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Developing Teamwork Skills among First Year Chemical Engineering Students using Cooperative Problem-Based Learning in "Introduction to Engineering" Course

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This study was conducted to investigate the development of teamwork skills among first year chemical engineering students using Cooperative Problem-Based Learning in "Introduction to Engineering" course. A pre and post-test questionnaire using Team Assessment Tool (TAT) established by Moore and colleagues was administered to 52 first-year chemical engineering undergraduates. This instrument is useful to measure individuals' rate on team's performance using 24 Likert-scale items. The main constructs for this instrument consist of interdependency, potency, goal-setting and learning. The descriptive analysis provides the mean, standard deviation and frequency to see the significance of the pre and post-test results. The paired sample t-test was used to determine the significant differences of teamwork level between at the beginning and end of the course. The results from paired sample t-test shows that there was significant increment ($p < 0.05$) for teamwork in its constructs like interdependency, potency, goal-setting and learning. This shows that the students have developed teamwork skills after undergoing the "Introduction to Engineering" course.

1. Introduction

The world is facing new and complex challenges that require collective efforts of professionals. To be successful in today's world, engineers must possess professional skills, especially team working skills to tackle the novel, complex problems of today. One of the Engineering Accreditation Council (EAC, 2012) criteria requires graduates to have the ability to work on multi-disciplinary teams (Moore et al., 2006). A team which consists of individuals has seen themselves as a social entity, and they are relying with others because they have to complete the task as members in one group. This educational process will affect both individual and group learning development while completing the given task (Guzzo, 1986).
There is a need to distinguish the terms "groups" and "teams". A group of people in one team have to be interdependent, which means that every team members must cooperate and rely on the others when completing the given task (Moore, 2006). Other characteristics of teams are potency, where the team members have to share their belief so that they can be effective (Guzzo, 1993). The next characteristic is goal setting, where the team members have to set their own goals and sub-goals to complete the task (Locke, 1990). These characteristics distinguish "teams" from the term "groups." By working cooperatively, students can enhance their professional skills as well as being motivated towards completing their task and goals (Barak and Maymon, 1998).

2. Cooperative-Problem Based Learning

Teamwork is defined as a cooperative learning process which enables a group of students to achieve extraordinary results (Scarnati, 2001). Team members also have the same goal and they can develop effective relationships to achieve their goals (Harris and Harris, 1996). The team members work together under cooperative environment by sharing knowledge, ideas and perceptions to achieve their team goals. A

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team members that are willing to participate, cooperate and contribute in order to promote and nurture a positive environment will leads to a successful teamwork (Tarricone and Luca, 2002). The engineering students should prepare themselves with teamwork skills to get familiar with the business environment if they want to be successful engineers in future (Asonitou, 2013). The educational system provides very few opportunities for students to develop teamwork skills (Glaze, 2014). Students are expected to develop team working skills on their own when they are grouped together to do assignments or projects (Ettington and Camp, 2002).

To overcome this problem, the appropriate learning environment must be implemented to support the development of learning teams in engineering courses. To develop team working skills, first year chemical engineering students in a research university in Malaysia takes a compulsory 3-credit hour course called "Introduction to Engineering". To constructively align the desired outcomes to the teaching and learning activities, Cooperative Problem-Based Learning (CPBL) is implemented in the course. CPBL is the infusion of Cooperative Learning (CL) into the Problem-Based Learning (PBL) cycle to develop team-based problem solving skills among students (Mohd-Yusof et al., 2016).

PBL is known as an innovative learning process that enhance students' deep learning, professional skills, especially self-directed learning and problem solving. PBL is implemented in medical school in small group of student (max. 10 students) and it is not effective to be implement in engineering course which has a large number of students in one class (Yusof et al., 2012). Students do not automatically attain teamwork skills when they are assigned in a group (Wee, 2005). CL is promoted to support PBL approach so that the students are able to function cooperatively with the others. For successful of CPBL, PBL implementation and the addition with five principles of CL; (i) positive interdependence; (ii) individual accountability; (iii) face to face interaction; (iv) interpersonal skills; and (v) group assessment; will encourage the students to work together as a team as they need to accomplish the task gained the same goals.

CL also helps to enhance students' accountability and cooperation which is important towards becoming a functioning team (Mohd-Yusof et al., 2013). With CPBL, the learning in class is now moving towards learning in teams and the students in the whole class are now learned in a learning community. The interaction and communication between the students can enhance their collaboration, that will give positive impacts on learning (Mohd-Yusof et al., 2013).

3. "Introduction to Engineering" course

"Introduction to Engineering" course has been introduced and is compulsory to all first-year Chemical Engineering students since 2010 in Malaysian universities. This three-credit hour course is implemented to bridge the gap between learning in a school and university (Knight et al., 2007). The purpose of this course is to support students to understand engineering and to motivate them to see themselves as future engineers (Mohd-Yusof et al., 2014). The contents of this course include the overview of engineering, the profession and its requirements in the Malaysian scenario, basic calculations of common process variables and unit conversions, create an engineering graph, solve simple iterative problems using Excel, a case study related to sustainability and also an introduction to engineering ethics (Mohd-Yusof et al., 2014).

In this course, student-centred learning approach using Cooperative Problem-Based Learning (CPBL) is implemented. CPBL has been proven to enhance students' learning while developing students' teamwork skills, improve motivation in learning strategies, deep learning, as well as develop team based problem solving skills (Yusof et al., 2013). During the CPBL implementation, lecturer assists and supports students to arrange class activities or provide scaffolding activities to enhance the students' skills development. To promote Cooperative Learning (CL) principles into Problem-Based Learning (PBL) cycle, the CL activities are used to expand in every phase; (i) individual construction; (ii) interaction with peer or team members; and (iii) overall class interaction for closure. In CPBL cycle, the instructor has provided the main problem-based project that need to be resolved by the students in three phases, where each phase will help the students to slowly develop the process to solve the problem. During this process, students will experience three main pillar of CL; (i) face to face interaction with team members, (ii) individual accountability and (iii) positive interdependence (Froyd, 2014).

There are various activities in this course including formal and informal cooperative learning activity, such as brainstorming, group discussion, peer teaching notes, teams' logbook, peer rating, individual reflections, feedback session, group competition, tournament and exhibition participation, which can help students to enhance their contributions with other team members (Mohd-Yusof et al., 2016). CPBL also requires students to solve complex, open ended problems that are related to sustainable development, do engineering overviews, basic engineering calculations and engineering ethics. At the end of this course, students will be able to understand the field of engineering and develop important skills to learn especially team working, as well as prepare them to be good future engineers.

A previous study on third year chemical engineering students has proven the significant impact of CPBL on the development of team working skills (Mohd-Yusof et al., 2013). From the qualitative study, the third-year students have successfully gained teamwork skills after undergone “Introduction to Engineering” course. In this study, CPBL also has been implemented to the first-year introductory course. This study was conducted to investigate; to what extends the Cooperative Problem-Based Learning approach can develop the team work skills after the first year chemical engineering students undergone “Introduction to Engineering” course?

4. Research Objective, Research Question and Hypothesis of the Study

This study was conducted to investigate the development of team work skills among first year chemical engineering students using CPBL in “Introduction to Engineering” course. The research question for this study is (i) To what extends the CPBL Learning approach can develop the team work skills after the first-year chemical engineering students undergone “Introduction to Engineering” course? The null hypothesis for this study is as follows;

H_o: There are no statistical significant differences of first year students’ development in teamwork skills after experiencing CPBL approach in “Introduction to Engineering” course.

5. Methodology

A quantitative research via survey questionnaire was employed among first year chemical engineering students at a university in Malaysia. The survey questionnaire was conducted from September 2015 to January 2016 with 52 chemical engineering students throughout the semester. The respondents were selected among first year engineering students from two classes that were taught by different lecturers. 60 students enrolled in the “Introduction to Engineering” course were divided into two sections. 52 respondents were selected among the first-year chemical engineering students based on Krejcie and Morgan Table (Krejcie and Morgan, 1970). Items from established inventory of Team Assessment Tool (TAT) introduced by Moore and colleagues (2006) were selected as the survey questionnaire and statistically tested. The data collection was performed in two different classes at the beginning and at the end of semester to investigate the development of team working skills among the first-year students after experiencing CPBL in “Introduction to Engineering” course. The survey utilised TAT questionnaire, which comprises of four main constructs(i) interdependency; (ii) potency; (iii) goal-setting; and (iv) learning. The questionnaire was completed by the respondents by selecting one of the five possible responses to each question (Kaul and Adam, 2014). The survey was conducted in the printed form and the respondents were given five to ten minutes to answer all questions. The questionnaire consists of 24 items using 5-point Likert scale (1 - Strongly Disagree, 2 - Disagree, 3 - Neutral 4 - Agree, 5 - Strongly Agree), which assess interdependency, potency, and goal-setting, as well as learning. The Cronbach’s Alpha reliability coefficient for each construct were (i) interdependency ($\alpha = 0.907$); (ii) learning ($\alpha = 0.765$); (iii) potency ($\alpha = 0.853$); and (iv) goal setting ($\alpha = 0.856$), which are reliable since the values of $\alpha > 0.6$. Table 1 shows the number of items and Cronbach’s Alpha value under four main constructs.

Table 1: The Cronbach’s Alpha value for each construct in TAT questionnaire

Construct	No. of Items	α
Interdependency	9	0.907
Learning	5	0.765
Potency	5	0.853
Goal Setting	5	0.856

6. Results

The quantitative study was carried out to investigate the development of team work skills among first year chemical engineering students using Cooperative Problem-Based Learning in “Introduction to Engineering” course. Table 2 displays the overall descriptive statistic on the constructs of interdependency, learning, potency and goal setting of first year engineering students in Faculty of Chemical and Energy Engineering. Referring to Table 2, it is clearly indicated that there is a significant difference on individuals’ rate on team’s performance. From Table 2, students that undergone “Introduction to Engineering” course have improved their interdependency to contribute and collaborate with the others since the mean value of post-test (4.11) > pre-test (3.91). The students also perceived that they manage to improve their learning process while collaborating in community since they have to work and cooperate together to accomplish the give task (Post-test (4.38) > Pre-test (4.18)). Working in community also has improved students’ potency in sharing their belief

(confidence and accomplishment of task), where the mean value of post-test (4.23) > pre-test (4.01). This course also helps the students to acknowledge and set their own goals, where the mean value of post-test (4.05) > pre-test (3.77). Overall results stated that all students have managed to develop their team work skills in interdependency, learning, potency and goal setting after going through the course.

Table 2: Mean and standard deviation value for first year students' teamwork skills development.

	Mean	N	Std. Deviation	Std. Error Mean
Mean interdependency (Pre)	3.9060	52	0.47006	0.06519
Mean interdependency (Post)	4.1111	52	0.57546	0.07980
Mean learning (Pre)	4.1769	52	0.53819	0.07463
Mean learning (Post)	4.3846	52	0.49125	0.06812
Mean potency (Pre)	4.0077	52	0.51634	0.07160
Mean potency (Post)	4.2269	52	0.57124	0.07922
Mean goal setting (Pre)	3.7731	52	0.48187	0.06682
Mean goal setting (Post)	4.0500	52	0.57514	0.07976

From Table 3 below, the p-value of interdependency, learning, potency and goal setting was less than 0.05 ($p < 0.05$). This means that the null hypothesis (H_o: There are no statistical significant differences of first year students' development in teamwork skills after experiencing CPBL in "Introduction to Engineering" course) should be rejected. There is a statistical significant difference of first year students' development in teamwork skills where the constructs' significant different (p-value) was interdependency ($p = 0.01$), learning ($p = 0.02$), potency ($p = 0.02$) and goal setting ($p = 0.001$).

Table 3: Paired sample t-test.

	Paired Differences	t	df	Sig. (2-tailed)	$p < 0.05$
	95 % Confidence Interval of the Difference				
	Upper				
Mean interdependency (Pre) Mean interdependency (Post)	-0.04951	-2.646	51	0.011	Significant
Mean learning (Pre) Mean learning (Post)	-0.02855	-2.328	51	0.024	Significant
Mean potency (Pre) Mean potency (Post)	-0.03696	-2.415	51	0.019	Significant
Mean goal setting (Pre) Mean goal setting (Post)	-0.11708	-3.478	51	0.001	Significant

7. Discussions

The first-year chemical engineering students were able to develop teamwork skills after undergone the "Introduction to Engineering" course. The results show that the first-year students perceived that they managed to improve their teamwork skills for each construct of interdependency, learning, potency and goal setting. At the beginning of the semester, the students were formed into three to four members' groups with different races, ability, prior knowledge and their own perception in engineering. Each member has their own ability, which can lead to perfect teamwork. The students stayed in the same group for the whole semester and they managed to attain the motivation to work in community and this helps to prepare them to work in the new environment of society once they graduated. The learning process in team has helped the students to cooperate and depend with others to accomplish the given task.

The "Introduction to Engineering" course has implemented CPBL as the learning approach and it assisted the students to works as a team to accomplish the given task. To ensure the students gained a perfect teamwork, the five principles of CL have been promoted in CPBL implementation; positive interdependence, individual accountability, face to face interaction, interpersonal skills and group assessment (Mohd-Yusof et al., 2013). The five principles were implemented to improve students' interdependency, potency, learning and goal setting.

For example, the team members were given the problem by the instructor and they must have their own logbook. Every task, roles, activity, Gantt chart schedule, meeting, including their team vision, mission and goals must be recorded in the logbook. The roles of every team members also kept changing as the project or

assignments added. This provided the opportunities for the students to become interdependence, responsible, accountable and belief with their role since they have to work the best for their teams. The logbook also became the reference for the teams as the progressive feedback to achieve the same goals and they must help one another to complete the task.

The “Introduction to Engineering” course also helps to develop students’ learning. Students that work in team will always share their knowledge, skills and ideas to ensure that their teams will success in achieving their goals. For example, the instructor has conducted a Team Games Tournament (TGT) in all class and the team with higher mark will win the tournament. TGT is proven to increased basic skills, students’ achievement, positive interactions between students and individual accountability (O’Mahony, 2006). In this tournament, every team members must practice and help each other to answer the questions. Later, they will be grouped according to their prior quiz marks and they must answer the tournament questions individually. Then, the marks were combined for each team and the team with the highest mark will be the winner of the tournament. So, with this tournament, students were able to gain their learning process as they discussed, explained, taught and helped one another to gain the highest mark for their own teams.

At the end of the semester, the students managed to develop the characteristic of teamwork skills such as interdependency, learning, potency and goal setting after they are cooperated with others. However, the results from mean, standard deviation and significant differences (p-value) gives a little impact or differences between pre and post test results. This happen because CPBL approach were only being implemented in the “Introduction to Engineering” course. Hopefully in the future, CPBL can be promoted in other course to help the students to inculcate their teamwork skills.

8. Conclusions

From the results, there is a statistical significant difference of first year students’ development in teamwork skills after experiencing CPBL approach in “Introduction to Engineering” course. The first-year chemical engineering students have perceived that they manage to improve their teamwork skills especially in interdependency, learning, potency and goal setting. This is very important since teamwork skills is one of the criteria needed in EAC 2012 manual, where the engineering graduates must have the ability to work on multi-disciplinary teams. The “Introduction to Engineering” course, which implements CPBL as the learning approach has also managed to improve students’ process to learn since the students have to work in a learning community and they must cooperate with others to share their knowledge, skills and ideas. This learning process has made the students became accountable, interdependence, motivated and responsible when they work in teams. Students are willing to do their best since they will be ranked based on individuals and teams’ performance and this will enhance their goals setting and potency belief. As for the conclusions, the “Introduction to Engineering” course is very effective to develop first year students’ team work skills by using CPBL implementation and this approach should be implemented in other courses so that students can achieve appropriate professional skills once they have graduated.

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