

Cooperative Problem-Based Learning (CPBL)

A Practical PBL Model for a Typical Course

<http://dx.doi.org/ijet.v6i3.1696>

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Abstract—Problem-Based Learning (PBL) is an inductive learning approach that uses a realistic problem as the starting point of learning. Unlike in medical education, which is more easily adaptable to PBL, implementing PBL in engineering courses in the traditional semester system set-up is challenging. While PBL is normally implemented in small groups of up to ten students with a dedicated tutor during PBL sessions in medical education, this is not plausible in engineering education because of the high enrolment and large class sizes. In a typical course, implementation of PBL consisting of students in small groups in medium to large classes is more practical. However, this type of implementation is more difficult to monitor, and thus requires good support and guidance in ensuring commitment and accountability of each student towards learning in his/her group. To provide the required support, Cooperative Learning (CL) is identified to have the much needed elements to develop the small student groups to functional learning teams. Combining both CL and PBL results in a Cooperative Problem-Based Learning (CPBL) model that provides a step by step guide for students to go through the PBL cycle in their teams, according to CL principles. Suitable for implementation in medium to large classes (approximately 40-60 students for one floating facilitator), with small groups consisting of 3-5 students, the CPBL model is designed to develop the students in the whole class into a learning community. This paper provides a detailed description of the CPBL model. A sample implementation in a third year Chemical Engineering course, Process Control and Dynamics, is also described.

Index Terms—cooperative problem-based learning, problem-based learning, cooperative learning, scaffolding

I. INTRODUCTION

Problem Based Learning (PBL) gained world-wide interest as an innovative technique that engage learners for deep learning, and develop a multitude of crucial professional skills, especially self-directed learning and problem solving [1], which are essential in graduates for the 21st Century [2,3]. It has been used as in numerous fields, including medicine, science, engineering and business related fields [4]. In engineering, PBL is favoured particularly because it promotes deep learning and problem-solving skills [4,5,6]. Other engineering implementations also noted enhanced generic skills and promotion of positive attitude among students who had gone through PBL [7,8].

In PBL, unstructured problems are used as the starting point of learning, creating deep interests among students to learn new knowledge and integrate existing ones, and forcing them to think critically and creatively to solve the

problem [5,6,9,10]. The strength of PBL in shaping attitudes as well as creating interest and excitement in learning otherwise dry content, and motivating students to cultivate interdependence in learning, thinking and problem-solving together in their teams and amongst teams, can be seen in the vignette posted by a student undergoing PBL in an electronic forum in Table I, expressing a typical scene in class.

TABLE I.
FORUM POST BY A STUDENT UNDERGOING PBL IN A COURSE

At first, when we started with problem 1a, i take the class so lightly by just studying in class and doing nothing at the hostel but then, when we start the discussion in class, i just sit and do nothing, and it really made me feel PRESSURED .. hohoh ... i don't wanna be the black sheep in the group, so later on i started study like hell and after that, i can strongly give opinions and argument to the cases hahaha IT'S ALL ABOUT THE PRESSURE. In class, that's the awesome part .. I've never seen a 2-hour class where no one is sleeping, even yawning ... my gosh and those sleepy heads in class for sure are pressured to see everyone so gutsy and up on their toes to give opinion and take part in class ... everyone struggling to state and protect their opinion which made the class in some sort of a debate...hohoh...

Various different PBL models exist, stemming from a variety of desired outcomes, implementation needs, as well as institutional systems, culture and constraints. There is no one-size fits all model [10], because strategies for implementation need to be suited to different conditions and needs. As a consequence of adaptations made by institutions to suit PBL for their needs, there is currently a multitude of definitions [4].

In the PBL models which originated from McMaster University and University of Maastrich medical schools, up to ten students undergo the PBL cycle facilitated by a tutor during tutorial sessions [11,12]. However, small group tutorials are not normally feasible and practical when the number of students to faculty member ratio is high. This model was even deemed to be costly for medical schools with class sizes of more than 100 [11].

An alternative is to have small groups (3-5 students in a group) in medium to large classes (20 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 facilitators or dedicated student or peer tutors may be utilized during class time [13]. 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, students do not automatically develop team working skills when they are assigned to groups, even in the small group tutorials in the medical school model of PBL [14,15,16]. Since having functional teams in which students can harmoniously cooperate is crucial for successful PBL implementation [17], a framework that can guide students to go through the whole PBL cycle step by step as a team would be helpful for small groups in medium to large class settings. Cooperative Learning (CL) is known to promote accountability and cooperation which is necessary for transforming learning groups into functioning teams [18, 19]. 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 (CPBL) model is explained. The CPBL model is a combination of PBL and CL 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 [20, 21], serves as scaffolding for guiding students in going through CPBL.

II. INTEGRATING PBL AND CL

A. Problem-Based Learning (PBL)

PBL, which has constructivist underpinnings, is a philosophy that needs to be adapted to the specific condition and environment of the institution and the nature of the field in which it is applied. This can be seen in the different models of PBL implementation throughout the world.

The typical PBL cycle, as shown in Fig. 1 [10], basically consists of:

- Phase 1: problem restatement and identification,
- Phase 2: peer teaching, synthesis of information, and solution formulation, and
- Phase 3: generalization, closure and reflection.

Despite variations in PBL implementation, these three phases are basically present in all the different models of PBL, through which facilitators will guide students.

B. Incorporation of Cooperative Learning

Supporting and monitoring students' learning in small groups by a floating facilitator can be challenging in a typical class while implementing PBL. A functioning team is critical for students undergoing PBL because they need to rely on one another for support to go through the PBL cycle to learn and integrate new knowledge to solve the problem since there is no dedicated tutor for each

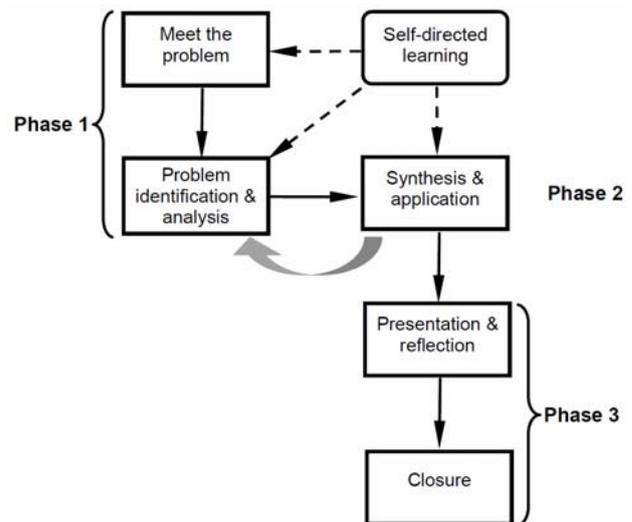


Figure 1. Typical PBL cycle

group [17]. Smith [22] described four types of learning group performance in the classroom:

- 1) Pseudo learning group: Group members do not want to work together and compete with each other. Group performance level lower than if members work individually.
- 2) Traditional classroom learning group: Members accept that they have to work together, but do very little joint work together because assignments given can be broken up and done individually. Support among members is non-existent. Free-riders cause responsible members to feel burdened, resulting in low performance and morale. Group performance level is about the same as the level if members work individually.
- 3) Cooperative learning group: Members relieved they can work together in a group, and understand that success depends on the effort of each member. Group performance level is higher than those of individual members.
- 4) High-performing cooperative group: In addition to meeting the criteria of Cooperative Learning group, members are committed to help each other and the group succeeds. Synergy is achieved resulting in a group performance level that is much higher than those of individual members.

Students typically resist working in groups, be it in laboratories or class projects, because of prior experiences working in a group that falls under the pseudo learning group or traditional classroom learning group categories [18]. Therefore, for small groups in a medium to large class settings, the support needed does not only involve cognitive coaching at different PBL phases, guidance to develop team working skills in students is also essential. While it is challenging for a floating facilitator to monitor and support all groups closely, in a proper Cooperative Learning (CL) environment, part of the monitoring, support and feedback can be attained from peers, especially team members, instead of solely relying on the facilitator. In fact, support can be further enhanced by developing the whole class into a learning community. To achieve this, CL aspects is integrated, thus becoming Cooperative Problem Based Learning (CPBL). This is in-

line with the recommendation that the two methods be combined to take advantage of the natural synergy between them [23].

Cooperative Learning (CL) is proven, through various studies, to promote cooperation among students resulting in improved learning quality and skills, such as academic achievement, interpersonal skills and self esteem [23]. Social interaction among learners can create collaboration, leading to a significant positive impact on learning [24]. To ensure good team working, the five principles of cooperative learning [18,19] must be emphasized and promoted throughout the CPBL cycle. The five CL principles (C1 to C5) are:

- Positive interdependence (C1)
- Individual accountability (C2)
- Face to face interaction (C3)
- Appropriate interpersonal skills (C4)
- Regular group function assessment (C5)

Assigning students to work in groups does not mean that they are undergoing CL. Only when all five principles exist in the learning activity can it be classified as a cooperative learning. The difference between CL and group based learning can be clearly seen in part of the meta-reflection made at the end of the semester by a student who had undergone CPBL in her Process Control (PC) course and group work in her AB course, as shown in Table II.

III. THE CPBL MODEL

To develop the CPBL model, constructive alignment is used to formally integrate CL into the PBL cycle. Constructive alignment is based on two premises. The first premise is constructivism, where the learner constructs meaning through his learning activities, rather than what is transmitted by the instructor. The second is instructional design that aligns learning outcomes to teaching and learning activities, as well as assessment tasks. By integrating the two premises in constructive alignment, constructivism forms a basis to guide the design of instruction – from writing course outcomes to selecting the appropriate teaching and learning activities, and craft suitable assessment tasks that are well aligned to support learning [20,21].

From the PBL cycle shown in Fig. 1, the model evolves to the framework shown in Fig. 2 to emphasize the importance of ensuring cooperative work among students in the small groups and the whole class. The framework can be used to visualize the CPBL process to support students in grasping the overall requirements of the whole process, as well as the significance of each step in terms of the outcomes and activities in each block as they go through each of the three 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. The teaching and learning activities, assessment and rationale for each block must be explained step by step as students undergo the process from one block to the next in each of the three

TABLE II.
PART OF END OF SEMESTER META-REFLECTION AFTER
UNDERGOING CPBL BY A THIRD YEAR STUDENT

My best experience in team working was in this PC class. I can feel the strength of team work by working with my team. But, one thing I'm confused on: can cooperation in a team be achieved if just one member did the best? Here, I want to make a comparison with my PC team and AB class team this semester that have a big project.

<i>PC Team</i>	<i>AB Team</i>
<i>know her/his task well and also help others</i>	<i>doesn't know what to do (because doesn't want to know) and doesn't help others</i>
<i>finish task on time</i>	<i>always delay work for individual task</i>
<i>everyone play their role well</i>	<i>everyone doesn't want to lead (or be project manager)</i>

In PC Team and AB team, I gave the same effort that I could give to achieve the very best work at the end. But, the outputs that I got at the end were not the same. Here, a conclusion that I can make is a good team need to have all team members' effort, not just one person. The performance of a team member does not depend on how great he/she is, but by how much effort put in to help himself/herself and others. If left up to only one member, the one person is lastly very exhausted because of tiredness and frustration.

main phases for students who are new to CPBL to develop the necessary skills.

A. Phase 1: Problem Restatement and Identification

In Phase 1, the outcome is for learners to properly begin problem solving by understanding and analyzing the actual problem, thus preventing them from rushing to find the solution. Table 3 summarizes the teaching and learning activities (TLA) and the corresponding CL principles covered by the activities in Phase 1. Referring to Table III and Fig. 2, students are required to individually write in their own words and submit a problem restatement and identification (PR & PI) to invoke construction of their own understanding before coming to class for discussions with their team mates. The problem is analyzed by establishing the following categories of information:

- existing knowledge or information that is known or given in the problem (the spring board for the problem)
- further data and information needed to solve the problem (learners have the knowledge but lack the data or information)
- learning issues or new knowledge that must be learned to solve the problem.

An electronic forum post from a student that expressed the importance of phase 1 is shown in Table IV.

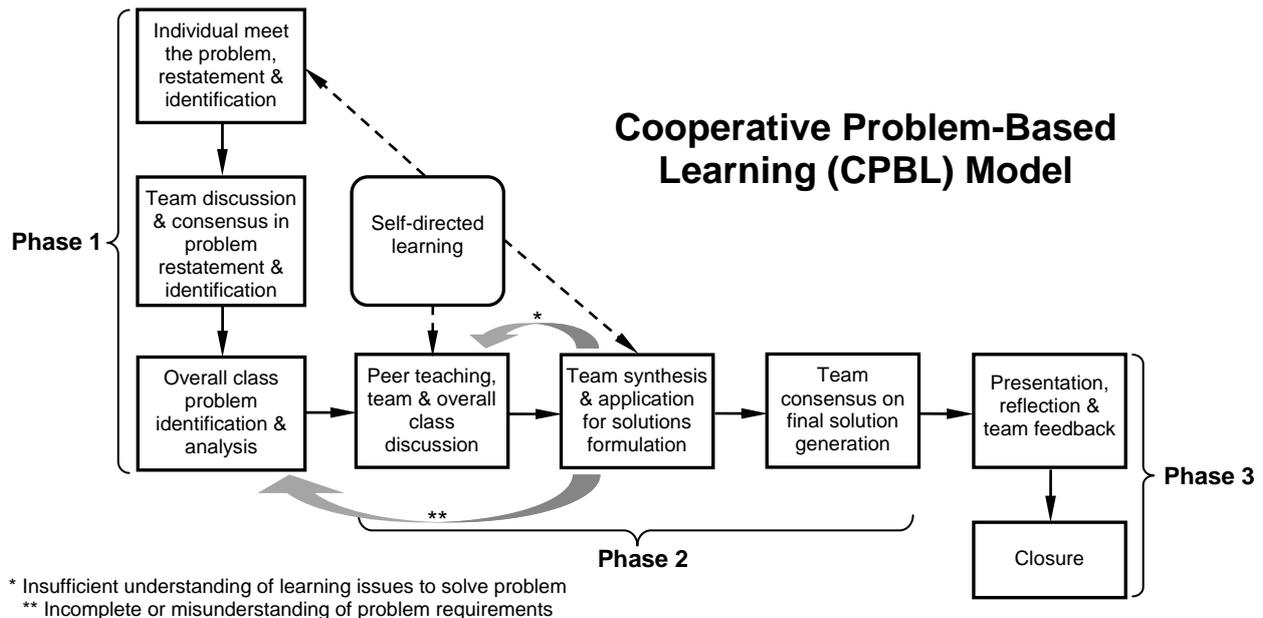


Figure 2. The CPBL framework

TABLE III.
PHASE 1 ACTIVITIES MAPPED TO CL PRINCIPLES

	TLA Activities	CL Principles
Individual	Before class, read and prepare individual PR&PI for submission	C1, C2
Team discussion & consensus	In class discussion, starting from individual PR&PI to find consensus for team PR&PI within the given time. Draw up action plan and assign learning issues to each member to prepare for peer teaching. May request team PR&PI be submitted or presented.	C1, C2, C3, C4
Overall Class	In-class discussion of each team PR&PI, where students may be randomly called to provide team answer. Conduct discussion to promote learning community among all students.	C1, C2, C3, C4, C5

Requiring learners to individually prepare and submit written problem identification constructively aligns the learning activities and assessment to the outcomes. In addition, the preparation allows teams to have productive discussions to find consensus in class. These small team discussions, in turn, give confidence for learners to volunteer their view during the overall class problem restatement and identification. In addition, these discussions are important in developing thinking skills required in starting and planning to solve the problem, as well as inculcating a sense of community and cooperation among the whole class. Assessment of individual problem restatement and identification also provides feedback and evidence for the instructor on the achievement level of students so that appropriate scaffolding can be given if the need arise.

TABLE IV.
FORUM POST DISCUSSING PHASE 1

When we get problem that need to be solve the best solution is not always what came to our mind the first time we look at the problem. ...most of the time we will not understand what we are supposed to do and what is our role to solve the problem. For example, in mosquito question none of us get the solution correctly because we failed to understand what the question is actually asking us to do. Therefore, phase one in CPBL is very important because it teaches to restate the problem in our own words to ensure us really understand the problem given to us. After that, we need to start analyzing the problem based on what we understand and construct a KNL table which is separated into 3 quadrants which is what we know, what we need to know, and learning issues.

B. Phase 2: Peer Teaching, Synthesis, and Solution Formulation

In phase 2, the outcome is to have learners develop the skill to learn new material and apply them to formulate the solution. Learners have to evaluate different approaches to solve the problem and justify the choices made. Table 5 summarizes the TLA and the corresponding CL principles. Referring to Table V and Fig. 2, at the beginning of phase 2, learners individually prepare peer teaching notes in the form of explanations of what is understood, ideas or concepts that needs to be verified and questions on hazy points on the learning issues that have been assigned by their teams. A copy of the individual peer teaching notes must be handed in to align the activity with assessment. Other than promoting accountability, students learn to construct new knowledge by extracting important concepts and information, explaining what they understand, and inquiring about what they do not fully understand to develop abilities to learn through questioning.

Peer teaching is essential in developing skills to learn in students, especially on technically challenging material, where they would easily give up if they were to study alone. Students explain what they understand to teach team members while learning together, and discuss the questions or unclear concepts before coming to class for the overall class peer teaching and learning session. An electronic forum post shown in Table VI illustrates the effectiveness of learning through peer teaching, which is a sample typical opinion on the effect of peer teaching.

The overall class peer teaching discussion is a 2-hour session monitored by the facilitator where each student understand that they need to be prepared to participate in the discussion as part of the learning community to gain most and maximize their learning. Each team is expected to come to class with a list of questions or ideas on concepts that they want to verify with other teams. A quiz on important learning issues may be given as formative assessment to enable students to gauge their understanding, and indicate to the facilitator if additional scaffolding, like tutorials or mini lectures, should be given.

TABLE V.
PHASE 2 ACTIVITIES MAPPED TO CL PRINCIPLES

	TLA Activities	CL Principles
Peer T&L	Individually prepare peer T&L notes, and conduct team peer T&L out of class. Submit individual peer T&L notes during class and have overall class peer T&L coordinated by a group. May give tutorials, quiz or mini lecture.	C1, C2, C3, C4
Synthesis & application	Synthesize knowledge and information together as a team and use them to come up with possible solutions. Conduct progress check for problems with a duration of more than 2 weeks.	C1, C2, C3, C4
Consensus on final solution	Reach a consensus on a solution that is deemed to be the best to all team members. Submit one report per team.	C1, C2, C3, C4

During the rest of phase 2, all collated information and knowledge is shared and critically reviewed, before the relevant ones can be synthesized and applied to solve the problem. This step can be iterative, where students need to re-evaluate the analysis of the problem, pursue further learning, reporting and peer teaching. Usually, at this point students actively participate in e-learning forum designated for the problem – asking questions, giving opinions and views, discussing the concepts in order to solve the problem. The electronic forum is monitored by the facilitator and if necessary, will join in the discussion to probe, motivate and bring students to the right path whenever they are off-track. For problems lasting more than 2 weeks, a simple progress report or progress check on each team is recommended midway through the duration of the problem. The aim is to provide feedback to ensure that students do not stray too far from what is required, and prevent last minute work.

TABLE VI.
OPINION ON EFFECT OF READING AND PEER TEACHING

*A long time ago:
read + read = happy
i used to just read and felt happy i already read...still in a dream thinking i understand now. Thinking i'm safe now. Well, i already read. How bad things can be??
Better than not reading anything.*

*Now:
read + discussion = confuse + more reading
but when we continue our reading with discussion, it's a painful process. We have to be able to come up with what we understand from what we already read and ask question what we did not understand.
First time reading, we felt "yei...i read!!". Then someone ask a question. This is the time where the happiness vanished. haha..if i can't think of any answer, I know i don't understand what i actually read.
well, yes... I vote for reading where it will later lead us to discussion and next to understanding.*

C. Phase 3: Generalization, Closure and Internalization

In phase 3, the outcome is to have learners evaluate the final solution from each team, and internalize and generalize the concepts and skills learned. Referring to Table VII and Fig. 2, the teams submit the final product, whether it is a report, presentation or other deliverables. If there is insufficient time for all teams to present, presentation of solution from one or two teams would be sufficient to start the ball rolling to discuss solutions obtained. In this case, the assessment of the final solution will depend on the report or other deliverables handed in, rather than the presentation, which serves as a discussion session on the possible solutions found by the different teams. The facilitator should probe students during the discussions to determine acceptable solutions, and justify their choice of the best solution for the problem.

TABLE VII.
PHASE 3 ACTIVITIES MAPPED TO CL PRINCIPLES

	TLA Activities	CL Principles
Presentation, reflection, team peer rating and feedback	Teams present final solution in class. Conduct individual reflection, rate team members and provide written feedback on good actions to keep up and things to improve on. In-class discussion on overall team performance and strategies for improvements.	C1, C2, C3, C4, C5
Closure	Summarizes and generalizes important concepts covered in problem. May compare different approaches and solutions to suggest the best solution for the problem.	C1, C2, C3, C4

During the closure, the facilitator comments on the possible solutions, as well as identify the best solution. Mistakes or misconceptions in important concepts, and difficulties or good practices in process skills or team-working may also be analyzed and reviewed. Connections between concepts and applications in other areas are discussed. This is necessary to widen the views and generalize the knowledge transfer for other types of

applications, thus strengthening students' understanding. It is also important to tie up loose ends to avoid feelings of dissatisfaction among students.

To support the development of students' team working skills and improve their learning process, a team-based post-mortem on the process that they went through and the team performance must be conducted in class. Confidential peer rating and written feedback from each team member to his/her team mates, (eg: what is good and what needs to be improved) is also given during a class session.

Reflection may be assigned individually or team-based. Initially, prompting questions are provided as scaffolding for students to do a good reflection. In submitting individual reflections and the team feedback, students are guided to internalize what they have learned and develop meta-cognitive skills. Meta-cognitive skills are essential for life-long learning and for students to understand themselves as a learner, and as part of a community. By the end of the semester, most students learn to internalize not just knowledge, but also the process that they went through to develop their skills. In addition, as part of continuously improving themselves, they were also able to identify aspects that need improvements. This can be seen in Table VIII, which shows part of the end of semester meta-reflection written by a third year student.

TABLE VIII.
PART OF END OF SEMESTER META-REFLECTION

I felt, this class is incredible. Technical knowledge is a definite yes, of course we learnt what was supposed to be learnt, those things covered in the course outline. But more importantly, I think my thinking have matured, I think I learn how to look past what is in front of the eyes, and I think I can control my emotions better now compared to how I was when I first entered uni....I also discovered some weaknesses which I need to improve on. First thing first, I need to get some of my negative thinking out of the way, and focus more on the good stuff so that I don't get depressed so easily as I do now, haha. Second of all, I need to learn to calm down at critical times to think rationally. And third of all, I need to welcome feedback, opinions, and different perspectives in a better and more open minded way.

IV. SCAFFOLDING USING E-LEARNING

Scaffolding using e-learning, through a Learning Management Systems (LMS), can be very powerful to enhance and aid the implementation of CPBL. In the e-learning, scaffolding in the form of electronic forums can be used as a platform for problem discussion and motivation, as well as for assessing the level of students' understanding to decide the type of support needed for learning. This feature provides a channel of communication among students and lecturers that is not bounded by the class time and physical presence.

An electronic forum is very useful to boost up students' engagement and immersion in solving CPBL problems. In fact, it is an innovative approach to cultivate a learning community among students as they can continuously discuss learning issues, exchange ideas and validate

understanding related to the problems. Facilitation through electronic forums can be done by probing students' discussion with thought-provoking questions that can promote critical thinking and deep learning/understanding. At the same time, students learn the skills of learning through questioning. Electronic forums also allow class facilitators to monitor students' learning process and ensure that they are on the right track. In addition, students' discussion in the electronic forum is a form of feedback for class facilitators for gauging students' understanding for better in-class facilitation.

Electronic forums can also be beneficial as a platform to provide peer support and motivation. Students, especially those from the same learning team, are accountable to motivate their team members to solve challenging problems and maximize each other's learning. Discussion forums centered on appropriate themes for the week, such as learning issues related to the problem, working and learning in teams, team performance, challenges in learning and understanding, and managing conflict, can be very useful to draw their interest.

An important advantage of using electronic forums is that this virtual support allows the participation of experts and former students who have graduated to be roped in, no matter where they are. Topics may range from supporting understanding of the content, giving context on how the material learned are used in industry, providing information or data for solving the problem, or simply motivating students to properly undergo CPBL so that they may develop essential skills needed when they work in industry.

Former students who work in industry can have a strong impact in motivating current students. Their participation in motivating current students by sharing experiences and tips on how to do well and gain most in CPBL is valuable and enlightening. This approach provides opportunity for students to see the necessity of undergoing CPBL to develop important skills from those who have entered the workplace. A common topic for discussion is the impression, reaction and reflection of undergoing CPBL class, and the way CPBL train students to suit and fit themselves in the actual working environment. A sample can be seen in Table IX, which shows part of e-forum post written by a former student working in the oil and gas industry.

Having professionals from industry as expert resources for a certain problem is scaffolding not only in how the content is used in industry, but also in developing students' technical communication skills, and the skill to gain information and learn through questioning. In addition, this increases students' motivation to work on the problem. If it is difficult to find professionals to volunteer as experts, then a virtual expert can be created on the e-learning, where the students can post questions and hold discussions with the "expert" virtually. But in actual fact, class facilitators are behind the person answering all students' queries and doubts.

However, scaffolding using e-learning is not that easy to be done as students are not automatically interested to take part in the e-learning activities. Therefore, it may be necessary to allocate a small portion of course marks for e-learning participation.

V. IMPLEMENTATION OF CPBL

A. Overview of Implementation

The CPBL model given had been used on engineering undergraduate students at different levels in Universiti Teknologi Malaysia. First-timers must be motivated and encouraged more often than experienced students. In addition, students may need more guidance in the first one or two problems. Facilitators of students who are new to PBL must also be aware of the emotional cycle that students go through to help them persevere the initially “painful” and “confusing” process. Nevertheless, with proper support, students typically appreciate going the experience of going through CPBL by the second half of the semester, as expressed by a student in the vignette in Table X.

TABLE IX.
MOTIVATION FROM A WORKING GRADUATE

You see, my dear friends, PBL teaches me to work in team, to sacrifice for the team, to plan ahead of time, to manage time properly, to prioritize work, to understand the different working cultures and expectations, to NOT procrastinate, to speak with guts and content, to argue proactively, to trade and fork ideas from other groups, to accept failure and mistakes, and perhaps most important of all, to understand and instill the goodwill that I have in my team through respect of different religion and practices. I find all these still useful and I am practicing it in my work place. PBL gives you that opportunity to do so.

TABLE X.
FORUM POST ON PBL AT THE END OF THE SEMESTER

like i always said, i hate CPBL ... in the beginning, but now, lucky I'm in. Although we struggled a lot during all those case studies, but we were more relaxed when we came to the tests. If we were committed while doing those case studies and did our best, i think we still can score during the tests even without revision. Somehow this subject more or less requires concepts and thinking, which we became expert in (after doing case studies). Oh ya, this one i just realized it: my study skill is getting more efficient – faster reading speed, better summary and justification.

The duration of problems can be varied from a week, to a whole semester. It is advisable to divide long problems (ie. those that take two weeks or more) into parts, each with a short progress report submission. This is to force students to be consistent in learning, and avoid last-minute work.

Scaffolding can be given in different forms. When there are problems of time constraints, it is allowable to provide specific references or articles on the learning issues. Experts from a specific field that is required in the problem can also be included; these experts can be available on-line, or asked to give advice on certain days before the due date of the problem. It is possible to incorporate formal CL structures as part of a scaffolding activity. Choosing the appropriate scaffolding, which can be part of problem crafting, should be carefully thought out and planned.

B. Implementation in Process Dynamics & Control

Process Control and Dynamics is a three credit hour course for third year chemical engineering undergraduates. The course deals with mathematical modelling of process dynamics, and control systems design and analysis of chemical processes. The class size normally range from 40 to 60 students. Students need to understand and visualize a process in operation, and relate mathematical theories to the physical reality. This is the first time that they have to deal with processes in dynamics instead of steady-state. Thus, students need a strong background in mathematics and other chemical engineering concepts, learned earlier, to fully appreciate the course material. When lectures were used as the primary mode of instruction, the course was notorious for the high number of failures (usually around 30%, sometimes as high as 45%), low passing grades (mostly Cs and D+), and a challenging content. Those who failed clearly could not understand the content, and those who passed with low passing grades indicated that they barely understood and did not have good understanding of the concepts. Many graduates preferred to forget the course altogether.

Since 2002, CL, PBL and later CPBL was introduced into the course gradually [8]. Currently, up to 90% of the course is covered using CPBL using four problems 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, which is a part of the final examination, is a real industrial problem that requires students to act as consultants to design control systems. A detailed description on the design of engineering problems in CPBL can be seen in [25]. With proper CPBL implementation, students' grades, opinion and motivation towards the course were found to improve significantly. The percentage of students failing the course is now less than 10%.

Assessment for the course can be seen in Table XI. The final examination consists of a final problem and a written examination. During the final problem, students did not receive much guidance or facilitation. Since the final problem was normally a real industrial problem, students have to find out the information they need during industrial visits arranged with the company involved. During the most recent implementation, the final presentation was a poster session with engineers from the industry involved in the panel of judges. The final written examination is 40% because this is the requirement of the Malaysian Engineering Accreditation Council. Questions given in the written examination matched the cognitive taxonomy level of the outcomes as well as the teaching and learning activities that students had undergone in the course.

The assessment of problems was mostly individual, except for the final report, which is a team effort. Mark received by each student from the final report is multiplied with an autorating factor calculated based on the peer rating for the individual students at the end of each problem. Details for calculating the autorating factor can be seen in [26]. 5-point rubrics designed according to the SOLO taxonomy [20, 21] were used to grade problem restatement and identification, peer teaching notes, final reports and written reflections.

TABLE XI.
COURSE ASSESSMENT DIVISION

Course Assessment	Marks
1. Two written tests	15 %
2. Three problems Problem restatement & identification Peer teaching notes Final report Written reflection	25%
3. Final examination Final problem (10%) Final written examination (40%)	50%
4. Others Tutorials and quizzes e-learning and class participation	10%
Total	100%

Fig. 3 shows the final grade distribution of students taking the course in the most recent semester (second semester in the 2009/10 academic year). The distribution is fairly typical for the course when the teaching and learning method was changed to CPBL. As seen from the figure, nearly 66% of the class received A and A-, and the percentage of failure (D and below) was less than 5%. The average final grade was an A-, while the average grade for the written final examination was a B+ and the average grade for the overall final examination (written + final problem) was also a B+. The slightly lower average of the final examination marks compared to the overall grade is understandable, since some students tend to panic and were not really able to perform well in examination halls. From this, it can be concluded that although students did fairly well in the final examination (average grade of B+), their effort throughout the semester paid off because their coursework marks managed to pull up their final grade slightly, causing the final grade average (A-) to be slightly higher compared to the final examination (B+). Although the coursework assessment was worth 50% (of which 15% was for two written tests) as shown in Table 10, significant learning occurs while students complete the assessment tasks since the tasks were also part of the teaching and learning activities. Those who do not participate will normally end up failing the course because CPBL requires students to put in effort to learn and gain from a supportive and guided learning environment.

The good results in the course was not really surprising because students was observed to be motivated and engaged in learning, especially when they realized that the knowledge and skills gained were needed for their upcoming industrial training and in the workplace, especially in the second half of the semester. Overall class discussions were always engaging and lively. For the past three academic sessions, students in the course consistently asked for permission to go beyond the course syllabus in perfecting their solutions for the final problem. Details of the students' increase in motivation to learn at the end of the semester compared to the beginning of the semester can be seen in [27].

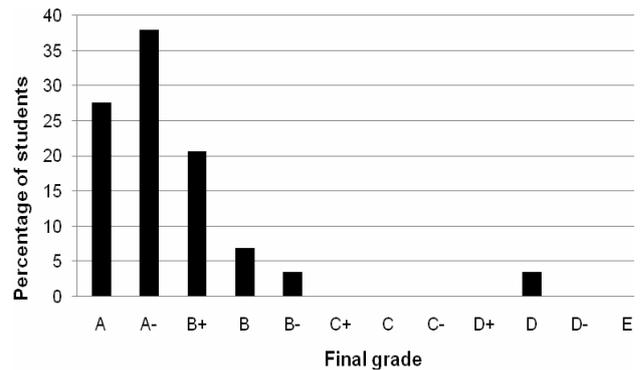


Figure 3. Final Grade for Students in Process Control & Dynamics

VI. CONCLUSION

The CPBL model proposed in this paper is suited for implementation in a typical engineering course. The CPBL process is an integration of CL into the PBL cycle, based on constructive alignment. At each of the three phases, the teaching and learning activities and the assessment tasks are designed for learners to construct knowledge through their own participation, while harnessing the support of their team members and classmates. Ensuring the activities support the five cooperative learning principles while undergoing PBL promote the attainment of cooperative learning teams. Thus, the "power" of PBL can now be unleashed using a practical CPBL model that is suitable for typical engineering courses.

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This article is an extended version of a paper presented at the International Conference EDUCON2011, held in April 2011 at PSUT, in Amman, Jordan. It has won the Best Paper Award. Received, June, 11th, 2011. Published as resubmitted by the authors August 2nd, 2011.