleaning was performed as a prerequisite for subsequent reliability and validity testing.

After the pilot test, the reliability and validity of the survey results were evaluated using CA and PCA, respectively. Once the reliability and validity of the

Table 1. The Questionnaire Domains and Descriptions for *Usability* (USE)

Domains	Descriptions
Usability 1. The Chemical Engineering Capstone Teaching & Learning Model (CEC) helps me to be more effective. 2. The CEC model increases my efficiency. 3. The CEC model is useful for me. 4. The CEC model made learning the Plant Design Course easy for me. 5. The CEC model allows me to easily make references. 6. I save time studying with the CEC model the learning activities are efficient. 7. The CEC model improves learning skills. 8. The CEC model helped improve my understanding of the Plant Design Course.	This domain reflects the respondents' perception of the usability or usefulness of the CEC model for their specific needs; in the perspective of teaching and learning delivery as well as the assessment method.
Satisfaction 9. The CEC model performs as predicted. 10. I like the CEC Teaching & Learning model. 11. I enjoy using the CEC model in my course. 12. I'll recommend the CEC model to colleagues at other universities. 13. I believe the CEC model is necessary for the Plant Design Course. 14. I am satisfied with the way I learned the Plant Design Course using the CEC model.	This domain reflects the respondents' perception of the satisfaction of the teaching delivery using the CEC model.
Ease of use 15. The CEC model is simple to implement. 16. The CEC model is user-friendly. 17. The CEC model is adaptable. 18. I learned to use the CEC model in learning the Plant Design Course quickly and effectively.	This domain reflects the respondents' perception of the usefulness of the CEC model.

Table 2. The Questionnaire Domains and PO Statements for *Effectiveness* (POs)

Domain	PO Statements
PO1 Engineering Knowledge	Apply knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialization as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
PO2 Problem Analysis	Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3 Design/development of solutions	Design solutions for complex engineering problems and design systems, components, or processes that meet specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.
PO4 Investigation	Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
PO5 Modern Tool Usage	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering problems, with an understanding of the limitations.
PO6 The Engineer and Society	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
PO7 Environment and Sustainability	Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
PO8 Ethics	Apply ethical principles and commit to professional ethics responsibilities and norms of engineering practice.
PO9 Individual and Teamwork	Function effectively as an individual, and as a member or leader in diverse teams

	and in multi-disciplinary settings.
PO10 Communication	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11 Project Management and Finance	Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12 Lifelong learning	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

questionnaires are achieved, and the survey questionnaire is ready for distribution to the target populations for actual data collection.

The reliability of the survey results is done to assess the internal consistency of the survey results. CA coefficient is a common indicator to measure the internal consistency of the survey results of the intended purpose. Table 3 displays the list of CA values and their interpretation according to the degree of reliability.

Table 3. The Interpretation of Cronbach Alpha (CA)

Value of Cronbach's Alpha (α)	Degree of Reliability
$\alpha \leq 0$	A serious problem in the design of the questionnaire and the researcher should relook into the format of the questionnaire intended to be used for the survey.
$0 < \alpha < 0.5$	Low internal consistency and hence poor inter-relatedness between items. Should be discarded or revised.
$0.5 < \alpha < 0.7$	Moderate internal consistency and reliability of a given questionnaire. Can be revised.
$\alpha = 0.7$	Adequate internal consistency and reliability of each questionnaire.
$0.7 < \alpha < 0.9$	High internal consistency and reliability in each questionnaire. Can be revised.
$0.9 < \alpha < 1.0$	Some questionnaire items may be redundant, and the researcher has to consider removing some items from the questionnaire that are repeated questions in multiple ways.
$\alpha = 1.0$	Perfect internal consistency in each questionnaire.

(Aithal & Aithal, 2020)

According to Christmann & Van Aelst (2006), CA's value suggested by the subject matter expert should be at least 0.7 to indicate adequate internal consistency and reliability in each questionnaire.

The survey results were further analyzed for their validity using the PCA test. The PCA test is used to measure the principal components of the questionnaires. This test provides empirically robust results and a better indicator of the data variability presentation (Ajtai et al., 2023). The PCA analysis employs factor loadings that determine the common theme of the questions therefore the set questions are valid to be combined in the survey questionnaires. The range of factor loading scale is set by default in the SPSS, between (-ve) 1 to (+ve) 1 value. Generally, Aithal & Aithal (2020) stated that the PCA indicator of 0.6 and above is broadly accepted by many researchers. The qualifying indicator for the PCA test is Kaiser-Meyer-Olkin (KMO) which measures the sampling adequacy and Bartlett's Test which measures the chi-square, degrees of freedom, and p-value of the survey questionnaire or the instrument. The KMO coefficient is expected to be equivalent to or above 0.7(Hair J et al., 2014). Whereas, for Bartlett's Test, the chi-square output is considered significant when the p-value is less than 0.05 ($p<0.05$) (Taherdoost et al., 2014).

Stage 3: Usability and Effectiveness of the Capstone Design Teaching and Learning Model

In Stage 3, the usability and the effectiveness of the capstone teaching and learning model were assessed using the survey questionnaires. The data analyses were done by deploying the Statistical Package for the Social Sciences (SPSS 27) software. The target population answered a research questionnaire on the usability of the model, which includes the domains and descriptions as in Table 1. The domain measured includes USE, which is Usability, Satisfaction, and Ease of use on the model carried out in teaching and learning for the KMJ42003 course. On the other hand, the effectiveness of the capstone teaching and learning model was assessed after the students had answered the survey questionnaires on the domain of PO1-PO12 and the PO statements. It is implemented in a quasi-experimental manner, namely *single-group pretest and post-test.*

Results and Discussions

Reliability and Validity of the Questionnaire

A total of thirty (30) students who have registered for the Chemical Plant Design course participated in the pilot test survey. Table 4 exhibits the processing summary of the pilot test survey response. The case processing summary indicates that all the survey response data are valid and 100% used for the analysis.

Table 4. Case Processing Summary for the Pilot Survey Response

Description		Number of respondents	100%
Cases	Valid	30	100.0
	Excluded[a]	0	0.0
	Total	30	100.0

[a] Listwise deletion based on all variables in the procedure.

Table 5 presents the reliability statistics analysis of the pilot survey response. The number of items in this analysis refers to the number of questions set in the survey questionnaires according to the usability and effectiveness domains (Table 1 & Table 2). Cronbach's Alpha (α), the values 0.891 and 0.884 indicate high internal consistency and homogeneity of the survey questionnaires.

Table 5. Results of the Reliability Test

Cronbach's Alpha (α)		Number of Items
Usability	0.891	18
Effectiveness	0.884	12

Table 6 shows the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test outcomes. The KMO coefficient of 0.690 indicates that the sample size of 30 respondents is sufficiently appropriate for factor analysis. Bartlett's sphericity test is significant with a chi-square value of 375.399 and degree of freedom 153; ($p<0.05$). These results indicate that the sampling data is adequate and fit for the PCA test.

Table 6. Results of KMO and Bartlett's Test

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy		0.690
Bartlett's Sphericity Test	Approx. Chi-Square	375.399
	degree of freedom	153
	Significance (p value).	<0.001

Usability and Effectiveness of the Capstone Design Teaching and Learning Model

In this part, descriptive statistics were used to analyze the data from the survey. The survey measures responses to statements about the usability and effectiveness of the CEC model in the context of a Plant Design course. The analysis was done in terms of the mean and standard deviation of each item in Tables 7 & 8 below.

Table 7. Case Processing Summary for the Usability (USE) Survey Response

Description		Number of respondents	100%
Cases	Valid	99	100.0
	Excluded[a]	0	0.0
	Total	99	100.0

[a] Listwise deletion based on all variables in the procedure.

Table 7 exhibits the processing summary of the survey response on the usability of the CEC model used for the Chemical Plant Design course session 2023/2024. The case processing summary indicates that all the survey response data are valid and 100% used for the analysis. Meanwhile, the statistics of mean, standard deviation, and the percentage of agreement are shown in Table 8 below respectively.

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Table 8. Descriptive Statistic Summary for the Usability (USE) Survey Response

Item USE	N	Mean statistic	Std. deviation statistic	Frequency of agreement (N/%)	
				n	%
U1	99	4.33	.655	93	93.9
U2	99	4.26	.790	87	87.9
U3	99	4.29	.918	85	85.9
U4	99	4.17	.904	78	78.8
U5	99	4.23	.831	83	83.8
U6	99	3.68	.946	59	59.6
U7	99	4.26	.864	89	89.9
U8	99	4.54	.660	92	92.9
S9	99	3.87	.933	68	68.7
S10	99	3.85	.908	69	69.7
S11	99	3.85	.850	70	70.7
S12	99	4.01	.985	70	70.7
S13	99	4.44	.772	89	89.9
S14	99	4.15	.861	83	83.9
E15	99	3.91	.797	69	69.7
E16	99	4.04	.856	75	75.7
E17	99	4.09	.834	78	78.7
E18	99	4.09	.744	88	88.8

The data provided in Table 8 consists of responses from 99 respondents about their experiences with the CEC model in the context of a Chemical Plant Design course. Figure 1 shows a bar chart plotted from the above data that compares the Mean Statistic and Frequency of Agreement (%) for each item. This visualization allows for a clear comparison of how each item performed in terms of average score and agreement frequency among respondents.

The items measure various aspects such as effectiveness, usefulness, time-efficiency, usability, implementation and usability, learning experience and understanding, enjoyment, necessity, and satisfaction with the model. In general observation, there are overall positive responses. Across almost all items, the mean scores are above 3.5, indicating that respondents generally feel positive about the CEC model's impact on their learning. This suggests that the CEC model can be used and is perceived as effective, useful, and enjoyable.

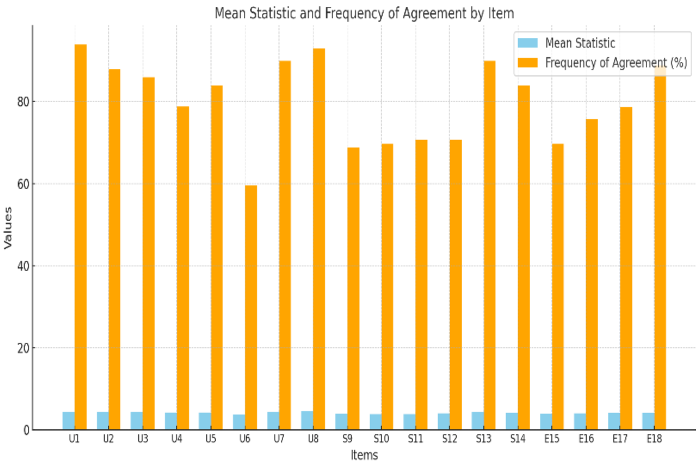

Figure 1. Mean Statistic and Frequency of Agreement (%) of the Usability (USE) Survey Response

The highest mean is 4.54 (for the item "*CEC model helped improve my understanding in the Plant Design course*"), and the lowest mean is 3.68 (for "*I save time studying with the CEC because the learning activities are efficient*"). There are also findings that high variability in responses. Many items have moderate to high standard deviations (ranging from 0.655 to .985), suggesting that responses varied among participants. For instance, the item "*I save time studying with the CEC model because the learning activities are efficient*" has a relatively high standard deviation of 0.946, indicating that there are mixed opinions on the time-saving aspect of the CEC model. For the terms of necessity and satisfaction: "*I believe a CEC model is necessary for the Plant Design Course*" received a high mean of 4.44, indicating strong agreement that the CEC model is necessary. Similarly, *"I am satisfied with the way I learned the Plant Design course using the CEC model"* (Mean = 4.15) indicates general satisfaction with the learning experience using the model.

Additionally, skewness and positive perception summarized that a significant number of items show negative skewness, which suggests that the data is skewed toward the more positive responses (i.e., respondents tended to agree more strongly than disagree). For example, the item "*CEC model improves learning skills"* has a skewness of -1.799, suggesting a strong tendency for respondents to rate it positively.

This positive skew across items indicates that the CEC model is viewed favorably overall by participants, with a larger proportion of responses leaning toward agreement. However, there were mixed views on time efficiency. While many respondents feel that CEC is effective, there is more variability in terms of its time-saving aspects. Some respondents may not find the model as efficient for saving time. This suggests that while some participants find the model time-saving, others may not. This might indicate a difference in how participants perceive the efficiency of the learning activities or how well the model fits their study styles.

On the other hand, the effectiveness of the CEC model has been determined by using a quasi-experimental design namely Single-Group Pretest Post-test. Respondents answered the questionnaire for the measurement of PO before and after using the model in the Chemical Plant Design course. The case processing summary and the descriptive statistics in mean, standard deviation, and frequency of agreement are shown in Table 9 and Table 10.

Table 9. Case Processing Summary for the Effectiveness (PO) Survey Response

Description		Number of respondents (single group)	100%
Cases	Valid	99	100.0
	Excluded[a]	0	0.0
	Total	99	100.0

[a]Listwise deletion based on all variables in the procedure.

Table 9 presents the processing summary of the survey response on the effectiveness of the CEC model used for the Chemical Plant Design course session 2023/2024. It indicates that all the survey response data are valid and 100% used for the analysis. However, the data was analyzed and the descriptive statistic of Pretest and Posttest is shown in Table 10. During the *pretest* and *posttest*, the data was collected from 99 respondents. This item measures the understanding of respondents toward PO through the CPDII course. A bar chart graph was plotted using the above data to see the comparison between the Pretest and Post-test mean scores for each PO (Figure 2).

From this finding, in the Pretest session, students had a relatively poor understanding of Program Outcomes and some of them did not agree with the PO statements. In this descriptive analysis, the mean score for each competency shows the average level of each item. The highest mean is for PO1 *"Engineering Knowledge"* (3.28), indicating that on average, participants rated this competency the highest. Meanwhile, PO8 "Ethics" has the lowest mean (2.72), indicating a relatively lower perceived level in this area of knowledge. However, the standard deviation reflects how much individual scores vary from the mean.

It was shown that PO5 *"Modern Tool Usage"* has the highest standard deviation (0.836), indicating that there is more variation in how participants rated their proficiency in this area while the lower values, while PO2 *"Problem Analysis"* (0.631), indicate more consistent responses. Overall, we can conclude that the item that has the highest mean scores indicates that respondents rate themselves more highly in these areas. However, for item that has the lowest mean, suggests that they feel less proficient in this competency.

Table 10. Descriptive Statistic Summary for the Effectiveness (PO) Survey Response

Item PO	N	Mean statistic	Std. deviation statistic	Frequency of agreement (N/%)	
				n	%
Pretest					
PO1	99	3.28	.756	46	46.4
PO2	99	3.01	.631	20	20.2
PO3	99	2.90	.721	70	70.7
PO4	99	2.91	.716	21	21.2
PO5	99	3.21	.836	27	27.3
PO6	99	2.75	.747	10	10.1
PO7	99	2.96	.781	17	17.2
PO8	99	2.72	.671	6	6.0
PO9	99	2.87	.723	12	12.1
PO10	99	3.19	.841	46	46.4
PO11	99	2.93	.732	15	15.1
PO12	99	2.73	.753	10	10.1
Post-test					
PO1	99	4.79	.411	99	100
PO2	99	4.90	.303	99	100
PO3	99	4.81	.467	96	96.9
PO4	99	4.90	.364	97	98.0
PO5	99	4.68	.620	91	92.0
PO6	99	4.19	.710	88	88.9
PO7	99	4.39	.740	88	88.9
PO8	99	4.20	.622	90	90.8
PO9	99	4.93	.258	99	100
PO10	99	4.65	.611	94	94.9
PO11	99	4.60	.669	93	94.0
PO12	99	4.52	.774	90	91.0

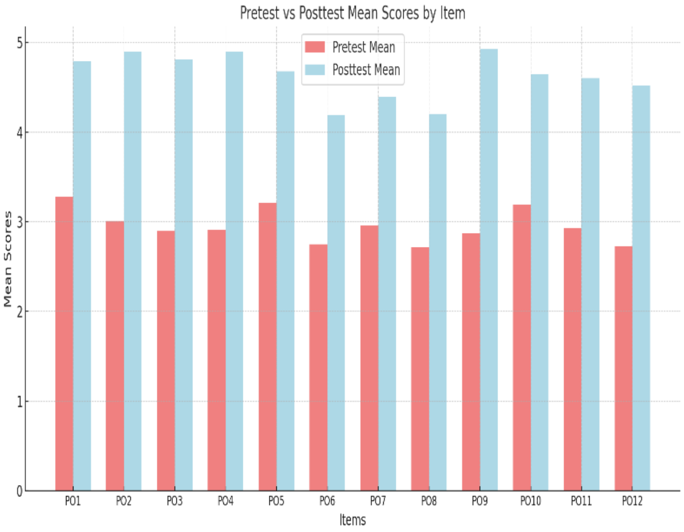

Figure 2. Comparison between the Pretest and Posttest Mean Statistic of each PO.

However, in the Post-test session, the understanding of respondents toward Program Outcomes through the Chemical Plant Design course was much better. It was proven when the mean scores for each item ranged between 4.19 (PO7 Environment and Sustainability) and 4.93 (PO9 Individual and Teamwork), suggesting high ratings across all PO statements. The lowest-rated item appears to be "PO7 Environment and Sustainability" (Mean = 4.19). In terms of the spread of scores, standard deviations ranged from 0.258 (PO9 Individual and Teamwork) to 0.774 (PO12 Lifelong Learning), indicating some variation in responses. Items like "PO9 Individual and Teamwork" and "PO10 Communication" show low variance, suggesting consistently high ratings, while "PO5 Modern Tool Usage" and "PO12 Lifelong Learning" show relatively higher variability. To enhance consistency, consider more personalized or differentiated instruction for these competencies, such as individual feedback sessions or small group discussions to address specific areas of misunderstanding. Overall, scores are high indicating a focus on improvement efforts. Skewness values are negative for all competencies, meaning distributions are left-skewed with a higher concentration of high scores. Negative skewness across competencies suggests an overall positive perception or self-assessment among respondents.

Conclusion

The pilot test provides a decisive view of the survey questionnaire's conformity for the intended purpose. The CA value of 0.891 exhibits a high internal consistency of the survey questionnaires. In addition, the reliability and validity were acceptable. In terms of usability findings, we can conclude that the CEC model is perceived positively in terms of usefulness, satisfaction, and efficiency. Most respondents agree that it helps them become more effective and improves their understanding of the course. From the survey also, we can conclude that respondents express high satisfaction with the CEC model and indicate they would recommend it to others, suggesting that the overall experience is positive, and they found that the CEC model was conducive to learning.

Overall, from a usability point of view, the CEC model seems to have a positive impact on student learning, though there's room for improvement in terms of its time-saving efficiency and ease of implementation. It may be worth exploring how the model could be adjusted to better support time management, or if different types of users have varying perceptions about its efficiency. In terms of the implementation process, some participants could find the model more challenging to apply than expected. As a result, more detailed feedback on this aspect will be collected to help improve its implementation or make the process more seamless for future users.

From the point of view of the effectiveness of the model, the mean scores improved significantly from the pretest to the posttest across all items of Program Outcome. It indicated an overall positive effect and showed substantial improvement from the intervention or learning experience using the CEC model in the CPDII course. The standard deviations in the posttest were decreased for most items compared to the pretest. This indicates reduced variability in responses, which means that more respondents achieved a better understanding. They achieved higher and consistent scores in the posttest. Additionally, the frequency of agreement also increased significantly from the pretest to the posttest, with several items reaching 100% agreement in the post-test, indicating that almost all respondents achieved high scores after the intervention. In the pretest, items like PO8 (6.0%) and PO6 (10.1%) showed particularly low frequencies of agreement. It might be that the respondents have initial weaknesses like initially they felt less confident before intervention. However, in the posttest, several items reached 100% agreement (PO1, PO2, PO4, PO9). This indicates strong learning outcomes or significant improvement in their understanding across the POs. Overall, this study showed impressive improvements across all items reflecting effective learning interventions. This can also help to identify areas of strength and potential gaps in the group's skill set. For example, training programs and improving teaching and learning strategies can focus on improving understanding in "PO6 *Engineering and Society*" or "PO8 *Ethics*," where scores and consistency are lower. In addition, opportunities for continuous learning and feedback should be provided. Continuous improvement measures should also be taken to ensure that the positive reflections observed are sustained and further enhanced.

Significance of the Research

By focusing on the capstone design project course for chemical engineering students at UniMAP, the study addresses a gap in engineering education. Traditionally, engineering programs have struggled to fully integrate theoretical knowledge with practical industry skills, but this research offers a comprehensive approach to bridge that gap. The core importance of the work lies in the methodology for evaluating and improving educational practices. Through statistical analysis, including PCA and CA testing, the researchers developed a robust framework for assessing educational outcomes. The high reliability of their survey instrument (with a Cronbach Alpha of 0.891) provides a scientifically validated method for understanding and improving student learning experiences.

The research also directly impacts student development. By carefully designing a teaching and learning model that comprehensively addresses the program outcomes, the study demonstrates a holistic approach to engineering education. The results show significant improvements in students' understanding of professional expectations and their career preparedness. The research provides a replicable model for other educational institutions seeking to align academic curricula with professional requirements. By offering detailed insights into course design, assessment, and student feedback mechanisms, the study presents a more effective engineering education. It underscores the importance of continuous evaluation and adaptation in educational approaches, highlighting how carefully designed pedagogical methods can substantially improve student learning outcomes and professional readiness.

The broader implications of this research extend to addressing the ongoing challenge of preparing engineering students for rapidly evolving industry landscapes. By creating a more dynamic, responsive approach to education, the study contributes to closing the gap between academic learning and real-world professional expectations, ultimately benefiting students, educational institutions, and the broader engineering industry.

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Conflict of Interest

The authors declare no conflict of interest.

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