Engineering Team Project Course for Development of Teamwork Skills

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Abstract

The globalization trend prevalent in the business and industry has created the demand for engineers with multidisciplinary teamwork skills. Great emphasis is given on technical knowledge in institutions of higher learning, in order to equip engineering graduates with technical competence that is required of the workplace. In the real working environment, however, engineers are expected to not only be technically competent, but also to have the ability to work well within a multidisciplinary team situation. Effective teaching and cooperative learning skills are vital in equipping students with the experience of collaboration and interaction with peers of diverse discipline and background. A unique course identified as Engineering Team Project (ETP) was introduced as a tool to inculcate multidisciplinary teamwork skills among the engineering students from various backgrounds. This paper highlights the curriculum structure, operational mechanism, and the experience of operating the course in providing the students with the environment for building teamwork skills.

Keywords: multidisciplinary; teamwork; engineering project

1. Introduction

Traditional engineering programs at institutions of higher learning put emphasis on technical knowledge in order to produce graduates who meet the job demands. The stakeholders of the degree programs have high hopes that each of the graduates would be able to meet expectations of employers. Nevertheless, in the fast moving and challenging engineering industries nowadays, individual technical competency is not sufficient to help companies or organizations stay competitive. Soft skills such as the ability to communicate with others are among the important traits that graduates must have in order to acquaint well on the technical and business information.

At Universiti Teknologi PETRONAS (UTP) in Malaysia, the engineering education programs are outcome based and designed in line with the University mission that is to produce well-rounded graduates. The context of well-rounded quality that is defined by the University [1] desires its graduates to possess seven attributes, which are solution synthesis ability, practical aptitude, business acumen, communications and behavioral skills, critical thinking, technical competency, and lifelong learning capacity.

The communication and behavioral skills, among others, require graduates to be able to demonstrate teamwork. This is also in line with one of the program outcomes of the engineering programs at UTP; graduates are expected to function and communicate effectively in a variety of professional context as an individual and in a team based approach, with the capability to be a leader.

Then university views teamwork as a vital skill for engineering graduates. In real working environment, engineers have to rely on and work with others at various stages of a job assignment. With the rapidly increasing technological and operational complexity in engineering practices nowadays, multi-disciplinary teams are prevalent. Diverse perspectives in projects are becoming common in order to produce quality products or services that can meet the market requirement and hence provide a competitive edge for the company. In addition, engineers are also expected to work with people of different background, ethnicity, nationality and gender. This is prompted by the current trend of globalization in business and industry where diversity is the norm. As multi-disciplinary teamwork skill is usually gained through working with peers over a period of time, young engineers would normally face difficulty at the development stage of their career when working with others, whereas their employers expect them to be good team players at the instant they join the company. Motivated by such requirements, UTP has initiated a course known as the Engineering Team Project (ETP) to inculcate multi-disciplinary teamwork skills that are required in real working environment.

There is no known institution of higher learning in Malaysia that offers a similar course like the ETP. However, there are a few institutions of higher learning elsewhere that offer similar courses such as in Denmark [2], United States of America [3, 4], Israel [5] and Sweden [6], although the structure of the courses and their perspectives differ. In addition, most of these courses are offered as first-year design courses, in which the students' knowledge, in relation to the projects, is mainly based on physics, chemistry and mathematics. On the other hand, ETP explores a wider scope of engineering knowledge, considering the course is taken by third year students. This paper aims to discuss the framework and operation of ETP in UTP as a tool for engineering graduates to develop teamwork and communication skills that are necessary for their professions. The scope of discussion of this paper is limited to UTP.

2. Course Descriptions

The ETP course emphasizes on teamwork, creativity, originality and application of engineering fundamentals. At the end of the course, students should be able to:

1. Apply engineering knowledge and solve engineering design problem
2. Work in a multi disciplinary team-based project work
3. Apply the principles of project management
4. Apply proper design process to produce creative and innovative solution
5. Demonstrate effective communication, report writing, presentation and entrepreneur skills

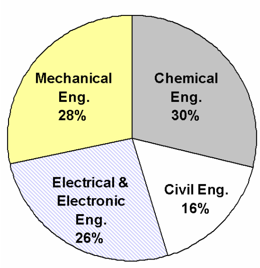
The course is compulsory for all undergraduate engineering students at UTP in fulfilling the graduation requirement [7].

2.1. Formation of Project Groups

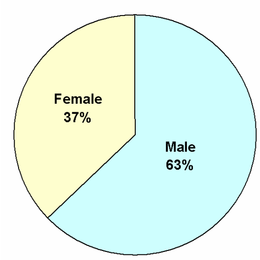
In every semester, about 400 engineering students from different programs and backgrounds enroll for this course, which is offered twice a year. Shown in Fig. 1 is the distribution of students in terms of program, gender and nationality for a recent semester. Allocation of groups with perfectly heterogeneous composition of members is not always possible; for example, the male students outnumber their female counterparts with a ratio of about 1.7:1. Further to the distribution of students in Fig. 1, the assignment of student groups was generally made based on the following guidelines:

1. The number of students in each group was between four and six
2. One female member in each group
3. Optimum number of members of the same ethnic groups
4. One foreign student in each group
5. A maximum of two students of the same program in each group

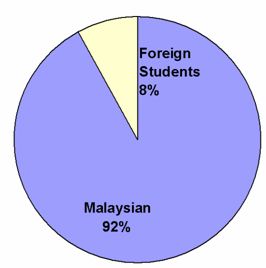
An example of the distribution of students for an ETP group is shown in Table 1.



(a) Program



(a) Gender



(a) Nationality

Fig. 1. Typical distribution of students in a semester.

Table 1: Typical composition of students in a group

Background	Students					
	1	2	3	4	5	6
PROGRAM						
Electrical				■	■	
Chemical		■				
Civil						■
Mechanical	■		■			
GENDER						
Male	■	■			■	■
Female			■	■		
RACE						
Malay			■	■	■	■
Chinese		■				
Indian						
Others	■					
NATIONALITY						
Malaysian		■	■	■	■	■
Non-Malaysian	■					

2.2. Choice of Projects

Each group is responsible to produce a working conceptual prototype or model using fundamental engineering knowledge acquired for the last four semesters in the university. The time frame to materialize the prototype is about 12 weeks, with the remainder of two weeks to prepare and present the report of their findings.

Fig. 2 shows the number of students and evolution of ETP project determinations since its inception. In the early years, two projects were specified and assigned to the students. At a later stage, more projects were allocated but the students could not choose the topics. In 2003, as the population of the university increased, the students were given freedom to generate their own topics, although they may also choose to work on projects identified by lecturers.

Since 2007, in line with the main research interest of the university, the project topics have been generated by the students and supervisors, based on a few pre-determined themes. The themes in the July 2007 semester were automotive, automation and robotics, energy, environment, innovations for the disabled and petroleum-related researches.

Table 2 shows a few sample projects that were undertaken by students in the past. The project themes may vary over time depending on the current interest. For example, the theme Innovation for Special People was generated following an invitation from a local company to participate in a national level competition.

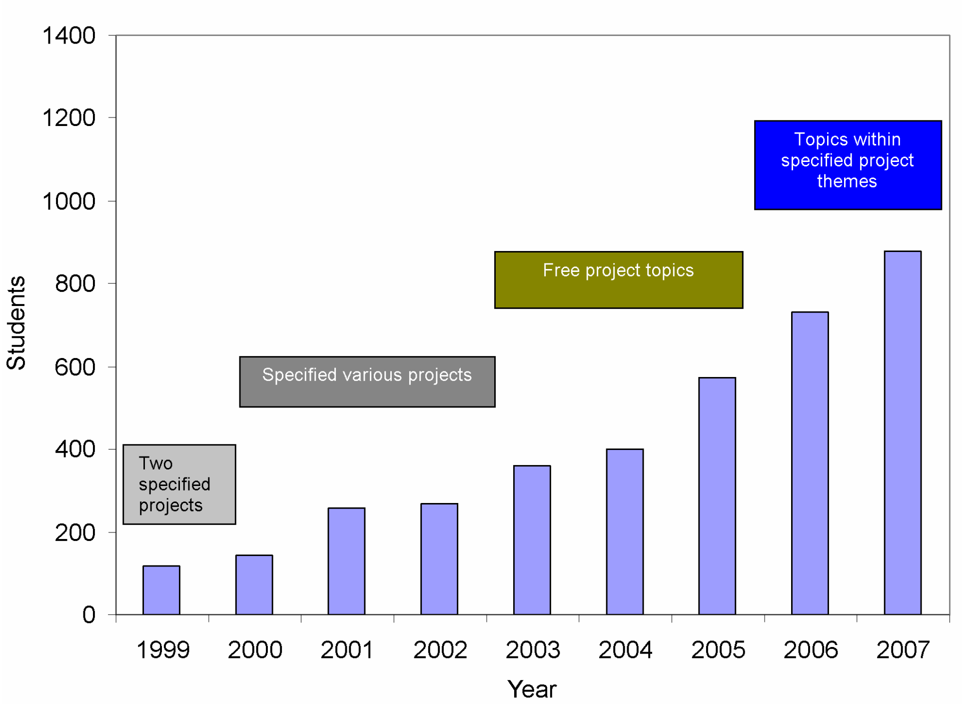


Fig. 2. Course enrolment and project selection methods.

Table 2: Samples of past projects.

No	Titles	Theme
1	Solar-Powered Evaporative Cooler	Energy
2	Portable Bio-Diesel Production System	
3	Improving Brick using Sludge	Environment
4	Activated Carbon from Oil Palm Waste for Waste Water Treatment in Batik Industry	
5	Portable Eye-Therapy Device	Innovation for Special People
6	Intelligent Guiding Device for the Blind	
7	Development of Asam Gelugor Slicer	Automation and Robotics
8	Motorcycle Parking Security System	
9	Vehicular Communication System	Automotive
10	Smart Window System for Cars	

2.3. Course Schedule

In the past [8, 9], students were assigned with groups, topics and supervisors during the first week of the semester. Recently, the allocations of groups and supervisors have been carried out before the start of the semester via e-mails and e-learning [10]. Thus, students commence their work earlier and with proper project management, would give them ample time to manage the project and produce prototypes of acceptable quality. The number of supervisors is based on the number of student cohort for the semester. The coordinators assign a lecturer to be the supervisor to every student group. Most lecturers supervise only one group. As soon as the supervisor assignment is finalized, students begin consulting their respective supervisors to decide on the title.

Throughout the whole course, team members are responsible to arrange for mandatory weekly meetings with the supervisors in order to meet with the deadlines. The meetings are intended for planning and monitoring of each of the team projects. Students identify their leaders and distribute the tasks and responsibilities from conception and design until fabrication and testing of the prototypes. Since the projects are of multi-discipline, it is common that the responsibilities for each components or parts are given to the corresponding student; e.g. electronic controls are designed by students from the Electrical and Electronic Engineering program. Shown in Fig. 3 is the schedule of the ETP course, indicating the major activities or milestones throughout the 14-week semester.

Week Number / Activities/Milestone	1	2	3	4	5	6	7		8	9	10	11	12	13	14
ETP Briefing	X							Mid-Semester Break							
Seminar I		X													
Submission of Project Proposal			X												
Seminar II				X											
Submission of Progress Report						X									
Seminar III									X						
Evaluation on Fabrication												X			
Oral Presentation, Poster Exhibition, Demonstration													X		
Submission of Final Project Report															X

Fig. 3. Course schedule.

In the first week of the semester, the students are required to attend a briefing session during which they are informed about the operation, expectations and deliverables of the ETP course. Seminars are conducted intermittently during the semester to provide motivation and useful information to help students plan and manage their projects. By the third week of the semester, each group is required to submit a project proposal, which comprises of, among others, the problem definition, project objective, preliminary study, project plan and methodology. The project proposals are graded by the supervisors, who will also provide feedbacks to the students in order for them to make necessary improvements. Before the mid-semester break, as shown in Fig. 3, each group is required to submit to the supervisor a progress report, which provides details of the activities that have been implemented as well as those that need to be carried out. In addition, the reports also address potential problems, the conceptual designs that have been considered, the necessary preliminary engineering calculations, data collection and benefit-cost analysis that have been used in deciding the final design. Similar to the project proposals, progress reports are evaluated by the supervisors, who are also required to disclose the score marks and comments to the students.

Four weeks after the mid-semester break, the prototype shall be completed. The group supervisor will evaluate the prototype in terms of fabrication methods, functionality and quality. It is common that the students will put efforts on improving their prototypes based on the comments provided by their supervisors. About one week after the evaluation, all groups are required to present their project, to a panel of examiners whom are non-supervising engineering lecturers via posters, oral presentations and demonstration of the prototypes. In the final week of the semester, each group is required to submit a final report, which presents the ultimate results and findings of the project. Further details of the operation of the ETP course is explained in the ETP guidelines [11], which are circulated to students and supervisors at the beginning of the course.

2.4. Deliverables

Table 3 shows the breakdown of the deliverables of the course. The evaluations by group supervisors are shown in the second column in Table 3 and represents 60 % of the total course mark. The remainder 40 % comes from the evaluation by the panel examiners. It is usual to expect differences in the performance by every member in the team, and thus two approaches to differentiate students' marks individually have been put in place. The first approach is the individual oral presentation, which carries 5 % of the total course mark. The individual oral presentation is delivered in series by team members.

The other approach, which is more stringent, is known as the F-factor and is evaluated by the group supervisor. The F-factor is determined through weekly evaluations of logbooks and attendance in meetings throughout the semester. The summation of the weekly scores will be normalized to become a factorial number with a minimum value of 0 and a maximum value of 1.0. The individual F-factor obtained by each student will be multiplied with the scores for the deliverables that are evaluated by the supervisors.

Table 3: Course deliverables

Components	Assessment Contribution	
	Supervisor	Panel of Examiners
Project Proposal	S1 10 %	
Progress Report	S2 10 %	
Evaluation on Fabrication	S3 10 %	
Demonstration of Prototype		E1 15 %
Poster Evaluation		E2 10 %
Group Oral Presentation		E3 10 %
Individual Presentation		E4 5 %
Final Report	S4 30 %	
SUB-TOTAL	S5 60 % S1+S2+S3+S4	
Individual F-factor; 0 to 1.0 (Logbook & Meeting)	S6 1.0	
Total	**60 %** S5 x S6	**40 %** E1+E2+E3+E4

2.5. Seminars

The role of supervisors is eminent in guiding the students to independently explore and manage their projects within the achievable scope as outlined in the course. However, until the time they enroll for the course, certain aspects, such as project management and innovation, have never been taught or demonstrated to students. Therefore, a few seminars with suitable themes are presented to students throughout the semester to provide useful tools in the planning and implementation of their projects. The speakers of the seminars are the ETP coordinators, in-house lecturers and adjunct lecturers. Each seminar usually runs for about an hour, followed by a session for questions and answers.

3. Discussions

3.1. Challenges and Problems

At the early stage of the course, the students have the opportunity to explore potential topics by weighing the feasibility, advantages and benefits of each topic. They are expected to be actively involved in negotiation and communication, which in turn could become a good exposure in preparing them for future career. However, there are times when the supervisors insist on carrying out project topics of their interests despite the students' inclination for different topics. Usually students tend to abide by the recommendations made by their supervisor, given the fact that their supervisor will be the main evaluator of their work. The drawback of this situation is that the students would tend to be followers rather than thinkers or leaders.

When the concept of free topic was introduced, as depicted in Fig. 2, there was no proper control on the suitability of the project topic due to the large number of groups and supervisors besides the time limit. As a result, certain impractical projects were allowed at the discretion of the supervisor. For example, there was a project that involved poisonous material and was only realized to be infeasible at the end of the project. To minimize this problem, a self-assessment system with regard to the feasibility of a chosen project topic has been put in place in January 2008. Through this approach, the project topic shall be assessed by the supervisor using a rubric form against nine criteria, which are:

1. Opportunity for teamwork development
2. Technical competency and capability of team vis-à-vis project
3. Availability of equipment required
4. Opportunity to incorporate creativity, innovativeness and business acumen
5. Risk in operational safety (e.g. laser cutting)
6. Involvement of hazardous materials (e.g. arsenic)
7. Time required for project completion
8. Variability in discipline, knowledge and skills
9. Project cost

The completed self-assessment shall be checked by the coordinator who will try to seek clarifications from the respective supervisors on the options in case of non-compliance.

Git and Sulaiman (2008) reported that about 10 % of students who enrolled in the course in the July 2007 semester responded having difficulty in working with others. This was probably due to the fact that, they had to work together with members of various personalities, in addition to the diversity in discipline, gender, ethnicity and nationality of the group members. Due to time limitation and commitment for other courses, team-building exercise, which is an important tool for effective team development, is almost impossible. Therefore, it is usual to anticipate weak relationship and understanding between members especially during the initial phase, which in turn, could result in ineffective and non-productive teams. Thus, it is a vital role of the supervisors in guiding and coaching the students to work together successfully. Occasionally, there are also complaints from team members, which require specific attention, such as:

- Discrimination by gender
- Domination by an individual
- Members not participating (being a passenger)
- Disturbance or failure caused by personal problem of an individual member

Another challenge in the operation of the ETP course is the tendency of supervisors and appointed examiners in giving greater consideration on the evaluation of the products as compared to the process undertaken in the project development. A similar issue was also highlighted by Malmqvist et al., (2004). In addition to good project management, there are many factors that contribute to high quality prototypes such as complexity of the prototype development, availability of material, and cost, of which the evaluators may overlook. As good or high quality prototypes may not necessarily indicate that students have acquired the learning outcomes of the course, supervisors and examiners are continuously reminded to avoid evaluations that are solely biased towards the quality of the prototypes.

3.2. Perceptions from Stakeholders

In a recent work [12], it was shown that the ETP course was perceived by the majority of students and supervisors as an effective tool in developing teamwork skills for students. Despite the effectiveness of the ETP, there are various challenges, in which the university continuously seeks ways to overcome.

In this work, a survey was conducted among the local industries to investigate their perceptions on the students who underwent internship programs at their companies in the succeeding semester. The purpose of the survey was to measure the learning outcome of the ETP course. The total number of respondents was 149.

Shown in Tables 4 and 5 are the results of the survey. The scores range from 1 (strongly disagree) to 7 (strongly agree). Questions that were deemed not applicable (NA) to the students are recorded in the second last column from the left. In Table 4, the lowest score is shown to be 5.6 and highest is 6.0. The overall average score is 5.73. Thus, it is shown that from the industrial point of view the respondents satisfactorily agree that the learning outcomes of the ETP course were met.

Table 4: Survey responses on comes learning outcomes

	ETP LEARNING OUTCOMES	1 (Strongly Disagree)	2	3	4	5	6	7 (Strongly Agree)	NA	Average
Q1	Able to apply engineering knowledge to solve engineering design problem, when given the opportunity	0	0	0	13	45	39	24	*28*	***5.6***
Q2	Able to work in a multi disciplinary team	0	0	0	10	33	57	46	*3*	***6.0***
Q3	Able to demonstrate good project management skills	0	0	2	12	35	48	26	*26*	***5.7***
Q4	Able to apply proper design process in producing creative and innovative solution, when given the opportunity	0	0	1	13	38	28	28	*41*	***5.6***
Q5	Able to demonstrate effective communication, report writing and presentation skills	0	1	3	8	34	57	45	*1*	***5.9***
Q6	Able to demonstrate entrepreneur skills, when given the opportunity	0	0	2	9	35	32	21	*50*	***5.6***

Table 5: Survey responses on teamwork skills

	TEAMWORK SKILLS	1 (Strongly Disagree)	2	3	4	5	6	7 (Strongly Agree)	NA	Average
Q7	Quality of work: Provides work of highest quality that contributes to excellence of the team's work	0	0	1	8	34	50	54	2	***6.0***
Q8	Time management: Gets things done on time in meeting deadlines set by the team	0	0	2	10	23	56	56	2	***6.0***
Q9	Problem-solving: Actively looks for and suggests solutions to problems	0	0	2	15	39	50	35	8	***5.7***
Q10	Reliability: Others can count on this person	0	0	2	11	32	51	52	1	***5.9***
Q11	Ability to listen, share and motivate team members	0	1	4	10	31	66	32	5	***5.8***
Q12	Feedback: Always provides and seeks constructive feedback	0	0	2	15	34	56	40	2	***5.8***
Q13	Conflict resolution: Able to find common ground with other team members. Student is not disruptive and does not require intervention	0	0	1	11	31	50	41	15	***5.9***

It is also shown in Table 4 that some of the questions were significantly responded as "not applicable"; for example, 34% on the ability of students to demonstrate entrepreneur skills (Q6).

This was mainly due to the inability of the host companies to provide training related to entrepreneurship. Furthermore, the feature of their industrial internship programs was mainly focused on exposure to technical related experience. Similarly, 28% of the respondents answered "not applicable' on the ability of students to demonstrate the ability to apply proper design process in producing creative and innovative solution (Q4). This was mainly due to the fact that most of the companies that participated in the industrial internship program were not involved in design activities.

The same trend of the results in Table 4 is shown in Table 5, which is specific on teamwork skills. The overall average score in Table 5 is 5.87, with the lowest and highest scores of 5.7 and 6.0, respectively. This suggests that from the industrial point of view, the students possessed good teamwork skills. The number of responses for "not applicable" is low, with the maximum of 15 (10%). These are significant for problem solving (Q9) and conflict resolution (Q13), which are probably caused by lack of authority given the students who were only trainees at the host companies.

4. Conclusions

The Engineering Team Project at Universiti Teknologi PETRONAS has been instrumental in developing multidisciplinary teamwork for its engineering undergraduate students, to meet the workplace requirement for such skills. The course provides students with early exposure to working in teams with members of diverse technical background, ethnic, nationality and gender. The project-based course requires each team to produce a conceptual working prototype or model based on a topic from a list of pre-determined themes. In the process of planning and execution of the projects, students acquire skills in project management, effective communications, management of diverse perspectives and teamwork dynamics. The course structure and operation have been designed and continuously reviewed for improvement to achieve the objectives of teamwork development. Various strategies have been put in place with the aim to maintain and upgrade the quality of the course in all aspects. Attention and timely responses to arising issues and complaints are important in the improvement effort, in addition to an effective feedback system. As the requirements and expectations of stakeholders change over time, the course needs to be continuously reviewed and developed to keep pace and stay relevant.

Acknowledgements

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