Cooperative problem-based learning experience and coaching strategies of engineering course

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ABSTRACT

The problem-based learning (PBL) methodologies are considered adequate for core engineering courses. The integration between cooperative learning and PBL methodologies establishes an encouraging environment for the students. However, for effective implementation of cooperative problem-based learning (CPBL) environment, close supervision of students' experiences is vital, and deficient areas are to be improved, as PBL is a dynamic process. A study was conducted for the first-year undergraduate engineering class taught under the PBL environment. The objective was to evaluate the course by the preview of students, for highlighting weak domains in the teaching methodology for future improvements. A course experience questionnaire was designed considering PBL implications, with 35 question items, and 31 responses were collected by the end of the semester. Three different analyses were performed on the collected data, i.e., descriptive statistics and Cronbach's alpha, Student's t-test, and Pearson Chi-square test. The achieved results supported the effective adoption of the PBL system by the students. However, few areas were highlighted requiring special consideration, such as PBL workload, pressure due to extra course content, and assessment opportunities under the PBL system. It was proved that maximum students considered PBL methodologies convenient and effective for learning than the traditional learning approach.

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1. INTRODUCTION

The emerging challenges of the 21st century are imposing the educators to learn problem-solving skills to manage complex situations, which can be achieved by modifying conventional educational strategies to active and cooperative learning strategies [1], [2]. The engineering professionals are showing efforts to provide the solution for world challenges, such as increasing pollution, resource depletion, digitalization and provision of high sustainably living standards, to ensure stabilized social, environmental, and economic growth [3]–[7]. The conventional lecture-based teaching methodologies have been criticized for their inability to develop professional skills in graduates, such as problem-solving, critical thinking, and teamwork [8]. In the 2017 global university employability ranking, 80% of respondents identified the problem-solving skills and collaboration as the essential key qualities for the graduates. These facts give insight into the changing requirements and expectations of the industry for fresh graduates, i.e., to be equipped with critical thinking, problem-solving skills, and teamwork capabilities to operate in a fast-paced society [9].

The problem based learning (PBL) method was developed in the 1960s at McMaster University Medical School in Canada [10]. Since then, it has been adopted in many disciplines, especially in civil engineering schools [11]. Barker [12] described PBL in the context of civil engineering by utilizing PBL methodology in the conventional educational environment and motivated the students towards unique learning and teaching experience. Mills and Treagust [13] referred to PBL as project-based learning in civil engineering, in the perspective of long project timelines for short spanned problems and directed learning by projects. Ahern [14] performed two case studies by implementing PBL in civil engineering transportation courses, which resulted in the improved attitude of students towards the course with an in-depth and critical learning attitude. Hall, Palmer, and Bennett [15] highlighted teamwork issues among students, such as long timeline demands, lack of teamwork spirit, and efforts, which were addressed by developing a strategy in PBL module planning. Chandrasekaran *et al*. [16] concluded the PBL as the well-adopted system by engineering schools worldwide in developed and matured form. However, this study emphasizes the need for efforts, which would be required to improve interdisciplinary PBL strategies at the undergraduate level in engineering. Barkley, Major, and Cross [17] discussed the positive outcomes of collective group learning by building knowledge footing based on interactions and developing shared understanding. Radcliffe and Kumar [18] evaluated the suitability of PBL for engineering courses by conducting three days workshop. It was concluded, with the help of the quantitative survey, that superior outcome could be achieved by top of class 5-20% of students with required available resources. Dahms, Spliid, and Nielsen [19] analyzed the role of the instructor in PBL active learning, in which it was concluded that effective implementation of PBL could only be possible by joint efforts of instructors' teams. A single instructor cannot be the jack of all trades in PBL, but a team can come over each other's weaknesses and becomes a source of strength. Beagon *et al*. [20] analyzed the student perception for the effectiveness of developing professional skills, for engineering practices, by assigning a group project under the PBL environment. The assessment was made by adopting a questionnaire survey with quantitative analysis, and encouraging outcomes were collected, indicating improved professional skills such as communicational, and teamwork.

Many researchers have shared implications and comparisons of the PBL education system over other education systems. Bi *et al*. [21] studied two groups for the same content; one taught on the case-based study and the other on traditional method at Bengbu Medical College, China. A questionnaire was designed to understand the self-efficacy and satisfaction level of the taught course. The final assessment was performed based on a post-study examination. Overall, the group that followed the case-based study methodology performed better than traditional teaching groups. Al-Jehani *et al*. [22] conducted an analytical-based cross-sectional study at Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia. Two medical students' batches were taught under a problem-based learning environment, and two under a traditional learning environment. Evaluation between two teaching strategies was performed via adopting a Likert-scale questionnaire. The assessment was performed by performing statistical analyses, which included logistic regression and Chi-square. However, found results represented no significant difference between the two study approaches. Brinkman *et al*. [23] performed a study at NOVA Medical School, Lisbon, Portugal, to analyze the effects of undergraduate curriculum change from discipline-based traditional learning systems to PBL systems with the integrated and case-based learning approaches. Questionnaire and validated prescribing assessment methodology were performed for evaluation on final year programs. The study concluded that the PBL learning environment was more suitable for students in terms of self-confidence, being well-prepared for the future, and better technical growth. Dawilai *et al*. [24] compared the problem-based blended learning (PBBL) instructions with traditional PBL by assessing the effectiveness of creative writing at Chiang Rai Rajabhat University, Thailand. During the 14 weeks course, post-test and pre-test strategy was adopted for evaluation. It was concluded that students with the PBBL strategy were able to gain better scores with improved performance.

However, few researchers also criticized PBL methodologies. Perrenet, Bouhuijs, and Smits [25] disregarded the adoption of PBL methodologies in engineering programs by highlighting its lack of capability for complex problem-solving skills and teaching hierarchic knowledge structure. Kirschner, Sweller, and Clark [26] also scathed the PBL by concluding that no organization of research support PBL techniques. Yadav *et al*. [27] also criticized PBL methodologies for their incapability of teaching students concepts at hand. Dolog, Thomsen, and Thomsen [28] developed a model to save students' time spent by following the PBL approach from 70% to 50% and give them more time to learn by conventional method to enhance knowledge. Despite criticism on the PBL methodologies, overall, the literature review concludes the importance of PBL in engineering courses. PBL methodologies develop professional attributes in students such as team working spirit, confidence for taking self-initiatives, creativity, and many more, which are esteemed in the professional field. These aforementioned factors make the PBL approach to be valued for enhancing engineering education [20].

PBL is an instructional methodology that is student-centered and independent learning style operated under the guidance of a facilitator. The environment of PBL motivates the students towards the self-directed learning approach, which is more problem-focused than instructor-directed [29]. The problem-solving attitude creates planning, reasoning, and decision-making skills in students [2]. PBL methodology is established on a constructivist theme. Students are engaged in small combined groups to recognize the knowledge domains and strategies required for solving complex problems [30]. PBL uses designed ill-structured questions illustrating the realistic scenario, which increases students' interest and triggers their urge to learn the fundamentals as a team [31]. Moreover, several studies show that compared to conventional approaches, the adoption of PBL methodology helps students improve their grades for engineering subjects. In the aspect of short-term information acquisition, students following the PBL approach learn almost equivalent knowledge as the conventional approach. However, students in the PBL environment last such information longer than in the conventional environment. The processes of group discussions and targeted knowledge elaboration in PBL make the information organized and better structured in memory [32]. In PBL, several techniques are adopted to encourage self-centered learning among students to develop high order decision making and promote teamwork [33]. Moreover, PBL improves creative thinking skills among students [34]. Cooperation among functional teams of students is the key to the successful implementation of PBL, which implies the need for a PBL guided framework to be followed by a small group of students based on cooperative learning principles. This integration between cooperative learning and PBL establishes an encouraging environment for the students to develop team working and team-supportive skills under the PBL cycle [35]. Group interactions create a collaborative spirit among students, which leads to major positive impacts on the learning process.

In recent years, a significant evolution has occurred in the engineering profession by facing complex engineering problems due to the cross contradiction between the parameters of sustainable development. These complex engineering problems have also impacted the educational model of engineering, and learning through real-life exercises is becoming a requirement [36]. Furthermore, the creativity of an engineer lets him be a good problem solver. Thus, engineering knowledge develops the problem-solving and problem designing ability of an individual. Currently, researchers are emphasizing the socio-technical characteristics of engineering, i.e., skills to work as a group. In 2007, the Royal Academy of Engineering (RAE) published a report focused on engineering graduates' existing and forthcoming requirements to train them to accomplish industrial needs. The report concluded that engineering graduates lack the skills and attitude to solve real-world problems, and it was recommended to the higher educational institutions (HEIs) to modify the engineering curriculum towards more practical knowledge gain opportunities. Also, theoretical understanding, practical applications, innovations, and creativity were identified as key characteristics required for future graduates [37]. Likewise, in 2013 the American Society for Engineering Education (ASEE) performed a consultation process to develop new strategies to fulfill industrial requirements in future graduates. It was concluded that engineering graduates should have a broad knowledge base with deep technical expertise (T-shaped) and be capable of working as team members [20].

PBL has gained a lot of popularity, and it has been adopted in engineering education for decades. Students under the PBL environment are expected to become skilled engineers with a problem-solving attitude while performing tasks collectively as a team [9]. The engineering problem-solving process is usually divided into three phases, i.e., problem definition, problem strategy, and problem solution. In the first phase, the students try to collect all the known and unknown knowledge correlated to the identified problem along with the problem scope, gaps, learnings issues, and constraints to its solution. In the second phase of developing a strategy for the problem, the students apply the collected knowledge to the highlighted problem and generate solutions by performing various tests for analyzing and synthesizing the outcomes depending upon related constraints. This process is performed by studying the relevant studies and literature to the identified learning issues. In the final phase of the problem solution, the students analyze the outcomes, and the solution is recommended based on synthesized results. The students in this phase share their findings in group discussions for the solutions under the supervision of the instructor [38], [39]. Figure 1 illustrates the actions and procedures involved in the three phases mentioned above of the engineering problem-solving process. It can be seen that iteration of actions until the attainment of a rational outcome is a consistent feature of this problem-solving process. In the problem-solving of specific activities, these phases act as critical anchors for more effective outcomes and solutions.

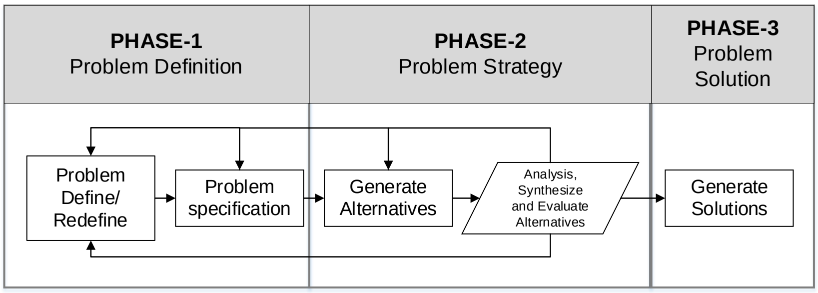

Figure 1. Engineering problem-solving process

The civil engineering department, Universiti Teknologi PETRONAS, Malaysia, is promoting the PBL approach, especially for the core courses. A first-year undergraduate engineering class was the first time taught under the PBL environment. The core course teaching methodology was designed specifically on the following cooperative problem-based learning (CPBL) principles [35]: i) Individual accountability; ii) Appropriate interpersonal skills; iii) Positive interdependence; iv) Regular group functional assessment; and v) Face to face interactions. Also, a basic PBL framework was adopted, designed by Tan [40], which was modified to CPBL based on the aforementioned principles. However, instead of having tutorial groups of approximately ten students, the students were divided into small groups of three to four individuals. Based on the modified CPBL framework, this core course was designed with four course-learning outcomes (CLOs) and with each CLO having some weightage. During the semester, two PBL based group assignments were given to the students covering each CLO. In each such group task, one of the team members acted as the leader. The time duration allotted for each group assignment for the completion and submission was one week. All the problems during the semester were crafted to be authentic, and their difficulty level matched the students' level for the first year [35]. Moreover, e-learning activities were also integrated with the learning process to achieve designed educational objectives. These activities included designing realistic engineering problems to create interest, assisting students by the provision of necessary scaffolding along with additional discussion platforms and peer education. The developed framework was based on constructive alignment, which provides scaffolding to manage students to follow CPBL. Under this scenario, an assessment of the overall CPBL learning experience of the students for the semester was required under the designed CPBL framework. This study aimed to devise evaluation methodology for the taught PBL-based core course by the preview of students and assess the instructor's achievement level of CPBL objectives, i.e., sense of responsibility, polishing of interpersonal skills, team working spirit, and team-leading spirit. As the department was new to the PBL system, the current study was planned to devise the assessment methodology to help the self-evaluation of the adopted CPBL-based system and highlighting weak domains for future improvements in the applied PBL environment.

2. RESEARCH METHOD

2.1. Research design

This study was quasi-experimental, performed on the engineering class of first-year students at Universiti Teknologi PETRONAS, Malaysia. This batch was the first time introduced to the PBL theme, and the response of students was required for their adaptability and obstacles they had faced due to this transition. Therefore, a study was designed to assess the resilience of students towards this change, i.e., lecture-based education towards problem-based education, for modifying methodologies and improvement of the system.

2.2. Research population and sample

A PBL-course experience questionnaire (CEQ) was designed for feedback. There were 31 responses collected from the students of the first-year batch by the end of the Spring 2020 semester. The previous studies by Bujang, Omar, and Baharum [41]; Conroy [42]; and Delice [43] support the sample size of 30 as a minimum desired number for the questionnaire-based survey for reliable analyses outcomes.

2.3. Research instruments

Lancaster University originally designed the CEQ theme in the 1980s for observing teaching excellence in degree programs, and various studies have been performed by researchers for modifying CEQ for better outputs. However, the CEQ model designed by previous researchers [44], [45] was used to measure the quality of the learning experience by students, and this theme was adopted for this study. The CEQ model for this study was modified for the PBL environment under the guidelines provided by previous researchers [46]–[48] and 35 questions for the PBL-CEQ model were designed.

The designed PBL-CEQ consisted of two parts (the first part is demographic data form and the latter is CEQ form). The demographic data form consisted of information regarding student's age, gender, study group, and last semester's grade point average (GPA). Whereas, in CEQ form, the questionnaire was designed containing 35 items (questions), based on the theme of CPBL principles, with 5 points Likert response scale, i.e., 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree. In the PBL-CEQ questionnaire, the designed 35 items (questions) were arranged under seven groups. The detail for seven scales are as: i) Good teaching scale (GTS); ii) Clear goals scale (CGS); iii) Appropriate workload scale (AWS); iv) Appropriate assessment scale (AAS); v) Generic skills scale (GSS); vi) Overall satisfaction scale (OSS); vii) Workforce relevance scale (WRS).

The PBL-CEQ was designed to cover the overall aspects of the PBL environment experienced by the students. The first scale, i.e., GTS, targets to assess teaching excellence, and it covers significant teaching quality parameters for evaluation. Likewise, the second scale, i.e., CGS, assesses students for their understanding of PBL and their adopted strategies to achieve targeted goals under provided scaffolding. The third scale, i.e., AWS, helps the instructor to monitor the sheer volume of work pressures on students and to keep the workload under the threshold point for students to be psychologically healthy. The fourth scale, i.e., AAS, helps the instructor to measure students' satisfaction on the criteria adopted for assessments. The fifth scale, i.e., GSS, is a self-evaluation of students for the development of skills after following PBL and helps the instructor to measure students' confidence towards PBL. The sixth scale, i.e., OSS, measures the overall satisfaction of students towards PBL than lecture-based learning. Whereas the seventh scale, i.e., WRS, targets the CPBL approach of students towards learning activities.

2.4. Data analysis techniques

Collected data were analyzed for its reliability by using Cronbach's alpha. Its descriptive statistics were analyzed in percentage responses, means, and standard deviation (SD). Its significance difference was analyzed with the expected outcomes by Pearson Chi-square test. Moreover, to analyze the varying response of students towards PBL the Student's t-test was applied.

3. RESULTS

The questionnaire feedback (PBL-CEQ) was collected by the end of semester Spring 2020, which was executed under the PBL environment, and 31 students' feedbacks were collected from the selected engineering course. Besides using descriptive statistics, the reliability of the collected data was validated by Cronbach's alpha. Cronbach's alpha evaluates internal reliability or consistency between several objects, ratings, or measurements. In other words, it calculates how credible is the response of the survey or collected feedback [41]. Likewise, for presenting or evaluating the data quantitatively by describing it in a manageable form, the descriptive statistics in the form of percentage responses, means, and SD were calculated for analyzing students' feedback about their PBL experience.

Firstly, the reliability test, i.e., Cronbach's alpha coefficient, was performed for the overall collected responses on 35 items in PBL-CEQ by 31 students. The Cronbach's alpha value for overall PBL-CEQ, for response data of complete 35 items, was found to be as $\alpha=0.948$, which is an excellent value [49]. As a rule of thumb, $\alpha\geq0.7$ is considered reliable; however, most researchers have identified $\alpha\leq0.55$ as not satisfactory [50]. Of the total of 31 students, 22.6% (n=7) were female, and 77.4% (n=24) were male. The mean age of the students was 19.55±0.84, and the mean of their last semester GPAs was 3.40±0.36. Moreover, each group of PBL-CEQ (07 scales) was evaluated separately to assess students' experience under the PBL environment.

3.1. Cronbach's alpha and descriptive statistics

The GTS covered the assessment of teaching quality and the adopted strategy of the instructor under the PBL environment. The GTS consisted of 10 questions, and the response was studied for each. The Cronbach's alpha value of the collected data for this scale was $\alpha=0.869$, which is considered a good scale value. Table 1 shows the frequency percentage, mean, and SD for each question. The results show the students were overall satisfied by the instructor's efforts for the PBL course. It can be seen that means of all items (Q1 to Q10) lies between 4.13 to 4.61. Students gave a higher rating to Q8 (instructors' familiarity with the curriculum) with a mean of 4.61±0.56; whereas, the lowest score was given to Q6 (use of audio-visual and technical materials) with a mean of 4.13±0.85. Although Q6 got the minimum rating by the students, however, under the PBL environment the students receive more scaffolding rather than conventional teaching and PBL motivates students to adopt self-directed approaches. Therefore, the instructor expected the students to explore learning opportunities by themselves, which included the utilization of audio-visual and technical materials for education.

Table 1. Descriptive statistics for GTS

Q	Items	Frequency percentage					Mean	Std. dev
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q1	The educator had a clearly discernible lesson plan for PBL active learning approach.	-	-	9.68	48.39	41.94	4.32	0.65
Q2	The educator used the target-language and thinking approach in the classroom appropriately and effectively for PBL application.	-	-	3.23	58.06	38.71	4.35	0.55
Q3	We often discussed with our educator about how to solve PBL assignments through provided scaffolding.	-	-	12.90	48.39	38.71	4.26	0.68
Q4	The educator of this course motivated me to self-directed learning through PBL implementation	-	-	22.58	32.26	45.16	4.23	0.80
Q5	The educator was extremely good at explaining the concepts and systematic problem-solving technique	-	-	12.90	35.48	51.61	4.39	0.72
Q6	The use of audio-visual & technical materials was effective in PBL session.	-	3.23	19.35	38.71	38.71	4.13	0.85
Q7	The educator worked hard to make the subject interesting in PBL implementation.	-	-	3.23	38.71	58.06	4.55	0.57
Q8	The educator was familiar with the curriculum, available materials and resources	-	-	3.23	32.26	64.52	4.61	0.56
Q9	The educator made a real effort to understand the difficulties we were facing during PBL learning and provided the necessary scaffolding.	-	-	9.68	45.16	45.16	4.35	0.66
Q10	The educator demonstrated the knowledge of the subject matter that extended beyond the textbook to support PBL implementation.	-	-	6.45	41.94	51.61	4.45	0.62

The CGS consisted of four questions, and it was designed to evaluate the understanding level of the students regarding awareness of their targeted goals and tools required for scoring good grades in the PBL course. The Cronbach's alpha value of the collected data for this scale was α=0.857. Table 2 illustrates the frequency percentage, mean, and SD for each question. The results show that students were made clear about PBL course requirements by the instructor, and they were also aware of the attributes being expected from them for attaining a good score.

Table 2. Descriptive statistics for CGS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q11	I had a clear idea, what were the requirements, I needed to fulfill regarding PBL in this course.	-	-	12.90	48.39	38.71	4.26	0.68
Q12	The educator made it clear right from the start, what were the expected outcomes from students in the PBL.	-	-	22.58	41.94	35.48	4.13	0.76
Q13	The educator gave a detailed briefing on PBL benefits and implementation before commencing this course.	-	-	25.81	41.94	32.26	4.06	0.77
Q14	The KNL (what we know, what we need, what to learn) Table:							
(a)	I am familiar with KNL procedure.	-	-	3.23	45.16	51.61	4.48	0.57
(b)	I developed KNL tables for each PBL assignment.	-	-	12.90	58.06	29.03	4.16	0.63
(c)	KNL tables were effective in PBL assignments.	-	3.23	9.68	48.39	38.71	4.23	0.76

However, the results of Q13 (4.06±0.77) and Q12 (4.13±0.76) showed that efforts would be required, by the instructor in the future, for the pre-semester briefing to students regarding PBL implementation, benefits, and expected outcomes. Moreover, it would also be required to educate and train the students regarding the benefits of using more tools like KNL tables (what we know, what we need, what to learn) [51] for better goal clearance and achievements. The range of means (Q11 to Q14) was between 4.06 to 4.48.

The AWS was designed to assess the workload on students in the PBL course, and it consisted of four related questions. The Cronbach's alpha value for this scale was α=0.751, which is considered reliable. This Cronbach's alpha value means that poor interrelatedness exists between opinions among students regarding their workload under PBL. Table 3 illustrates that students were not certain regarding their workload, which required the instructor's counseling. In this scale, the maximum mean was calculated for Q18 (participation in activities), i.e., 3.87±0.80; however, Q17 (too many topics) had the lowest mean with 3.16±1.21 but high SD. The overall response of the students was neutral. However, few students showed concern regarding workload for the PBL course. The range of means (Q15 to Q18) was between 3.16 to 3.87.

Table 3. Descriptive statistics for AWS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q15	The workload in PBL for courses becomes too heavy.	6.45	3.22	51.61	22.58	16.12	3.38	1.02
Q16	There was a lot of pressure on me to do well in this course, due to PBL implementation.	3.22	19.35	38.71	25.80	12.90	3.25	1.03
Q17	It seemed to me that for, PBL implementation, educators tried to cover too many topics.	9.67	19.35	32.25	22.58	16.12	3.16	1.21
Q18	The educator provided opportunities for all students to participate in activities and discussions using PBL scaffolding.	-	-	38.71	35.48	25.80	3.87	0.80

The AAS was designed to gain insight into the students' views regarding their assessment criteria for the PBL course, and three questions were designed for this scale. The Cronbach's alpha value of the collected data for this scale was α=0.632, which was weak but considered moderate and acceptable. This Cronbach's alpha value showed that students were perplexed about their assessment in the PBL course. Table 4 illustrates the varying responses of the students in Q20 (learning opportunities) with a mean of 3.90±0.79, and for Q19 approximately 75% of students showed agreement towards having little choice to be assessed in the PBL course (4.03±0.70). These results also showed that the instructor should counsel the students regarding their assessment criteria to improve the methodologies.

Table 4. Descriptive statistics for AAS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q19	There was very little choice in the PBL course, in the ways for students to be assessed	-	-	22.58	51.61	25.81	4.03	0.70
Q20	The PBL system gives an opportunity to students for selecting their own ways to learn the course.	-	3.23	25.81	48.39	22.58	3.90	.79
Q21	Following the PBL active learning approach, the educator seemed more interested in testing what I had understood than what I had memorized	-	-	9.68	54.84	35.48	4.26	.63

The GSS was designed to get insight into the self-learned skills that would have been developed in students due to the PBL environment, and this group consisted of five questions. The Cronbach's alpha value of the collected data for this scale was α=0.888, which is considered a good scale value. Table 5 shows the frequency percentage, mean, and SD for each question. The results showed that the students were confident about self-learning skills under the PBL environment and gaining self-confidence. It can be seen that means of all items (Q22 to Q26) were between 3.90 to 4.42. Students gave a higher rating to Q26(a) and Q26(b) (engagement towards problem-solving and critical thinking) with a mean of 4.42±0.62 and 4.42±0.67. However, the lowest rating was given to Q24 (confident for tackling unfamiliar problems) with 3.90±0.83, which shows instructors need to focus on this area to build up students' confidence towards practical problem-solving skills.

Table 5. Descriptive statistics for GSS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q22	The PBL active learning approach developed and improved my problem-solving skills.	-	-	19.35	41.94	38.71	4.19	0.75
Q23	The PBL active learning approach sharpened my analytic skills.	-	-	19.35	51.61	29.03	4.10	0.70
Q24	As a result of the PBL active learning approach, I feel confident about tackling unfamiliar problems.	-	6.45	19.35	51.61	22.58	3.90	0.83
Q25	The PBL active learning approach improved my skills in written communication.	-	3.23	22.58	51.61	22.58	3.94	0.77
Q26	PBL active learning system engages students in:							
(a)	Problem-solving.	-	-	6.45	45.16	48.39	4.42	0.62
(b)	Critical thinking.	-	-	9.68	38.71	51.61	4.42	0.67
(c)	Open-ended questions.	-	-	16.13	35.48	48.39	4.32	0.75
(d)	Class Discussions.	-	3.23	19.35	41.94	35.48	4.10	0.83

The OSS helped to identify the overall contentment of students under the PBL environment after being transitioned from the lecture-based learning environment and resources provided by the institution. This group consisted of six questions, and each item targeted the criterion for overall satisfaction, such as material provided, class atmosphere, teaching and learning approaches. The Cronbach's alpha value of the collected data for this scale was α=0.833, and the results in Table 6 showed that overall, students were satisfied with the PBL methodologies. However, few students showed concern about the impacts of 'study groups' for PBL problem-solving. Also, very few students voted for the previously adopted old teaching approach better than PBL. In general, students rated Q29 (PBL as active learning approach) at highest in this group with a mean 4.52±0.63 and rated Q32(b) (My Group dynamics) at lowest for this group with mean 3.90±0.79.

Table 6. Descriptive statistics for OSS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q27	I am satisfied with the facilities (books, slides, etc.) recommended and provided by the educators	-	-	16.13	45.16	38.71	4.23	0.72
Q28	Students feel free to ask questions related to PBL assignments in an atmosphere of open communication.	-	-	16.13	29.03	54.84	4.39	0.76
Q29	Overall, I was satisfied with the quality of education provided by this PBL active learning approach.	-	-	6.45	35.48	58.06	4.52	0.63
Q30	I am satisfied with the method of evaluation in the PBL system of our courses, and I think it is fair.	-	-	16.13	45.16	38.71	4.23	0.72
Q31	In my opinion, the PBL learning approach is better than the traditional learning approach.	-	3.23	19.35	48.39	29.03	4.03	0.80
Q32	I was satisfied with the PBL learning approach for:							
(a)	Problem scenario.	-	-	19.35	48.39	32.26	4.13	0.72
(b)	My Group dynamics.	-	3.23	25.81	48.39	22.58	3.90	0.79
(c)	Educator evaluation.	-	-	22.58	45.16	32.26	4.10	0.75

The WRS was designed to assess the students for developed capabilities under the CPBL environment, such as teamwork, confidence for self-initiatives, and effective utilization of time. This group covered three questions along with a few sub-questions. The Cronbach's alpha value of the collected data for this scale was α=0.788. Table 7 reveals Q33 (teamwork) with a mean of 4.16±0.78; illustrated that the students had varying opinions for teamwork, such as most of the students claimed the development of teamwork attitude due to the PBL environment and a very few students opposed. Likewise, most of the students admitted that PBL had changed their attitude towards studies, and they spent their available time in positive educational activities; however, few students thought the other way around (Q34). The mean of all items (Q33 to Q35) was between 3.65 to 4.26. Students gave higher ratings to Q34(a) (weekly time spent: understanding the problem & finding objectives) and Q35(b) (dependency: lectures) with a mean of

4.26±0.73 and 4.26±0.86, and the lowest rating was given to Q35(a) (dependency: books) with 3.65±0.75. These results show that the instructor has to design class exercises to create the interest of students towards books rather than only to lectures and the internet.

Table 7. Descriptive statistics for WRS

Q	Items	Frequency percentage					Mean	Std. dev.
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree		
Q33	The PBL active learning approach helped me develop my ability to work as a team member.	-	3.23	12.90	48.39	35.48	4.16	0.78
Q34	For the weekly problem solving I spend my time in:							
(a)	Understanding the problem & finding objectives.	-	-	16.13	41.94	41.94	4.26	0.73
(b)	Searching the literature.	-	6.45	19.35	41.94	32.26	4.00	0.89
(c)	Preparing report.	-	3.23	12.90	45.16	38.71	4.19	0.79
Q35	After adopting PBL active learning approach, I depend mostly on the following source:							
(a)	Books.	-	6.45	32.26	51.61	9.68	3.65	0.75
(b)	Internet.	-	-	16.13	48.39	35.48	4.19	0.70
(c)	Lectures.	-	6.45	6.45	41.94	45.16	4.26	0.86
(d)	Group discussions.	3.23	3.23	16.13	35.48	41.94	4.10	1.01

3.2. Pearson Chi-square test

Pearson's Chi-square test was also performed on the collected data to determine and evaluate its statistically significant difference between the expected and observed outcomes for $p<0.05$. It was noted that for almost all the items under 35 questions, the results were found in line with expectations, i.e., calculated $p>0.05$. However, results for Q15 (PBL workload), Q16 (pressure under PBL), Q17 (too many topics), Q18 (opportunities for participation), and Q19 (choice in PBL) were found not in line with expected outcomes, i.e., calculated $p<0.05$. For $p<0.05$, these outcomes highlighted the areas under which students were experiencing difficulties and needed attention. Table 8 summarizes only results acquired with calculated $p<0.05$ for the Chi-square test values ($\chi 2$).

Table 8. Results summary for items acquired p<0.05

Q	Items	χ2	p-value
Q15	The workload in PBL for courses becomes too heavy.	10.96	0.00093
Q16	There was a lot of pressure on me to do well in this course, due to PBL implementation.	11.15	0.00084
Q17	It seemed to me that for, PBL implementation, educators tried to cover too many topics.	8.83	0.00295
Q18	The educator provided opportunities for all students to participate in activities and discussions using PBL scaffolding.	4.88	0.02709
Q19	There was very little choice in the PBL course, in the ways for students to be assessed.	14.06	0.00017

3.3. Student's t-test

Besides adopting various analyses by performing Cronbach's alpha for the reliability of collected data, the significance of data by using the Pearson chi-square test and descriptive statistics for collected data, a small analysis was also performed for investigating the varying response of students towards PBL, based on GPA, by using Student's t-test. Student's t-test is a type of "statistical test that is used to compare the means of two groups" [52]. Two groups were formed for the students by taking the mean of last semester's GPA as a reference, i.e., 3.40±0.35. In the first group, the number of students was 16 (n=16) with the last semester GPA greater than 3.40, and in the second group, the number of students was 15 (n=15) with the last semester GPA less than 3.40. An unpaired, two-tailed t-test ($p<0.05$) was performed between these two groups to determine the significant difference of response between them towards the PBL approach.

However, it was found that for most of the items, no significant difference was found between the groups' responses, which showed that almost the maximum number of students were finding the PBL approach effective irrespective of their semester grades. However, significant differences were found for Q31 (PBL learning approach is better than the traditional learning approach) and Q35(c) (dependence on lectures). These aforementioned results showed that students with last semester's GPA less than the mean (3.40) were a little bit struggling in the PBL environment, and they are mostly dependent on class lectures. Therefore, the instructor needs to counsel such students to build up their confidence in the PBL system and design special exercises to end their dependencies only on class lectures. Table 9 shows the results summary of the t-test for the varied items for $p<0.05$. It was noted that students of the second group were facing more problems in the above-mentioned items than students of the first group. This outcome could give the instructor good insight for areas that troubles the students with low GPA for the improvement in future PBL course.

Table 9. Summary for items with varying behavior of groups for unpaired, two-tailed t-test ($p<0.05$)

Q	Items	t-test value	p-value
Q31	In my opinion, the PBL learning approach is better than the traditional learning approach.	2.05	0.037
Q35 (c)	After adopting PBL active learning approach, I depend mostly on the following source: Lectures.	2.06	0.027

4. DISCUSSION

The PBL-CEQ consists of seven scales or groups (GTS, CGS, AWS, AAS, GSS, OSS, and WRS) with an overall of 35 questions. Each group covers an area to assess the comprehensive student preview under the PBL experience. In addition, various analyses and tests were performed on the collected data, such as descriptive statistics (frequency percentage, mean, and SD), Cronbach's alpha, Student's t-test, and Pearson Chi-square test.

The first part evaluated the descriptive statistics for each item, along with Cronbach's alpha values for each group. The data were evaluated for percentage responses, means, and SD to get students' feedback about their PBL experience. The results for GTS revealed that students were well contented with the instructor and teaching methodologies under the PBL environment, and the instructor's clarity about the curriculum was excellent. Overall this group got a good score from the students and proved the effectiveness of PBL based curriculum, and the results are much alike with the previous study [23]. The second group CGS got a decent score; however, it was identified that pre-semester briefing to students regarding PBL implementation, benefits, and expected outcomes should be properly designed in the future. Moreover, a need was felt to demonstrate the KNL (what we know, what we need, what to learn) table and its outcomes. Also, new tools should be introduced to students for a better understanding of problem-solving tasks. Likewise, PBL provides more clarity and understanding to students in academic matters, improving their performance [53]. Merisier *et al*. [52] emphasized using tools to enhance critical thinking.

Ballesteros *et al*. [54] highlighted that the academic load under PBL is significantly high. In the same way, the results from the AWS group concluded that the students felt overloaded under PBL tasks and assignments. It was also highlighted that the instructor covers too many topics for each objective which creates a burden. Therefore, instructors should review the course outline and lesson plans to normalize this pressure on students. The questionnaire received varying feedback for the AAS group, with Cronbach's alpha value of $\alpha=0.632$, which was weak but considered moderate and acceptable. This low value engenders the need that the instructor should discuss these parameters with the students for their clarity, and results showed that students seemed uncertain about this criterion. This situation also required improvements in the assessment process, considering suggestions given by the students. The results outcomes of the GSS group were much similar to the study performed by Al-Jehani *et al*. [22], i.e., students felt confident and acknowledged the development of skills such as analytical skills, problem-solving skills, and communication skills. However, the survey also showed that students lack confidence in tackling unfamiliar problems. Therefore, to overcome this deficiency, the instructor should focus on this area to build up students' confidence towards problem-solving skills by designing class exercises with practical problems.

The results of the OSS group gave a clear impression that students have accepted the PBL system and a high satisfaction level. However, still 'my group dynamics' was low rated by the students, and this area needs special attention from the instructor. It was also concluded by this survey, from the results of the WRS group, that students have developed teamwork capabilities and habits of taking self-initiates towards learning opportunities. However, students pinpointed low dependency on books; therefore, the instructor should design class exercises to create the interest of students towards books rather than only to lectures and the internet. Moreover, the environment of group discussion sessions should be made more beneficial for the students and less time-wasting. In the preview of OSS and WRS outcomes, previous researchers [20], [55] also reported the satisfaction of students on the PBL process along with the development of professional characteristics such as teamwork.

It can be determined from this analysis part that students are readily adopting the PBL system, and they found it beneficial. However, some areas still need improvements, and PBL is a dynamic process that keeps improving from time to time. This study also gives insight that the implementation of the PBL system is not changeling for students only but also for the instructors, to keep the course explicable for students under the PBL guidelines. For this study, Q8 (curriculum understanding), Q7 (instructors' hard work), and Q29 (satisfied with PBL active learning approach) received the highest score of 4.61 ± 0.56, 4.55 ± 0.57, and

4.52±0.63. In contrast, Q15 (PBL workload), Q16 (PBL pressure), and Q17 (too many topics) received the lowest ranks with a mean of 3.38±1.02, 3.25±1.03, and 3.16±1.21.

The second part of this study evaluated the collected data for their significance difference from expected outcomes by performing the Pearson Chi-square test for $p<0.05$. Overall, the results were satisfactory, and outcomes were found to be as per expectations. However, a few of the areas needed special considerations. It was found that students were feeling under pressure in the PBL environment due to excessive workload. Also, students highlighted the sheer volume of topics that were being covered under the PBL course outline. Students were also unhappy with the fewer opportunities for assessment and opportunities for class participation.

In the last part, an analysis was performed for varying responses of students towards PBL by creating two groups based on last semester's GPA and performing the Student’s t-test. It was found that the students were finding the PBL approach effective irrespective of their semester grades, and both groups were showing the same response. However, the second group of students (GPA less than 3.4) were a little bit struggling in the PBL environment, and they were mostly dependent on class lectures rather than other resources. Table 10 shows the overall summary of all the analyses for their highlighted items with unsatisfactory outcomes concerning PBL-CEQ, along with suggestions for mitigation.

Table 10 highlights the overall areas in which students felt difficulties under the PBL environment. An interesting finding can be seen, i.e., a few of the items highlighted by the first analysis and the second analysis are common. Whereas, the third analysis was performed by considering special conditions; however, all these analyses were able to highlight the areas, which require attention from the instructor for better implementation of the PBL system. Based on highlighted deficient areas, mitigating actions have also been suggested. It can be seen that most of the issues could be resolved by a pre-semester in-detail briefing to students on course PBL implementation plan covering scope, curriculum, goals, assessment criteria, and related areas. Also, effective PBL implementation requires close supervision by the instructor for keeping students motivated and engaged in targeted goals as a team.

Table 10. Items with unsatisfactory outcomes from the analyses

First analysis Cronbach’s alpha and descriptive statistics	Second analysis Pearson Chi-square test	Third analysis Student's t-test	Item statement	Remarks/Mitigations
Q15	Q15		The workload in PBL for courses becomes too heavy.	Review workload.
Q16	Q16		There was a lot of pressure on me to do well in this course, due to PBL implementation.	Review workload and student counseling.
Q17	Q17		It seemed to me that for, PBL implementation, educators tried to cover too many topics.	Pre-semester presentation on curriculum and scope.
	Q18		The educator provided opportunities for all students to participate in activities and discussions using PBL scaffolding.	Review lecture delivering methodology/ Assigning group activities.
	Q19		There was very little choice in the PBL course, in the ways for students to be assessed	Pre-semester briefing on the assessment criteria.
		Q31	PBL active learning system engages students in: Problem Solving	Student counseling/ Assigning group activities.
Q35(a)			After adopting PBL active learning approach, I depend mostly on the following source: Books.	To design class exercises creating interest in books
		Q35(c)	After adopting PBL active learning approach, I depend mostly on the following source: Lectures	Open-ended exercises

5. CONCLUSION

This study provides a base guideline for instructors to evaluate their teaching methodology under the PBL environment and highlight discrepancies for improving the education model. The study was designed to investigate the students’ responses after their first experience in the PBL environment and highlight the obstacles to further improvement in the system. The results support the fact that effective implementation of PBL is dependent on the instructor, such as teaching methodology, assessment criteria, workload, and designed scaffolding framework for students. The integration of PBL and cooperative learning elements provides the necessary scaffolding towards a team working attitude and skills. It can be determined that overall, students have adopted the PBL environment, and they feel the PBL methodology is more beneficial than the old conventional teaching methodology. However, the PBL system is a dynamic process, and it keeps on improving with time. Taking students’ feedback is an effective tool for enhancing the PBL system and making education more practical.

In the current study, the survey feedback was limited to 31 students, which may be increased for future studies. Moreover, for future research, other teaching methodologies, such as flipped classroom, project-based cooperative learning, inquiry-based learning, reciprocal teaching, blended learning, or adopting inductive learning models, can be evaluated and compared for their efficacy, which will be beneficial for the educational sector.

In light of this study, few recommendations have been devised for the effective implementation of the PBL system. The instructor should give the pre-semester briefing (before course execution) by covering topics related to students' goals and assessment criteria. The instructor should monitor the workload of students for keeping them psychologically healthy. Appropriate assignments and activities should be designed following the CPBL theme to enhance team working and leadership skills under the instructor's supervision. Class exercises should be designed with an open-ended theme, encouraging students to effectively utilize all available resources (books, lectures, internet, and group discussions). Finally, students' feedback must be collected after each semester for modification and improvements in the PBL system.

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