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Cooperative Problem-based Learning (CPBL): Framework for Integrating Cooperative Learning and Problem-based Learning

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Abstract

To face the challenges of the 21st Century, problem-based learning (PBL) is touted as one of the effective teaching and learning methodology. In engineering education, where the enrolment and class size is high, PBL is more practical although the implementation is difficult to monitor. Cooperative learning (CL) is identified to have the added elements to develop groups into functional learning teams. Combining both CL and PBL results in a cooperative problem-based learning (CPBL) framework to guide students through the PBL cycle according to CL principles and to develop the whole class into a learning community. A sample case study included affirms the need for supporting students to learn in their teams, and the final outcome of positive development and experiences in team working while undergoing CPBL.

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Keywords: problem-based learning; cooperative learning; engineering education; team working, cooperative problem-based learning

1. Introduction

The challenges facing the world today lead to wide-spread interest in producing high quality engineering graduates. Some of the challenges are: rapid technological development, innovation and change; exponential advancement in information and computer technologies; increase global competition; changing demographics; global sustainability; energy conservation and renewal [1, 2]. Today, engineering graduates need to be significantly better prepared to deal with information retrieval, integrating knowledge, and problem solving.

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They must be able to take a holistic approach to problems involving complex and ambiguous systems, and to employ creative problem solving skills. In an increasing global work place, engineering graduates are expected to work on multinational teams, to have global perspective, and to be culturally and linguistically literate [1, 3].

Among the techniques that attracted world-wide attention is Problem-based Learning (PBL), because of the multitude of benefits that it was claimed to bring about to students [4]. PBL in its current form originated as a response to low enrollments and general dissatisfaction with medical education [5]. Since its origin, PBL has been used in a variety of disciplines and educational levels (see [6] for a history; see [7] for an introduction). As Barrows [5] noted, PBL has taken on a myriad of definitions, pushed in part by institutions wanting to refine their particular approach.

It is commonly agreed that PBL starts with an unstructured problem that has more than one answer. Students have to collaboratively learn together through the PBL cycle. For PBL implementations in medical schools up to ten students work together facilitated by a tutor during PBL tutorial sessions. Nevertheless, small group tutorials are not normally feasible and practical when student enrolment is high.

An alternative is to have small groups (3-5 students in a group) in medium to large classes (25 to more than 100 students). In this case, instead of having a dedicated tutor facilitating a group at all times during the tutorial, one or more floating facilitator may be utilized during class time. This type of application, which is more feasible and common in non-medical programs, requires higher commitment and accountability on the part of students to go through the PBL cycle together in their groups.

Nevertheless, even though students may be assigned to groups in PBL, they do not automatically develop team working skills [8, 9] In fact, without proper support, the problems may arise in the small groups resulting in an unpleasant learning experience [10]. Since having functional teams in which students can harmoniously cooperate is crucial for successful undergo PBL implementation, a framework that can guide students to go through the whole PBL cycle step by step as a team according to the principles of cooperative learning would be helpful for small groups in medium to large class settings. Hence, integration between PBL and cooperative learning is proposed to purposefully create conducive environments for developing team working skills in students while they undergo the PBL cycle.

In this paper, the cooperative problem based learning model (CPBL) model is explained. The CPBL model is a combination of PBL and cooperative learning to emphasize learning and solving problems in small student teams (consisting of 3-5 students) in a medium sized class, of up to 60 students for one floating academic staff or facilitator. The model requires the problem to be realistic, if not real, with a scenario that serves to contextualize and immerse students in the problem. e-learning may also be integrated into the learning environment to include activities to reach the desired educational objectives, such as creating realistic problems to encourage immersion, facilitating students and providing scaffolding, as well as providing additional platform for discussion and peer teaching. The framework, designed based on constructive alignment [11, 12] serves as scaffolding for guiding students in going through CPBL.

2. The CPBL Model

PBL is one the learning approaches with underpinnings on cognitive and social constructivist learning theory [7]. The original PBL framework implemented in UTM, modified from Tan [13], contains the typical PBL cycle, as described in many medical school implementations. However, rather than having small tutorial groups of up to 10 students, the whole cycle, shown in Figure 1, is implemented with small groups in a class of up to 60

students, which is the typical engineering class size in UTM. A detailed explanation of the UTM PBL cycle can be seen in [14].

Since supporting and monitoring students’ learning by a floating facilitator can be challenging in a typical class of up to 60 students, the cooperative learning aspects is integrated in the model to encourage cooperation and peer-based learning as well as monitoring and support, thus becoming Cooperative Problem Based Learning (CPBL). Social interaction among learners can create collaboration, leading to a significant positive impact on learning [15]. Through collaboration, learners will have opportunities to discuss, reflect, defend, and critique ideas or knowledge. According to Harasim [16], through a discussion and interaction with peers and experts, learners will be engaged in constructing knowledge. Since good team working cannot be instantly achieved but instead must be developed, the five principles of cooperative learning as defined by Johnson, Johnson and Smith [17] must be emphasized and promoted throughout the CPBL cycle, in accordance with the requirement of constructive alignment. The five cooperative learning principles are:

- Positive interdependence
- Individual accountability
- Face to face interaction
- Appropriate interpersonal skills
- Regular group function assessment

Constructive alignment emphasizes on employing learning and assessment activities that are aligned to the learning outcomes. In addition, the learning outcomes are not topic-based, but encompass the use or the function of knowledge or skills learned. In other words, what can learners do with the knowledge, and why it is important. It is important to clearly relay these outcomes, as well as the learning process and assessment to students to engage them. Assessment is criterion referenced, rather than norm referenced, to encourage a collaborative rather than a competitive environment. A criterion referenced assessment, which can be rubrics designed based on the SOLO taxonomy, will also provide information on expectations and formative feedback [12].

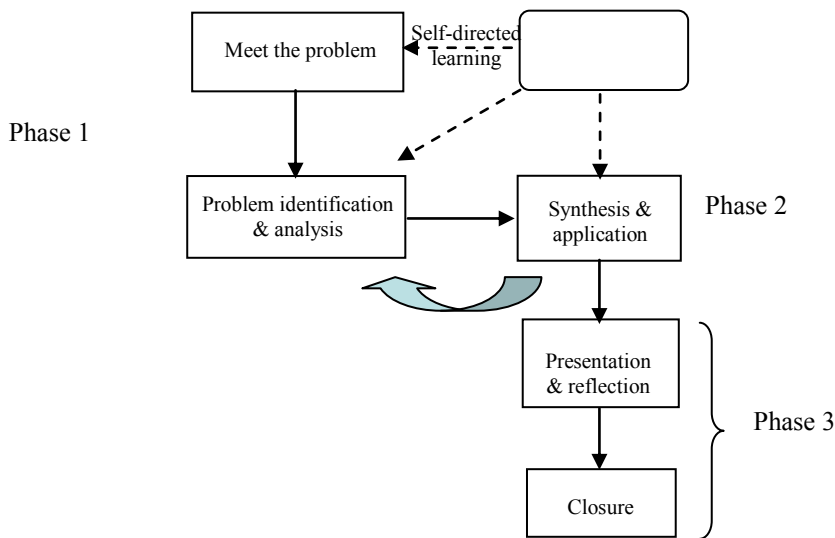


Fig. 1. The UTM PBL framework

From the framework shown in Figure 1, the model evolves to the framework shown in Figure 2 to emphasize the importance of ensuring cooperative work among students in the small groups and the whole class. Referring to Figure 2, there are 3 phases in the CPBL cycle. Phase 1 consists of the problem identification and analysis stage. Phase 2 is the learning, application and solution formulation stage. Phase 3 is the generalization, internalization and closure stage. This modification to the CPBL framework shown in Figure 2 is necessary to ensure the learning activities and assessment tasks throughout the CPBL cycle is aligned and support all the learning outcomes.

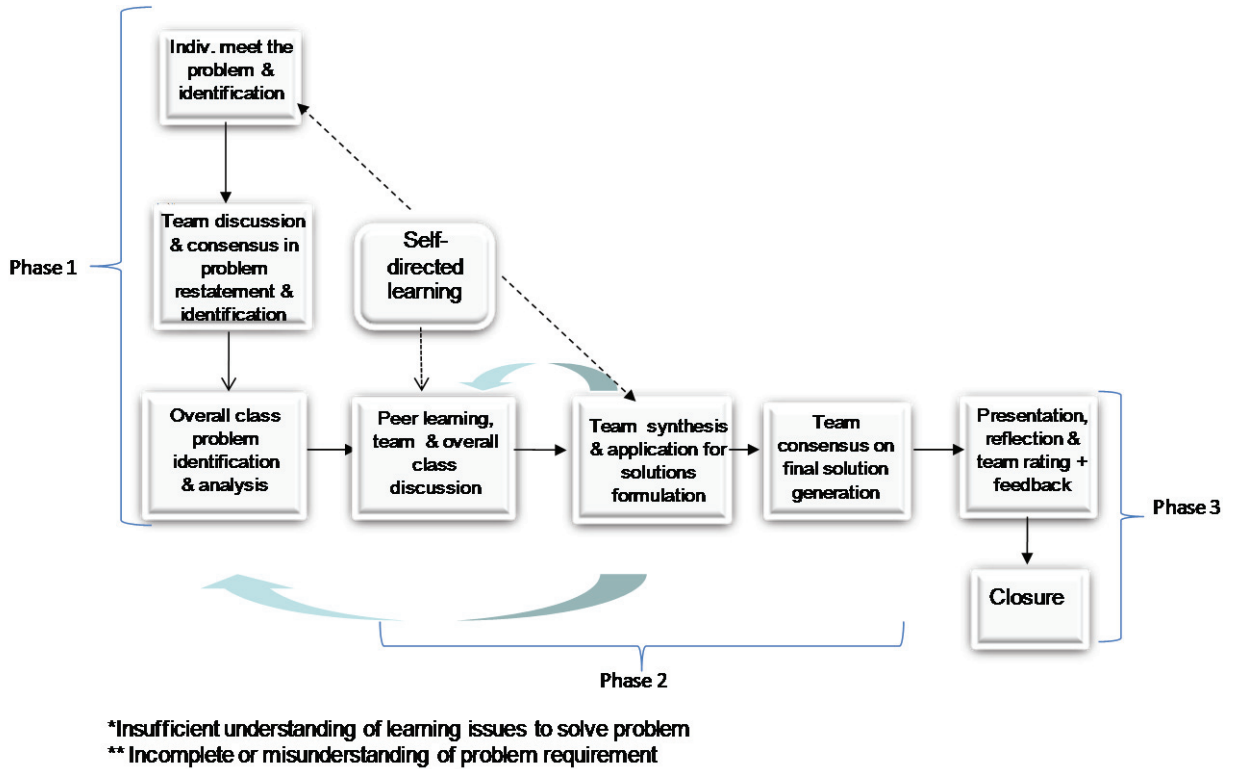


Fig. 2. The cooperative problem-based learning (CPBL) framework

The learning activities throughout the CPBL cycle are aligned to ensure fulfilment of the five principles of cooperative learning, as illustrated in Table 1, because ensuring cooperation and functional teams for students to learn together is crucial. As seen in Table 1, an important part of the scaffolding is the formative assessment given in each phase, which may be in oral or written form, during the class or virtually outside of class time. Since it is not possible to monitor individual learning and all the discussions in the small teams, the assessment provided is aligned the learners’ activities to provide feedback not only to facilitators, but also to students, on their progress towards achieving the desired outcomes. The assessment results can be used to further decide on the kind of scaffolding needed by learners.

Table 1. Teaching and learning activities and assessment tasks aligned to promote CL principles in CPBL

CL Principles		Positive interdependence	Individual accountability	Face to face interaction	Interpersonal skills	Group function assessment
Phase 1 Problem restatement & Identification	Individual	Prepare to discuss with team	Submit PR & PI before discussions			
	Team discussion & consensus	Consensus to bring to whole class; may submit team PR & PI; assign learning issues for each team member	Start discussion based on individual answer; agree on learning issues to read and learn by each member	In- class discussion; assign roles for each team member during duration of problem	Reach consensus within given time	Overall observation of participation and body language
	Overall class discussion	Each team provide opinion	Anyone may be randomly called	In- class discussion	Proper etiquette in discussion, Q&A to reach overall consensus	Observation of participation
Phase 2 Learning, application & solution	Peer learning	Notes contain summary of concepts understood and questions on hazy points to help learning in team; assume role play	Individually prepare peer learning/teaching notes for team; submit individual peer learning notes; role play	Learn in team – explain concepts understood and ask those still hazy; overall class peer learning/teaching/ discussion led by designated team	Reach consensus on understanding of concepts or learning issues and questions to ask during in-class session	Observation of participation during overall class peer learning/teaching/discussion
	Synthesis & application	Quiz or tutorial questions on important concepts; e-learning forum	Quiz or tutorial questions on important concepts	Out-of class sessions	Out of class sessions	Progress check
	Consensus on final solution	Submit 1 report for each team	Optional quiz, test/exam	Out of class sessions	Out of class sessions	
Phase 3 Generalization, closure & internalization	Presentation, reflection, team rating & feedback	Comparison of solution between different teams in class	Individual feedback from team members on performance	Presentation of final solution and discussion led by designated team	Sincere comments to help team improve	Peer rating and feedback on team members and team process
	Closure	Generalize concepts to other types of problems	Internalize lessons learned from content and process through written reflection	In-class closure session	Motivation on team working & conflict management	In-class session on improvement to be made

3. Case Study of Team Working in CPBL

To analyze the process and outcomes of team working in CPBL, the implementation in a third year chemical engineering undergraduate course in UTM, Process Control & Dynamics, was studied. The course typically has 30 to 40 students in a class. CPBL had been implemented in course since 2003, in which there are 4 problems

given throughout the semester, with different scenarios and content outcomes. The first problem is the shortest and the simplest, while the second and third problems are challenging, both in terms of technical content and the required thinking skills. The last problem is a real industrial problem that requires students to act as consultants to design control systems. A detailed description on the design of the whole semester CPBL implementation can be seen in Mohammad-Zamry, et al. [18].

The process of developing a cooperative team among students in the class is qualitatively analyzed through one of the early peer and team feedback, as well as the final meta-reflection, which is a reflection at the end of the semester based on the individual reflection made at the end of every problem. Although the analysis on team working through the implementation of CPBL is focused on students in the 2009/10-2 semester, the response seen is typical since early in CPBL implementation.

4. Team Working Analysis

In analyzing the meta-reflections of students in the course, the achievement in the outcome in cooperation and team working feature prominently in all of them. Through the peer rating and feedback that students give to their team mates at the end of every problem, the transition from traditional group to cooperative team can be seen in the maturity of the comments. Overall observation of participation during in-class activities like problem identification, peer learning and solution discussion also increase dramatically in the third and fourth problems.

As shown in part of a student's meta-reflection at the end of the semester:

“As I read back the reflections, I think the most memorable part of this semester would be the team working part. We spent a lot of time with each other, trying to solve the problems and finish the reports. Though sometimes there were some differences in views and opinions, we never had big fight. We always tried to analyze the solutions and reach a consensus to choose the best one. At first, we were just like a traditional group, but doing a little more than a traditional group. But as time goes by, we improved and performed better, and were more like a cooperative team. We shared with each other and worked with each other. From there, we learnt from each other. Though we are all of different backgrounds, we still worked together very well. I hope this can be a preparation of what I am going to face when I am working. There will always be team-work, especially for engineers. I hope that the team-working skill that I have learnt now can be a useful tool in the future. No doubt, working in a team can be more difficult when all of us have different backgrounds and experiences. But if everyone is willing to tolerate with each other, the outcome will be much better. Besides, I have also assigned to be the moderator for one of the case studies. I seldom become a leader of a group or team. Therefore it is not easy for me to be the moderator. Luckily enough, I have other helpful teammates to help me to lead the team. From here, I learnt that I need to be more independent and be bold to make decisions, especially when I am leading a team. I am glad to be given the chance to be the moderator, though just for once. This definitely helps to boost my confidence to be a leader.”

Nevertheless, all was not well in the early part of the semester. It is common to see teams storming, especially while going through Problem 2 (also called CS2). Tables 2 and 3 show a sample of individual and team feedback, respectively, after the completion of Problem 2. In Table 2, the rows are feedback received by the students from their team mates. In Table 3, students identify challenges faced by their team and suggest ways of overcoming them. From the comments in Tables 2 and 3, there were clearly misunderstandings between team members, which may be partly caused by miscommunication. While student B slacked off during problem 1, when he wanted to contribute in problem 2, he felt that there were dominating members blocking him. In going through the CPBL cycle, those who lack preparation will normally feel left behind and confused over the

discussions held in class. This will normally make students feel uncomfortable, motivating them to prepare for discussions. Other members of the team, on the other hand, felt the need to dictate student B what he should do to prevent student B from slacking. Lack of proper planning and delegation of tasks also resulted in inefficiencies, and frustrated some team members, which was mostly identified by all. After evaluating the group process and feedback during class time, teams were asked to list improvements they want to make and share with the class. Motivation on team working (eg types of groups), team communication (eg JOHARI window) and conflict management must also be given during appropriate class times. Details of motivation for CPBL can be seen in [19]. As seen in the meta-reflection, these motivation and techniques are mostly internalized by students to help them overcome challenges to cooperate with one another.

Extracts of meta-reflections on team working of the same team are shown in Table 4. In analyzing the meta-reflections, it is obvious that they were able to overcome their earlier challenges in cooperating together. Each member managed to overcome their personal shortcomings, and open up to their team, thus creating conducive environment for them to learn together in problems 3 and 4. Though they initially disliked working in a team, all of them could see the benefit. By learning together in a functional team, they appreciated the experience, and gained much through CPBL. In the end, student A obtained an A while students B and C obtained A-.

Table 2. Feedback to each individual team mate for students in the same team

	A's comments	B's comments	C's comments
A		A is always motivated but his ego always make me sick to cooperate with him. From case study one, he look a good leader, but in case study 2, he try to lead the team to the best by conquer the team and just look like he always right. But when im not understand, he always try to teach me.	A is very consistent and always tried his best. There is a time when our group having hard time to get a clue how to do something, he tried his best to find the solution and not give up. He easily get bother when something going wrong or something not right...don't think too much or you will get headache..hahaha.. we need you. Thanks for all your support throughout this case study.
B	B seems like lost his passionate when doing case study 2. I wish I could motivate him so that he can more concentrate on PBL. I think sometimes he should prepare more and join more in our discussion. In my opinion, it is good for B if he can try on to do the case study first before come to discussion so that we all can have more effective discussion together.		He did what he was supposed to do and never miss the discussion. He showed interest on what had been discussed. But somehow it's not enough for the team. He needs to realize what he is supposed to do without people ask him to do it. In this case study, his contribution was insufficient. For the next case study we really anticipate him to give more contribution for the team to perform better.
C	C is very hardworking girl who always try to seek solution for our case study. Some time I think she is too rush for getting the answer instead of understanding the concept first. If she can notice this, I think overall performance will improve a lot.	She is good worker but not a good leader. For this case study, she work very hard to complete it, but she forgot to manage team to do work together.	

Table 3. Feedback on challenges and improvements needed by students in the same team

	Comments on challenges faced in team and suggestions for improvement
A	<p>I think the major problems in our team are that we always didn't realise what we need to do or realise it in very slow manner. This might be due to the improper preparation before the case study or lack of brainstorming among team members. Besides, I think if there are problems among team members, we should speak to each other and not to keep it. As Dr K said, if we didn't speak out, we won't know what is in the mind of other.</p> <p>I think all of the team mate should change our attitude from right now! We always hope to put in least effort and straight away jump to the solution for the problems. I think that this is very "unhealthy" learning style. We should be well understood of all the problems and concepts before we can start to do our task. In order to do so, please bear in mind that we should do enough preparation before come to discussion. I think in our team, even peer teaching also not as effective as all team members didn't take it serious. I think all of us should change our negative behaviours as mentioned above. Please remind each other if any of us start to show such behaviour again.!</p>
B	<p>The most challenging I face here is acceptance of my other team mate on me. I know in case study one im a bit clumsy. Then i tried to wake up from my clumsiness for case study 2, tried to contribute in discussion. But every time i tried, there is no space for. When moderator ask me to do transfer function for energy balance, i tried to finish it in my own way, what i mean is like in short note just to give them the idea from me, not the whole path way to finish it like already in soft copy, typing already. But i tried to give my idea from what i understand, where there is only one transfer function for energy balance. Then my other team mate said, we need to build more transfer function like other team done. But from my understanding there is not only one transfer function. I give my justification on my idea, but rejected because it is so simple. They are expected to get more transfer function on energy balance like other team get.why they care much about other team done? Why they like to compare their work in quantity? Then they tried build 4 transfer function from energy balance. ... Then after that there is problem occur to our transfer function ,then they tried consider to reduced input variable that affected output variable, renovate our work from beginning that solve again. Then problem occur again, more renovation. And again and again. And my team only focus on that prolem.</p> <p>in order to finish the report, our team tried to overcome the problem occur to our transfer function. Till the last midnight there is still problem occur. Im a bit quite because every time i tried to contribute to understand the problem because it hard to understand back what my team done because always do renovation, im not given space. im a bitsad because i cant see any contribution on my work to finish the report. Then moderator ask me to do introduction and methodology. Very simple i think, may be this part that im excellent in. Then im finish it. But im not satisfied to what have i done, it like only 1% of the case studyt. i try ask any more work, then reply letter. From my understanding, there is no need reply letter like in case study one because the situation in case study 2 is different. I ask my moderator, the replied, just finish the reply letter, our senior done it in every case study. it look like my team don't want me to think anymore, but just follow the order. Argh.. i realize, i do not contribute anymore. I doesnt needed anymore. Very sad. Im not a sensitive guy, but im sad. Im trying to wake up, from early i state that i don't like team work, work in team, but i want to give myself a chance to learn again to work as a team because engineer work as a team. I realize that. So I tried to. Please, give me chance to participate, give me space. I don't want banana fruit two times.hehe</p>
C	<p>Our progress was a bit late than other team, I guess. We take much time in modelling part when it supposedly already done before case study 2 part 2. I would say that our team do not have a strong basic regarding to the case study. We had problem in calculating the transfer function and to explain the response of dynamic behaviour from the graph. The team functional well but sometimes everybody want to do the same thing which causes the team to have lesser time to do other things.</p> <p>List what we need to do and assign somebody in the team to do this or that. Then, we discussed in team and find if any problem occur.</p>

Table 4. Extract on team working from end of semester meta-reflection

End-of-semester Meta-reflection	
A	Before enter control class, I always think that I am good enough in communicate with other people but when divide in team, I just realize that I am not good at all. Egoism within myself always makes me not listen to other and always think that I am the right one. Conflicts with teammate, misunderstood between each other make our team performance very poor. I hardly discover my problems until we are shown with the Johari window. I just realize that there are many hidden part that I not realize within myself. I am glad that I have my team members' support to help me overcome all these. Through their peer rating, I know my weaknesses. It is difficult for me to change my negative behaviours in a sudden. My team members are willing to accept me and notice me when I repeat my problems. Through them, I learn how to work with people from different background. Accepting the difference in ability, culture and working style, it really more comfort to work together as a team.
B	From beginning, I begin to deal with working as a team and as a team member, I need to know how to participate in discussion, how to deal with each of my teammate attitude, behavior because before I got into PC class, I hate being in group or study group, but I gave myself chance to learn how to deal with studying as a team. And obviously, now I think I got all advantages from this class, studying in group, how to contribute as a team, how to deal with each person attitude, and how to deal myself among my teammates.
C	If I recall back about my own team bonding, there is a lot of improvement. Firstly, when the beginning of the PBL we barely know each other well... The main problem of my team in the beginning was not able to express feeling or any satisfaction. There were time when my team discuss about something or choose some solutions or do something...we hardly tell our satisfaction in team. ... Some of us seem hesitated to suggest ideas or reject ideas. ,,I preferred working in team than individually. Well, there a time where I felt that it is better for me to do individually but for the most part working in team helps me widen my perspectives.... During case study 2 there conflicts but we manage to overcome it and our team seems to work really well during case study 3. There was someone said that first impression is really important. So, in the beginning I tried I was not being a good leader. The leader is to lead and it did not mean that the best ideas or solutions must come from a leader. From this situation I realize that at the end is how much that I learn and how good I have becomes. After that incident, I was not shame to ask silly question to my team mates and whatever suggestions I had, even though I think it simple, I let it out. Then, I found myself less stressful and happy to complete my work and contribute to the team.

5. Conclusion

From the illustration of the case study of a group in the Process Control course, integration of cooperative learning elements provide the needed scaffolding for developing team working skills in implementing PBL in a class consisting of small groups in a medium to large class. The strong emphasis on cooperative learning in CPBL drives students to learn together with team members, as well as the whole class. The significance of working in teams was reported by all students that underwent CPBL in the Process Control and Dynamics course.

Although students may initially go through rough patches while undergoing CPBL, the cooperative elements put in place in the framework will provide them with means to overcome the challenges. Therefore, it is not surprising to find that students who did not initially like working in teams to appreciate and actually gained and enjoy the experience after undergoing one semester of CPBL.

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