AC 2011-2721: MOTIVATION AND ENGAGEMENT OF LEARNING IN THE COOPERATIVE PROBLEM-BASED LEARNING (CPBL) FRAME-WORK

Khairiyah Mohd-Yusof, Universiti Teknologi Malaysia

Khairiyah is an Associate Professor in the Department of Chemical Engineering, Universiti Teknologi Malaysia (UTM). She is presently the Director at the UTM Regional Centre for Engineering Education. She was previously the Deputy Director at the Centre for Teaching and Learning in UTM. Her main research areas are Process Modeling, Simulation and Control, and Engineering Education. She has been implementing PBL in her courses since 2002 and is also involved in training engineering instructors in teaching and learning throughout Malaysia.

Syed Helmi Syed Hassan, Universiti Teknologi Malaysia Mohammad Zamry Jamaludin, Universiti Teknologi Malaysia (UTM)

Mohammad Zamry is a tutor at the Department of Chemical Engineering, Faculty of Chemical Engineering,Universiti Teknologi Malaysia (UTM), since 2007. He is one of the class facilitators for a third-year chemical engineering course, Process Control and Dynamics, that employs cooperative problem-based learning (CPBL) as the teaching and learning methodology. He also implements CPBL lab for Process Control Laboratory, a lab course for the final year students. Mohammad Zamry is an active member of engineering education research team in UTM. The team is now very progressive in doing research related to cooperative learning (CL), problem-based learning (PBL) and cooperative problem-based learning (CPBL), and providing training for academician from higher institutions in Malaysia on active learning (AL), cooperative learning (CL) and problem-based learning (PBL). His particular research interest is in crafting engineering problems for PBL, and has produced conference papers on book chapter on this matter.

Nor Farida Harun, Department of Chemical Engineering, Faculty of Chemical Engineering, Universiti Teknologi Malaysia

Motivation and Engagement of Learning in the Cooperative Problem-based Learning (CPBL) Framework

Abstract

Motivation and engagement in learning is very important for students to understand challenging engineering content. Problem-Based Learning (PBL) is well known for engaging students in learning. However, the small group PBL tutorials with up to ten students assigned to a dedicated tutor to facilitate learning common in medical schools is not practical in typical engineering courses, which normally have high enrolment.

The Cooperative Problem-Based Learning (CPBL) framework integrates Cooperative Learning (CL) principles into the Problem-Based Learning (PBL) cycle to allow implementation in a typical class by having small groups of students in a medium to large class where one instructor can function as a floating facilitator for up to sixty students. Although PBL has constructivist underpinnings, incorporating CL into PBL to become CPBL includes social constructionist principles into the model. Designed in accordance with constructive alignment, the framework provides a systematic structure to scaffold students in undergoing CPBL step by step to support as well as engage students in learning. The cooperative learning elements in the model drive students to cooperate and support one another to learn as a team, allowing less monitoring from the facilitator compared to the small tutorial group PBL model.

The motivation and engagement of students undergoing CPBL in learning were studied. A case study on the implementation of CPBL in the Process Control and Dynamics course for third year chemical engineering students is reported. During the course, students go through six CPBL cycles to solve four problems that cover all the course outcomes in one semester. Selected constructs of Pintrich's Motivated Strategy for Learning Questionnaire (MSLQ) relevant to a CPBL class, which are intrinsic and extrinsic goal orientation, task value, control of learning belief, organization, critical thinking, effort regulation and help seeking, were administered to determine the effect of CPBL. The results showed a significant increase in students' engagement and motivation in learning. These findings are further supported by students' reflections made at the end of every problem and the course e-learning forum postings throughout the semester.

Introduction

Problem based learning (PBL) has been widely used in higher education in various fields, including medicine, law, engineering and business.¹ PBL implementations had been shown to promote deep learning, meta-cognition and positive attitude, as well as enhance a multitude of professional skills such as problem solving, thinking and communication skills in students.^{1,2,3,4} The strength of PBL is in shaping attitudes as well as creating interest and excitement in learning otherwise challenging content, and motivating students to cultivate interdependence in learning, thinking and problem-solving.^{5,6}

Motivation is important in influencing student learning.^{7,8} Motivating engineering students to be engaged in learning is important, given the high level of difficulty in engineering content and the

amount of time and effort needed to learn them. In addition, deep understanding of the content knowledge is required so that different concepts can be integrated and applied in typical engineering contexts such as solving a problem, troubleshooting, decision making, etc. Since PBL had been shown to motivate and develop crucial learning and professional skills, implementing PBL effectively is desirable for engaging students to learn in a typical engineering course.

The starting point of learning in PBL is an unstructured, realistic problem that serves to contextualize the new content that students have to learn before solving the problem. Lectures on the new content are not given. Instead, students are guided through a PBL cycle that helps them to identify and construct new knowledge that is synthesized with their existing knowledge to be applied in solving the given problem.^{10, 11} As shown in Figure 1, the typical PBL cycle¹¹ basically consists of

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



Figure 1. Typical PBL cycle

Although this is the basic PBL cycle, many variations exist in the implementation of the cycle. For example, in the medical school model which originated from McMaster University and University of Maastrich, a group of around ten students undergo the PBL cycle facilitated by a tutor during tutorial sessions.¹² Nevertheless, small group tutorials are not normally feasible and practical when student enrolment is high.¹³

For a typical class implementation, 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 may be utilized during class time. Peer monitoring and support is required because it will not be possible for the facilitator be available for all groups at the same time. Although this is more feasible in a typical course, it requires higher commitment and accountability on the part of students to go through the PBL cycle together in their groups. Therefore, for the

implementation to be successful, students must be in functional teams so that they can harmoniously cooperate and support one another.^{14, 15, 16} Since students do not automatically have team working skills, Cooperative Learning (CL), which is known to promote accountability and cooperation necessary for transforming learning groups into functioning teams ^{17,18} is integrated into the PBL cycle, resulting in the Cooperative Problem-Based Learning (CPBL) model. The CPBL framework is designed to purposefully drive students towards developing team working skills. Most importantly, the framework serves as scaffolding for guiding students, who are novice problem solvers, step by step in going through the CPBL cycle.

In this paper, the CPBL model and its implementation in the Process Control and Dynamics course taken by third year chemical engineering undergraduates is described. To study if CPBL affected motivation and learning strategies, the change in students after going through CPBL for one semester were measured using selected constructs of Pintrich's Motivated Strategy for Learning Questionnaire (MSLQ) relevant to CPBL. Students' results and selected reflections from the latest session of the Process Control and Dynamics course are included to further explain and support the findings of the study.

Integrating Cooperative Learning (CL) into 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.

There are, however, essential features of PBL. PBL is an inductive learning approach that embeds small groups of students in the role of a professional and presents them with a messy, unstructured, realistic (if not real) problem, to solve. The problem should be well crafted to engage and immerse students in learning new issues, as well as challenge existing knowledge, skills and attitude. Students are guided by cognitive coaches through the PBL cycle to learn and solve the problem. PBL sought to make students' thinking visible – it is no longer solely limited to making content visible as in the traditional transmission mode.¹¹ It is important to emphasize that PBL is "not only about infusing problems into the class, but also about creating opportunities for students to construct knowledge through effective interactions and collaborative inquiry."¹¹

Supporting and monitoring students' learning in small groups by a floating facilitator can be challenging in a typical class while implementing PBL. It is typical for students to resist working in groups, be it in laboratories or class projects, because of negative prior experiences.¹⁷ Therefore, the support needed does not only involve cognitive coaching at different PBL phases, guidance and monitoring to develop team working skills in students is also essential. 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 from Prince that the two methods be combined to take advantage of the natural synergy between them.¹⁹

To ensure good team working, the five principles of cooperative learning ^{17,18} must be emphasized and promoted throughout the CPBL cycle, in accordance with the requirement of constructive alignment. 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 five CL principles (C1 to C5) are^{17,18}:

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

The Cooperative Problem-Based Learning (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}.

Incorporating CL into the PBL cycle 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. 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.

Table 1 provides a summary of the teaching and learning activities (TLA) and assessment tasks (AT) for each block in the three phases of the CPBL model. In accordance with constructive alignment, the TLAs and ATs are aligned to the outcomes, and encourage the construction of knowledge and skills. In addition, each activity promotes the CL principles shown in the last column of the table. 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. In each phase, the individual activities are designed to enhance learning and accountability, which will be strengthened with team-based activities, and further supported in the overall class activities to form a learning community.

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. Referring to Table 1 and Figure 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.



Figure 2. The CPBL Framework

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. Referring to Table 1 and Figure 2, at the beginning of phase 2, learners individually prepare and submit peer teaching and learning (T&L) 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. Peer teaching and learning 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. The overall class peer teaching discussion is a 2-hour session monitored by the facilitator where each team 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.

In phase 3, the outcome is to have learners evaluate the final solution from each team, as well as internalize and generalize the concepts and skills learned. Referring to Table 1 and Figure 2, the teams submit the final product, whether it is a report, presentation or other deliverables. During the solution presentation discussion, the facilitator probes students to guide them to determine acceptable solutions, and justify their choice of the best solution for the problem. For the closure, the facilitator provides feedback on the possible solutions, as well as identifies the best solution. Connections between concepts and applications in other areas are discussed to widen the views and generalize the knowledge transfer for other types of applications.

Phase	TLA	Description of TLA	AT	CL Principle
1	Individual PR&PI	Post or give problem a day or two prior to class. Before class, students read and prepare individual PR&PI for submission.	Individual PR&PI	C1, C2
	Team discussion & consensus	Submission of individual PR&PI at the beginning of class. Students discuss in teams, starting from individual PR&PI to find consensus for team PR&PI, and draw up action plan and assign learning issues to each member to prepare for peer teaching, within a given time in the class. May request presentation of team PR&PI.	Feedback on PR&PI discussed	C1, C2, C3, C4
	Overall Class PR&PI	In-class discussion of each team PR&PI, where students may be randomly called to provide team answer and discuss differences. Conduct discussion to promote learning community among all students.	Feedback on overall PR&PI discussed	C1, C2, C3, C4, C5
2	Peer T&L	Students individually prepare peer T&L notes, and conduct team peer T&L outside of class before overall class peer teaching session. A copy of the individual peer T&L notes is submitted at the beginning of class and an overall class peer T&L discussion coordinated by a team assigned in the previous class. May give tutorials, quiz or mini lecture if required.	Individual peer T&L notes. Quiz and/or tutorial on important concepts	C1, C2, C3, C4
	Synthesis & application	Students 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.	Progress check/report, e-learning forum	C1, C2, C3, C4
	Consensus on final solution	Students reach a consensus on a solution that is deemed to be the best to all team members, with proper justification. Submit one product per team.	Final product	C1, C2, C3, C4
3	Presentation, reflection, team peer rating and feedback	Final solution presented in class, with different solutions and approaches discussed. 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.	Reflection, peer and self rating, written peer feedback	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, given the scenario. May also include "what if" or variations in conditions in which the concepts may apply.	Feedback on solutions and final reports	C1, C2, C3, C4

Table 1. Summarized description for activities in each phase of CPBL model

To support the development of students' team working skills and improve their learning process, a team-based post-mortem on how 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. In submitting individual reflections and the team feedback, students are guided to internalize what they have learned and develop meta-cognitive skills.

In recent years, CPBL have been implemented at different levels in Universiti Teknologi Malaysia. Other than different outcomes, the level of difficulty of the problems must be adjusted for different levels of students. Students facing CPBL for the first time need to be motivated and encouraged more often than experienced students. Close guidance must also be given in the first one or two problems. Motivation and guidance given to first year students differ from upper year students, given their different levels of maturity. In addition, time constraint should also be taken into account to decide on the support needed so that students spend their time on tasks that are meaningful, such as holding a session to start them off to use a software to assist in solving mathematical equations.

Motivation and CPBL: Developing the Desired Learning Strategies

Motivation plays a very important role in driving learning.⁸ It is one of the main basis for engagement in any activity, whether a person decides to spend his time and effort on a certain task.²² In educational psychology, there are various conceptualization of motivation in learning. Some theories focus on what comes from within the individual, like beliefs or interest, while others focus on the surroundings, like the learning environment. Nevertheless, both aspects are inadvertently interconnected.

Problem-based learning had been shown in several studies to shape attitudes and motivate students to learn. Students were found to be more positive towards learning compared to those undergoing traditional lectures, and hence it is not surprising to see them developing challenging skills such as critical thinking and meta-cognitive skills. This may seem like a paradox, since students new to PBL will normally be "traumatized" by a learning environment that is very much different than what they are used to, and resist going through the learning process. Woods described the typical stages of students facing PBL for the first time as similar to the typical stages of a person facing trauma or a major change: shock, denial, strong emotion, resistance, acceptance, struggle, better understanding and integration. ²³ Once students are able to get over the stages and reach integration, they will actually realize that they have reached a higher level of performance.

The CPBL framework is scaffolding that provides a step by step guide on how to go through each phase of the process successfully. It is important to explain the breakdown of the overall process to solve the problem to avoid overwhelming students, and to show them what has to be done to be successful. The instructor has an important role in determining the appropriate support and scaffolding to assist them through the initial negative emotions, such as providing motivation (eg. what is the benefit of the knowledge and skills learned, where will they be used) and explaining the rationale as well as the outcomes of each phase. Normally, after going through the CPBL cycle while being closely guided two to three times, the scaffolding is faded out and students will be able to go through it on their own with minimal assistance.

The learning environment within the CPBL model is in accordance to the expectancy-value theory. Expectancy-value theory states that students choose to engage in a task that they expect to succeed in, and that they deem to be beneficial if they completed the task successfully.^{24,25} In showing the overall CPBL process and breaking it down into phases and phases into smaller steps makes the process of solving a difficult problem manageable. Students gain mastery as they go through subsequent CPBL cycles, reflecting after each cycle in the third phase. As such, they become more aware of their achievements and gains, as well as shortcomings to improve on. This in turn developed their learning skills, including higher order cognitive skills such as critical thinking and meta-cognitive thinking skills.

Case Study: CPBL in Process Control & Dynamics Course

Background of the CPBL Implementation

Process Control and Dynamics is a three credit hour course for third year chemical engineering undergraduates. The class size range from 30 to 60 students. Students need to understand and visualize a process in operation, and relate mathematical theories to the physical reality. Thus, students need a strong background in mathematics and other chemical engineering concepts, learned earlier, to fully appreciate the course material. When traditional 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+). 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 were gradually introduced into the course.⁷ Currently, more than 90% of the course is covered using CPBL with four problems, as shown in Table 2. Topics in the syllabus not covered in the problems were usually included in the closure stage (Phase 3 of CPBL) when the learning issues of the problem were generalized. The total number of weeks for instruction is 14 in one semester. The first problem is the simplest, to introduce students to the content area and CPBL. A sample of a first problem (Case Study 1) is included in Appendix A at the end of this paper. The second and third problems are challenging, both in terms of technical content and the required thinking skills, taking up 4 weeks each. Because of the longer duration, problems 2 and 3 were divided into two parts, requiring two CPBL cycles to complete. Phase 3 of the first CPBL cycle for the problems was simplified by asking students to submit a progress report and in-class oral reflection without any closure, followed by the continuation of the problem for the second part, in which students had to go back to Phase 1 to restate and identify the problem. 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 Mohammad-Zamry, et al.²⁶

Breakdown in assessment for the course before implementation of CPBL and with the current implementation of CPBL can be seen in Table 3. The assessment was modified slightly with CPBL implementation for alignment to the course outcomes and teaching and learning activities. 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 examination is 50% 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 Kaufman and Felder.²⁷ 5-point rubrics are designed according to the SOLO taxonomy ^{20, 21} were used to grade problem restatement and identification, peer teaching notes, final reports and written reflections.

Problem #	Duration	No. of CPBL cycle
1	1 week	1
2	4 weeks	2
3	4 weeks	2
4	3 weeks	1

Table 2. Organization of CPBL problems in a semester

Table 3. Course assessment division

Course Assessment	Marks Breakdown (before CPBL)	Marks Breakdown (with CPBL)
Two written tests	30%	15%
 Three problems Problem restatement & identification Peer teaching notes Final report Written reflection 	none	25%
 Final examination Final problem (10%) Final written examination (40%) 	50%	50%
OthersTutorials and quizzese-learning and class participation	20%	10%
Total	100%	100%

The Research

To investigate if CPBL is effective in motivating and engaging students in learning challenging engineering content, the Motivated Strategies for Learning Questionnaire (MSLQ)²⁸ is given to third year chemical engineering students taking a Process Control & Dynamics course that fully utilized CPBL as the teaching method to see the differences in their motivational orientations and learning strategies between the beginning and the end of the semester. The final grades obtained by the students will also be used to gauge the effectiveness of CPBL. The instructor in charge of the course is an experienced facilitator that had experimented teaching with inductive learning methods since 2003. This initial study was conducted in the second semester of the 2009/2010 academic session, when the number of students in the course was 30. CPBL had been implemented several times before with up to 60 students in a class. This is part of a larger study on CPBL that will include generalizations to other courses and qualitative research approaches in the near future.

The selected constructs of the MSLQ are shown in Table 4. In accordance to the expectancyvalue conceptual framework, the motivation section is divided into two components: value and expectancy. The value component measures students' goal orientations and their beliefs on the value of a course through three scales consisting of intrinsic goal orientation, extrinsic goal orientation and task value. The expectancy component, which consists of control of learning beliefs, measures the students' expectancy for success in a course. The learning strategies section is also divided into two components: cognitive/meta-cognitive strategies and resource management strategies. Cognitive/meta-cognitive strategies measure students' use of these strategies by using organization (learning new content by making connections between concepts and new knowledge through diagrams, tables, etc.), and critical thinking (making evaluations and applying knowledge to new contexts). Resource management strategies measures students' ability to utilize resources for learning through effort regulation and help seeking. All scales are associated with adequate alpha reliability levels for the purpose of the study. The overall Cronbach alpha value is 0.97.²⁸

Section	Component	Scale	
Motivation	• Value	 Intrinsic Goal Orientation Extrinsic Goal Orientation Task Value 	
	• Expectancy	4. Control of Learning Beliefs	
Learning Strategies	Cognitive/ Meta-cognitive Strategies	 Organization Critical Thinking 	
	Resource Management Strategies	 7. Effort Regulation 8. Help Seeking 	

Table 4. The MSLQ sections and the corresponding components and scales

Results and Discussions

Figure 3 shows the MSLQ scores for the beginning and the end of the semester for the Process Control course. The data was tested for normality. Referring to Table 5, from a pair t-test based on a 95% confidence level (p<0.05), the means for all constructs for the end of the semester were found to have significant differences from those for the beginning of the semester. A negative mean indicates that the mean score at the beginning of the semester was lower than the mean score at the end of the semester. As indicated in Table 5, the effect sizes (d) for all the comparison are also greater than 0.8. However, the effect size of extrinsic goal orientation is smaller than 0.5. An effect size that is greater than 0.8 has great impact in the study, but an effect size that is lower than 0.5 has small impact. This means that the CPBL approach in learning does have greater impact on the students learning motivation and strategies. However the CPBL approach slightly reduced the extrinsic goal orientation of students.



Motivation & Learning Strategies

Figure 3: Students' Motivation Strategies for Learning for the beginning and end of semesters

Scale		Paired Difference		t	p<0.05	Effect Size	
		Mean	Std. Deviation	Std. Error Mean			(d)
1.	Intrinsic	-6.300	4.793	0.875	-7.199	0.000	1.49
2.	Extrinsic	1.667	3.623	0.661	2.520	0.018	0.41
3.	Task Value	-7.467	6.431	1.174	-6.359	0.000	1.41
4.	Control Belief	-3.367	3.792	0.692	-4.863	0.000	0.99
5.	Organization	-5.300	3.949	0.721	-7.351	0.000	1.38
6.	Critical Thinking	-8.433	5.673	1.036	-8.142	0.000	1.95
7.	Effort Regulation	-3.533	4.075	0.744	-4.750	0.000	0.89
8.	Help Seeking	-4.167	3.797	0.693	-6.010	0.000	1.30

Table 5. Dained Communic Tes	
Table 5. Paireo Namble Les	t

Referring to Figure 3 and Table 5, the first four constructs are the scales for the motivation section: intrinsic goal orientation, extrinsic goal orientation, task value and control of learning beliefs. It is interesting to note that all the motivation scales increased significantly, except for extrinsic motivation, which decreased slightly. Although the difference between the end and the beginning of the semester for extrinsic motivation is smaller compared to the other three (p =0.000), it is still significant (p = 0.018 < 0.05), though with a smaller impact compared to the rest of the scales. Based on the results, the students' intrinsic motivation, which is based on the desire for mastery and the satisfaction of learning, increased but surprisingly, there was a decrease in extrinsic motivation, which is based on external rewards, such as grades and competition. The smaller change in extrinsic motivation compared to the larger change in intrinsic motivation indicates that students have developed the driving force for learning that comes from within, while the smaller decrease in external motivation indicates that though external rewards were still important, they were not as essential as in the beginning of the semester. The task value had the highest increase which demonstrates that students appreciate the learning process that they went through, even though they initially complained that the problem was difficult and that there was a lot of work. The result of the expectancy component, which is measured using the control of learning beliefs, indicated that students had a higher level of confidence in their ability to successfully complete the task, despite the challenging nature of CPBL, at the end of the semester.

Referring to Figure 3 and Table 4, the last four constructs are scales for the learning strategies section: organization, critical thinking, effort regulation and help seeking. All four scales increased significantly. The increase in organization and critical thinking scales indicate an increase in cognitive and meta-cognitive component, which means that students had improved their thinking approach through connecting and representing knowledge to better understand, and making justified judgments as well as to transfer and apply knowledge in a different context. The increase in effort regulation and help seeking scales indicate an increase in resource management strategies, which means that students had increased their persistence in pursuing their learning goals even in the face of difficulties or boredom, and enlisting the support of others by properly utilizing resources and actively pursuing assistance.

The enhancement of students' motivation and learning strategies is clearly supported by the results obtained at the end of the semester, as shown in Figure 4. The grade distribution is typical for the course when the teaching and learning method was changed to CPBL. As shown in Figure 4, 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. Although the coursework assessment was worth 50% (of which 15% was for two written tests) as given in Table 3, significant learning occurred while students complete the assessment tasks as they undergo the CPBL process since the tasks were also part of the teaching and learning activities. Those who do not participate will normally end up failing the course (D and below) because CPBL requires students to put in effort to learn and gain from a supportive and guided learning environment. While grades had improved tremendously compared to when traditional lectures were given, this is not the main

purpose of this paper, knowing that there is a difference in the assessment strategy of the course as shown in Table 3. Nevertheless, the current assessment results show significant learning of the content, as well as learning motivation and strategies, had occurred with CPBL, even when solely measured using written examinations, compared to the dismal grades students used to achieve (at least 30% failures and low average grade) when traditional lectures were used.

The good results obtained corresponded to students' enhanced motivation and learning strategies that was revealed by the results of the MSLQ. This also corresponded to their electronic forum discussions, and their reflections as students go through the semester. Tables 5 and 6 contain vignettes expressing typical opinions of students that revealed their thoughts on motivational aspects associated with CPBL, and the learning strategies enhanced, respectively. Grammatical errors for some of the vignettes had been corrected without changing the meaning for ease of reading. Referring to the tables, although the vignettes were classified into different motivation and learning strategies scales, many of them can be classified under several scales. For example, the first vignette for help seeking in Table 6 can also be classified under effort regulation.



Figure 4. Distribution of final grades

Conclusion

The CPBL model, which incorporates cooperative learning into the PBL cycle, is suitable for implementation in a typical engineering course. The model provides a step by step guide for students to solve realistic problems which help them contextualize the new content that they have to learn. CPBL had been shown to be effective in increasing student motivation and enhancing learning strategies, as measured by the MSLQ. The good grades obtained by students after undergoing CPBL attest to the significant learning of challenging course material.

Future Work

CPBL is currently being implemented by other instructors in other courses. Research on the effectiveness of CPBL is currently being conducted on a larger scale. More in-depth study on how CPBL actually enhance motivation and learning is also being conducted.

Motivational aspects	Typical opinion of students
Intrinsic motivation	Perhaps, I should not take the grade so seriously. But, I did enjoy this case study very much. I won't say I love it but I appreciate it as part of my training because nobody loves problems. And for your info, my team took around three days to complete the reportOh God, so terrible but like I said, I enjoyed the moment.
	The teaching method will definitely increase your desire to get more knowledge and build up positive characteristic in terms of learning (with the requirement you must accept CPBL positively). Proud to say, after going through 4 PBLs in this subject, it really builds up my confidence in problem solving and now I know the techniques on how to analyze the problems prior to jumping into any conclusion promptly.
Extrinsic motivation / task value	In lectures, we absorb what is given, but PBL, we find what we want, and we will never forget it. This helps a lot. Let's see, if were given lectures, then most of the time we tend to do last minute STUDY instead of revision. Whereas in PBL, we are actually doing it and those things are actually carved in our mind. At least if we don't do any revision, we still being able to answer test questions.
Task value	I think from what I have learnt from the control class, it is a good start for me to prepare myself as an engineer.
	After undergoing CPBL, one thing I realized is I will automatically learn something and apply in the real situation. It is not just memorizing and not knowing how to apply it in real situation.
	CPBL is totally different from how I used to learn in the past we actually need to find the problem ourselves and solve it ourselves. This is not the same as the conventional learning skills we had in school. For me, at first it is quite tough because I have no knowledge, through discussion with teammates and in class, slowly ideas were generated, and at the end, our report was finally produced. CPBL will be a very good fundamental for us because in the future, when we become engineers, we will be facing all these challenges (even harder).
Control of Learning Beliefs	Going through the CPBL cycle has helped me a lot in completing the case study. With this cycle, I'm able to settle the problem step by step and at the same time reducing the stress on thinking how to settle this complicated problem myself. The discussions with team mates and during classes reduce my burden on this problem and it became easier for me to solve the problem.

 Table 5. Typical opinion of students undergoing CPBL on motivational aspects

Learning strategies aspects	Typical opinion of students	
Organization	I feel that control is not something new that we need to study but the purpose of control subject is to integrate what we have studied. Drawing back and applying it to existing problem or case study. It makes me realize that study does not mean only reading but also finding ways to apply.	
	Usually I will the problem given one time, then start doing the KNL table, because for me, I would like to write down things I know in the problem and things I don't understand first, then only i read the problem for the second or more times to determine the problem restatement. My step of doing the problem identification is quite different but i think this way really help me a lot in understand a problem	
Effort regulation	From CPBL, I can see that process control needs cooperation between team matse and our own self. This trains me more responsible and independent. For me, I need to prepare my teaching note and verify my understanding about the information together with my team mate. For discussion, I will try to search for more information on the issues so that I am able to answer my team mates and my own questions	
	Indeed the CPBL approach helped me learn the content differently, before this we were spoon fed and will only pay attention to those highlighted in class and hope to get an Abut through CPBL, not only do I have to learn and struggle everything myself but at the same time, I was able to apply them, unlike before this where I only studied theories but poor in applying them	
Help seeking	Going through the semester, I feel more comfortable to solve problem together with others. Of course we had lots of assignments and need to work in a group, but in problem solving, it is different. We learn to negotiate, discuss, listening, analyze things together. Doing things until the midnight because report had to be passed up the next day, make us struggled the whole night. But once finished, we felt satisfied and all the effort was worth it.	
	I also learn to how to ask a proper question so that I will be able to seek information from my friends.	
Critical thinking	Now I know that everything that comes out from my mouth needs justifications. Each point must be accompanied by strong reasoning in order to support them. This shows that I know what I am doing I think it helps me to develop life-long or independent learning skills as well as to be a critical thinker. Not all the information from books and internet is correct. Therefore, I need to know which is correct and applicable. That is the skills that engineers should have and not just follow blindly. Besides, it makes me more analyticalI need to know the expected results and compare it with the actual result. I need to know why it deviates from the actual and be able to justify the matter.	
	Now, I realize that one problem will have one best solution instead of one answer. There might be other ways to tackle the problem but it is up to us to evaluate the suitability and the need of it based on our previous knowledge and justification. There might be people that will influence us but it is up to us to judge the message conveyed by others.	

Table 6. Typical opinion of students undergoing CPBL on learning strategies aspects

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Appendix A

CASE STUDY 1

HDA Process at Polystyrene (M) Sdn. Bhd.

The Scenario

Polystyrene (M) Sdn. Bhd., located in Pasir Gudang, is one of the largest producers of polystyrene in South-East Asia. In the company, polystyrene is produced from toluene, which is converted into benzene, ethylbenzene and styrene monomer through a series of complex processes. Finally, styrene monomer is polymerized to produce polystyrene.

Currently, Polystyrene (M) Sdn. Bhd. is offering a place for a team of undergraduates to attend their industrial training program. In order to recruit the best candidates, the company had taken part in the 2009 Career Fair which was held during the university semester break. For those interested, they were required to submit their resume. The selected students would be put in a team and called for a team-interview at the company later on. You and your teammates did not want to miss the chance. One day, you and your teammates received an offer letter from the company to attend an interview with regards to the industrial training program.





Polystyrene (M) Sdn. Bhd.

www.polystyrenemalaysia.com

PLO 4225, Jalan Perdana 3/5,
81700 Pasir Gudang, Johor.

Tel: +607-8508290 Fax: +607-8508291

Dear candidates,

The selection committee of Polystyrene (M) Sdn. Bhd. is very interested in interviewing your team for the opportunity to undergo industrial training at our company. The interview session is scheduled on 28th December 2009, from 10 a.m. to 12 noon, in the meeting room, Human Resource Department, Polystyrene (M) Sdn. Bhd.

With regards to the interview session, we would like you to demonstrate your understanding on one of our processing plants, the HDA Process, in a 3-5 page report. Please systematically describe the process from a system's point of view. Be sure to include the input and output variables involved in the process. Explain all the automatic control systems: classify the variables, identify the control objective, and identify the control configuration used for each control loop. Please comment if the control configurations used are sufficient to tackle the disturbances. Enclosed are the process description and a simplified P&ID of the HDA Process for your reference.

The interview will be conducted mainly based on the report you will be submitting. If you have any queries, please do not hesitate to get in touch with me. I can be reached at 07-8508297 or iqbal.ridha@psm.my.

Yours Sincerely,

Iqbal Ridha

Iqbal Ridha, Factory Manager, Polystyrene (M) Sdn. Bhd.

PROCESS DESCRIPTION

HDA Process: Hydrodealkylation of Toluene to Benzene

In the HDA process, a pure toluene stream and a hydrogen stream (97% hydrogen and 3% methane) are mixed with recycle toluene and hydrogen via in-line mixers (refer to Figure 1). This reactant mixture is first preheated in a feed-effluent heat exchanger, FEHE (HE 101), using the reactor effluent stream, and then is heated in a furnace (HE 102) before being fed to an adiabatic plug-flow reactor (R 101).

A main reaction and a reversible side reaction occur in the reactor, as shown in Equation (1) and (2):

Toluene + HydrogenBenzene + Methane(1)2 BenzeneDiphenyl + Hydrogen(2)

The exothermic vapor phase reactions take place at 680°C and 35bar. Below 600°C, the reaction rate is too slow; while above 700°C, a significant amount of hydrocracking takes place. An excess amount of hydrogen, 5 hydrogen-to-1 toluene, is needed to prevent coking. The conversion of toluene inside the reactor is high, typically around 98%.

As the reaction temperature is extremely high and the reactor is adiabatic, a quench stream must be introduced at the reactor exit to reduce the reactor effluent stream temperature, stop the reactions and prevent coking of equipment. The reactor effluent is quenched by a portion of the flash separator liquid stream, and further cooled in the FEHE (HE 101) and a series of cooling system (HE 103) for steam generation, before being fed into the flash separator (F 101). The reactor effluent enters the flash separator (F 101) at 30°C and 35bar. There are two streams out of the flash separator, a vapor stream that rich in light components of hydrogen and methane, and a liquid stream that contains toluene, benzene and diphenyl. Part of the vapor stream is purged to avoid the accumulation of inert methane within the process, while the remaining stream is compressed and recycled back to the process, together with the fresh streams.

The liquid stream from the flash separator is processed in the separation section that consists of three distillation columns for complete removal of hydrogen and methane, and for recovery of benzene and nonreacted toluene.



Figure 1. HDA Process