Student Experiences with Collaborative Problem-Based Learning (CPBL) in a Second-Year Undergraduate Engineering Course

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***Abstract*—This Innovative Practice Work in Progress paper describes our recent efforts of implementing collaborative problem-based learning (CPBL) in a second-year undergraduate engineering course called Engineering Dynamics. The research method and data collection are described. Both positive and negative comments on CPBL were collected from a total of 59 student participants who took engineering dynamics in a recent semester. The results show that nearly 70% of the students had "positive" or "highly positive" overall experiences with CPBL. The analysis also shows that students liked CPBL for five reasons, and disliked CPBL for four reasons.**

Keywords— Collaborative problem-based learning (CPBL), engineering dynamics, questionnaire survey, student experiences

I. Introduction

Problem-based learning (PBL) is an instructional strategy where students learn about a subject in the context of multifaceted and realistic problems [1-3]. Since its concept was proposed in medical school programs at McMaster University (Hamilton, Canada) [4], PBL has been widely applied to a variety of academic disciplines, such as science [5], technology [6], engineering [7, 8], and mathematics [9].

Research evidence has shown that PBL improves student motivation and learning [4-9]. For example, Yadav, Subedi, Lundeberg, and Bunting [8] implemented PBL in an electrical engineering course. They reported that compared to traditional lectures, PBL doubled student learning gains. Student participants also reported that PBL allowed them to apply relevant concepts and develop problem-solving skills. Fatokun and Fatokun [9] employed PBL to teach mathematics and chemistry in both high school and college classrooms. Based on three case studies described in their study, Fatokun and Fatokun [9] reported that PBL helped students develop better conceptual understanding and problem-solving skills as well.

In educational practices, PBL is typically conducted in combination with collaborative learning, where students work together in small groups and use the resources and skills of one another to achieve a common goal [10, 11]. Therefore, the terms "collaborative problem-based learning" [12, 13] and "problem-based collaborative learning" [14, 15] are also employed in relevant literature. In the present study, the term "collaborative problem-based learning (CPBL)" is adopted to emphasize collaborative activities involved in PBL.

In the remaining sections of this Work in Progress paper (limited to four pages as per conference guidelines), the innovation of the present study is described. The implementation of CPBL in a second-year undergraduate Engineering Dynamics course is illustrated with an example. Methods of research and data collection are described. The comments collected from 59 student participants who took engineering dynamics in a recent semester were analyzed to answer the following research question: What were student experiences, both positive and negative, in problem-based collaborative learning in engineering dynamics? Limitation and future work are discussed with concluding remarks at the end of the paper.

Note that the scope of the present Work in Progress study is limited to analyzing student experiences with collaborative problem-based learning based on student comments. This scope is also reflected in the title of the paper. An experimental study that involves comparison between an experimental and a control group is beyond the scope of this paper.

II. Innovations Of The Present Study

The present study is innovative in two aspects: 1) the application of CPBL in a particular undergraduate engineering course, and 2) the research on both positive and negative comments (from student participants) on CPBL.

First, although CPBL (or PBL) has been employed for students to learn a variety of subject matters in various academic disciplines, literature review shows that few studies report applications of this strategy in Engineering Dynamics courses. Engineering Dynamics is a foundational, high-enrollment, and high-impact course that nearly all students in mechanical, civil, aerospace, biological, and biomedical engineering majors are required to take in their second year of undergraduate study [16, 17]. Nevertheless, this course is widely regarded as one of the most difficult courses in

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engineering, as it involves numerous concepts (such as motion, velocity, acceleration, force, work, energy, impulse, momentum, and vibration) and problem-solving procedures such as applying Newton's second law and the principle of work and energy to real-world problems [18, 19]. In the recent standard Fundamentals of Engineering examination in the U.S., the national average score on the Engineering Dynamics exam was only 53% [20].

In a traditional lecture, the instructor teaches students on a blackboard or via PowerPoint, and students solve homework problems after class. These traditional practices are not CPBL. Authentic CPBL always involves group activities, discussions, and reflections [1-4]. In the present study, CPBL was implemented as in-class group activities. See Section III for details.

Second, the vast majority of literature on CPBL report only positive comments from student participants. When discussing student reactions to CPBL, student quotes were cited: "it's better in a group…with everyone's input…you can bounce ideas off each other…and others' ideas might be better. In industry you work in teams" and "better equipped for the future. In the future we'll know (when confronted with real problems) we've done something similar. It gives us group working skills" [9]. However, negative comments are especially helpful for the continuous improvement of CPBL. The present study reports and analyzes both positive and negative comments from student participants on CPBL. See Section V for details.

III. COLLABORATIVE PROBLEM-BASED LEARNING (CPBL)

CPBL was implemented in a 16-week Engineering Dynamics class that the author of this paper taught. Through the course of the semester, the class met three times per week, 50 minutes per session. During each 50-minute class period, students learned the course material with lecture first, followed by in-class CPBL activities. The lectures covered the following eight major topics:

- Kinematics of a particle
- Kinetics of a particle: force and acceleration
- Kinetics of a particle: work and energy
- Kinetics of a particle: impulse and momentum
- Planar kinematics of a rigid body
- Kinetics of a rigid body: force and acceleration
- Kinetics of a rigid body: work and energy
- Kinetics of a rigid body: impulse and momentum

The following paragraph describes how CPBL activities were incorporated into a typical 50-minute class period:

First, the instructor taught a relevant theory (such as one of the topics listed above), and demonstrated how to apply the theory to solve the first problem.

Second, the instructor solved part of the second problem and asked students to solve the remaining part. Students worked in small groups to discuss problem solving.

Next, the instructor provided the third problem for each student group to solve. Student groups were initially formed based on individual students' preferences. Throughout the semester when solving different problems, students were encouraged to change group members, so each student had experiences working with as many other students as possible.

For example, the instructor provided the problem shown in Fig. 1 for each student group to solve. The problem involves a projectile motion in particle kinematics. Each student group discussed the following key issues:

- How to establish the coordination system?
- Which equations should be used?
- Should the equations be applied in X- or Y- direction, or both?
- Is the number of unknowns equal to the number of equations?

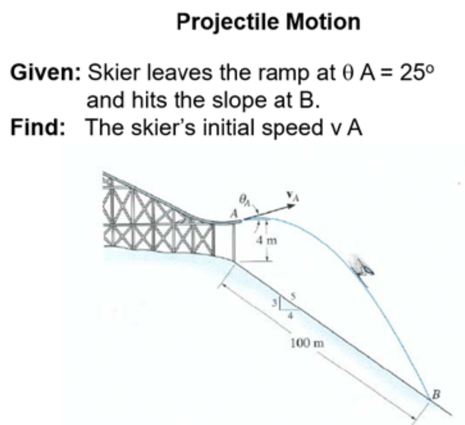

Fig. 1. An example problem for CPBL.

The instructor then walked around the classroom to answer any questions that students had. If multiple students asked the same question or made the same mistake during problem solving, the instructor would alert the entire class and address the problem as a group. In this Work in Progress study, we have not encountered a case in which one student answered all of the questions relatively quickly and everyone else in the group following along with no real participation. Based on our observations, there were a few occasional cases where students worked individually and then shared answers to check if they had a common answer. However, these occasional experiences of students were not described in the student responses to our questionnaire survey.

To conclude, a few student teams were invited to share with the entire class how they solved the third problem and what they had learned from this group problem-solving experience.

The design of CPBL activities plays a significant role in affecting student learning outcomes. Given that students in a large class have varying levels of intellectual skills and abilities, the technical problems selected for CPBL should not be too easy or too difficult for students to solve between 10 and 20 minutes within a typical 50-minute class period. In this Work in Progress study, we have observed that some student teams finished quicker than other teams. Depending on the level of difficulty of technical problems, some teams valued CPBL greatly, whilst other teams thought it was marginally helpful. Overall, students were more engaged in the process of learning as the semester went on. The major challenge for CPBL is that all activities must be completed within the typical 50-minute class period. Time constraints are a fundamental difference between in-class and after-class CPBL. Pacing, including learning the course material and applying what has been learned to solve new problems, is an issue especially when students find that new problems are difficult to solve.

IV. Research Method and Data Collection

A. Student Participants

A total of 59 undergraduates who took Engineering Dynamics in a recent semester participated in this study. The 59 students included 52 males and 7 females. Table I shows student demographics in terms of major. The majority of the students were mechanical and aerospace engineering (57.6%) and civil and environmental engineering (28.8%) majors.

TABLE I. STUDENT DEMOGRAPHICS

Total	**Mechanical & Aerospace Engng.**	**Civil & Environ-mental Engng.**	**Other**
59 (100%)	34 (57.6%)	17 (28.8%)	8 (13.6%)

B. Research Method and Data Collection

At the end of the semester, a questionnaire survey was administrated to ask students about their experiences with CPBL. The questionnaire survey included Likert-type and open-response items. In an Likert-type item, students were asked to rate their overall experiences with CPBL as highly positive, positive, neutral, negative, or highly negative. In an open-response item, students were asked to provide comments (either positive or negative) on why they liked or disliked CPBL.

Content analysis [21] was used to analyze and reduce the qualitative data collected through the open-response item to the themes. The analysis involved coding (i.e., categorizing) the collected data, member checks, and then counting the frequency of a particular code. The dominant codes emerged not only from content analysis of student responses to the open-response item, but was also initially guided by the research findings reported in relevant literature such as [7] and [8], especially regarding how students collaborate in a team learning environment. The coding process was iterative and involved both open coding and axial coding [22]. In open coding, the data was studied several times to create initial tentative codes that covered common themes. In axial coding, core themes were disaggregated [22].

V. Results and Analysis

A. Student Overall Experiences With CPBL

In the Likert-type item, 7 students (i.e., 11.9% of the 59 students surveyed) rated their overall experiences with CPBL "highly positive," 34 students (57.6%) "positive," 14 students (23.7%) "neutral," 3 students (5.1%) "negative," and 1 student (1.7%) "highly negative." Student responses are also shown in Fig. 2. Nearly 70% of the students had positive or highly positive experiences with CPBL.

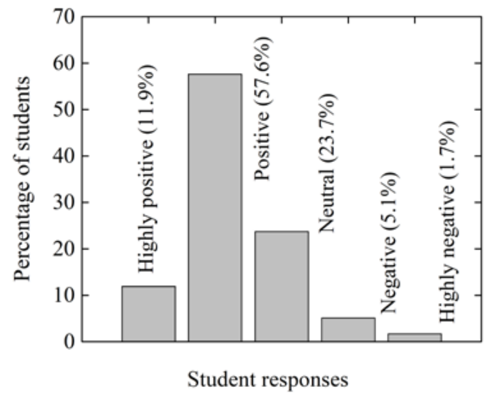

Fig. 2. Student overall experiences with CPBL.

B. Positive Comments on CPBL

Students provided both positive and negative comments on CPBL. Note that even if a student rated "positive" or "highly positive" for his/her overall experiences with CPBL, the student could still provide both positive and negative comments on CPBL.

The results of content analysis show that students liked CPBL because it provided students with opportunities to 1) teach and be taught by other students through comparing problem-solving steps and answers, helping others, and receiving help from others; 2) discuss problems with other students through asking and answering questions; 3) learn from the ideas and perspectives of other students; 4) personally engage in problem solving through practicing problems; and 5) take ownership in problem solving through not solely relying on other students. Table II summarizes the frequency of codes (categories). Note that the total number of frequency is not equal to the total number of students, because the same student could provide multiple positive and multiple negative comments.

TABLE II. POSTIVE COMMENTS ON CPBL

Category	**Frequency**
1. Teach and be taught by other students	16
2. Discuss problems with other students	12
3. Learn from the ideas and perspectives of other students	9
4. Personally engage in problem solving	9
5. Take ownership in problem solving	4

The following paragraphs provide representative comments from student participants:

1. Teach and be taught by other students: "I have learned because others can point out errors in my problem solving."

2. Discuss problems with other students: "I learn well because I can discuss with others and help them as well as myself."

3. Learn from the ideas and perspectives of other students: "It allows me to hear the ideas for problem solving from my friends and see what I am doing wrong."

4. Personally engage in problem solving: "It has helped me to actually practice the problems and get help when I need it."

5. Take ownership in problem solving: "I have learned because having those activities forces me to think about the concept we just learned."

The above results show that CPBL enhanced student learning by creating a positive environment where students learned from each other. The above results also imply that CPBL can be employed as an effective instructional strategy to engage students in the process of active learning, even in a large classroom setting.

C. *Negatvie Comments on CPBL*

The results of content analysis show that students disliked CPBL because students 1) are stuck on a problem due to not understanding it, 2) lack support from other students (in terms of efforts and expertise), 3) have not enough time to solve problems, and 4) prefer to study alone. Table III summarizes the frequency of codes (categories).

TABLE III. NEGATIVE COMMENTS ON CPBL

Category	Frequency
1. Be stuck on a problem	7
2. Lack support from other students	5
3. Have not enough time to solve problems	3
4. Prefer to study alone	3

Representative comments from student participants are provided in the following paragraphs:

1. Be stuck on a problem: "Sometimes I do not learn from group activities because if the majority of the group understands something that I don't, we typically run through it very fast and move on. Sometimes it is easy to get left behind."

2. Lack support from other students: "They work great if you have people in your group that are willing to participate. They are not so hot if they just sit around and wait for you to find the answer."

3. Have not enough time to solve problems: "I believe that class period [50 minutes] is very short for this kind of classes. Dynamics as well as other engineering classes should be longer."

4. Prefer to study alone: "It's just a personal preference. I know how to read and critically analyze the text, the lectures just add upon that. I personally like to challenge myself more than I like to be challenged in a group setting."

The above results show that despite its effectiveness in enhancing student learning in team environment, CPBL has its own limitations due to diverse backgrounds, experiences, skills, and learning styles of students. It should also be pointed out students did not provide contexts, e.g., a particular technical problem students encountered in CPBL activities, in their responses to the questionnaire survey. Follow-up interviews will be helpful to reveal in-depth details of students' negative comments and thus improve CPBL to maximum student learning outcomes.

D. *Comparison with Final Exam Scores*

Student responses to the Likert-type item were compared with their final exam scores. The final exam was comprehensive and included a variety of problems for students to solve. Those problems covered major learning topics students had learned throughout the semester.

Those who rated their overall experiences with CPBL "highly positive" or "positive" scored on average 2.7% higher than the 59-student average in the final exam. Those rated "neutral" scored on average 8.1% lower than the 59-student average. Those rated "negative" or "highly negative" scored on average 14% lower than the 59-student average. Although no causal relationship can be determined between CPBL and final exam scores, a positive correlation clearly exists.

VI. LIMITATION AND FUTURE WORK

The primary limitation of this Work in Progress study is that no control group was involved. The sample size (59) of the present study is marginal. In future expanded research, a control group will be used to study the extent to which CPBL can improve student learning. Moreover, particular attentions will be paid when forming student teams, so students with varying levels of skills and abilities can all benefit from CPBL.

VII. CONCLUDING REMARKS

The results of the present study showed that nearly 70% of the students had "positive" or "highly positive" overall experiences with collaborative problem-based learning. The content analysis on qualitative data showed that students liked CPBL for five reasons, and disliked CPBL for four reasons.

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