

## A Multi-Year Study of Professional Skills Development among First Year Chemical Engineering Students

Aziatul N. Sadikin<sup>\*,a,b</sup>, Khairiyah M. Yusof<sup>a,b</sup>, Azmahani A. Aziz<sup>a</sup>, Mimi H. Hassim<sup>b</sup>, Zaki Y. Yamani<sup>b</sup>, Azizul A. Mustaffa<sup>b</sup>, Mohd K. A. Hamid<sup>b</sup>

<sup>a</sup>Center for Engineering Education, Universiti Teknologi Malaysia, Johor, Malaysia

<sup>b</sup>Faculty of Chemical & Energy Engineering, Universiti Teknologi Malaysia, Johor, Malaysia  
 aziatulniza@cheme.utm.my

There is an increasing demand from employers and stakeholders for chemical engineering graduates to have a range of professional skills in addition to their chemical engineering knowledge. For chemical engineering to continuously flourish as a discipline, our graduates will need to demonstrate professional skills at a higher level. Chemical engineering graduates are expected to be good in communicating in various forms, able to work in teams, able to solve problems, able to manage time well and continue to learn (life-long learning). These professional skills are more likely to be developed within the students if the skills are embedded into the curriculum, rather than taught in separate classes. It is essential for engineering courses to implement teaching and learning approaches that can help students to not only learn the content and at the same time develop crucial professional skills. The Introduction to Engineering course is designed to stimulate students' passion and strengthen their motivation for further engineering studies as well as enhancing their technical knowledge and relevant professional skills. This 3-hour credit course is required for all first-year chemical engineering students in Universiti Teknologi Malaysia. First year experience in the introductory engineering course was enhanced by competitive challenges, student-centred learning activities, problem solving and seminars that strengthen the development of students' technical knowledge and professional skills. The objective of this study is to determine the effect of an integrated teaching and learning approach on the professional skills development among first year chemical engineering students for three consecutive years. To study the impact of the course, the students were asked to write reflective journals on what they have learnt. The three years' data, Semester 2012/2013, Semester 2013/2014 and Semester 2014/2015 were collected from reflective journals written by students of different batch. Using thematic analysis, four main professional skills were identified from the reflective journals, namely team working, communication, problem solving and time management skills. The results consistently indicate that the introductory course allows students to engage in engineering practice and provide an early start to ensure engineering graduates are equipped with a broader set of professional skills and greater experience of addressing 'real' engineering problems. It was concluded that the integrated teaching and learning approach in Introduction to Engineering course is effective in promoting positive professional skills development among engineering students.

### 1. Introduction

Globalisation has prompted the need for engineers to possess professional skills as well as technical knowledge. Engineers need to embrace a broader vision of their professional role to respond to global challenges. Numerous studies have addressed the importance of professional skills development for engineering graduates. Graduate engineers need to demonstrate effective communication, creativity, team working, and understand societal and global issues that can help them function well at the work place. Many issues have been raised about the quality of the new graduates to meet the needs of the employers (Grant and Dickson, 2006). Many employers have expressed dissatisfaction with the professional skills of engineering graduates that they have hired indicating problems in workforce were mainly due to poor professional skills, rather than a lack of technical knowledge (Rugarcia et al., 2000).

In order to integrate technical knowledge and professional skills in the university curriculum, the mode of teaching and learning must veer away from traditional lecture-based models to more student-centred and project-based approaches. According to Grant and Dickson (2006), professional skills are more likely to be developed by students if the skills are embedded within the curriculum, rather than taught in separate classes. It is crucial to provide the students with tools at the start of their degrees that will make them more effective during their university career. It is essential that the development of engineering education takes into account the current and likely future needs of employers on the types of learning experiences that enable students to fulfil their potential.

For this reason, the "Introduction to Engineering" (ITE) course was introduced in the chemical engineering program in the 2005 academic year. The ITE course is designed to have a supportive student-centred learning environment that allowed students to develop important skills to learn, as well as understand and develop abilities required to be a good engineer when they graduate. The course aims to help students understand what is actually engineering, in everyday and professional context, and the need for good engineers, especially in facing up to the challenges of the 21st Century. ITE course has integrated various teaching approach such as active learning, cooperative learning, problem based learning and others in order to improve student's understanding on knowledge content as well as enhance professional skills development.

### **1.1 Underlying Educational Principles**

The ITE course is designed based on the How People Learn Framework (Bransford et al., 2004) and Constructive Alignment (Biggs and Tang, 2007). Based on constructivist principles, CA asserts that both the teaching and learning activities and the assessment tasks should support the development of the learning outcomes among students. Whilst, HPL framework consists of four criteria that define an effective learning environment that is conducive for learning: knowledge, learner, assessment and community centred. To incorporate both educational principles, Problem-Based Learning and Cooperative Learning are implemented as the teaching and learning approach to learn and solve a sustainable development based problem. PBL embeds small groups of students and presents them with a messy, unstructured, realistic problem, to solve. The problem is crafted to engage and immerse students in going through engineering processes and sustainable development issues. Students are guided through a Cooperative PBL cycle that helps them to identify and construct new knowledge. CL is based on five principles to develop and promote learning teams: positive interdependence, individual accountability, face-to-face interaction, appropriate interpersonal skills and regular team role assessment.

### **1.2 Course Description**

The Introduction to Engineering (ITE) course is a three-credit hour course. There are normally 30 to 40 students in a class, with three sections, facilitated by different lecturers, of the Introduction to Engineering course, giving a total of around 100 students. In each class, students are divided into teams of three to five students. The team is formed based on careful consideration of various factors to ensure heterogeneous groups, including gender, race, cultural background, English proficiency and academic achievement. Heterogeneous groups promote more diverse thinking and provide opportunities for students to develop feelings of mutual concern. Each group needs to have diversity in all these aspects so that besides achieving the technical outcome of this course, the professional skills especially related to interpersonal skill can be acquired. In early sessions of the course, students need to go through several activities designed to help them bond with their team members. These include identifying suitable name for the group, designing group logo as well as agreeing on the group regulations, in which each team member needs to be committed with.

The contents of this course include a short project on overview of engineering, the profession and its requirements in the Malaysian scenario, basic calculations of common process variables and unit conversions using active learning, introduction to engineering ethics using case studies and a problem on sustainable development (SD) using cooperative problem based learning.

The problem is set as a competition to find engineering solutions for issues related to SD that is practical and cost effective for the society, related industries and agencies are solicited and included in the problem to make it realistic. The problem is designed in three stages to gradually challenge students with increasing difficulty, while systematically providing the necessary support to scaffold students' learning. Stage 1 is for learning about SD, finding information on current world scenario, and benchmarking. Stage 2 is focused on the specific element of SD, data collection and analysis of the students' and families' consumption or generation, and pattern of behaviour. In Stage 3, students propose best engineering solutions and cost analysis. During the competition, the panel judges consist of experts in the area will invite to evaluate students' innovative product.

## 2. Research Objective

The objective of this research is to identify the enhancement of professional skills that students develop as they go through student-centred learning environment in the Introduction to Engineering course by using reflection journals written by students.

## 3. Methodology

The research was based on information gathered from cohort of three year in Introduction to Engineering course. The three years' data, Semester 2012/2013, Semester 2013/2014 and Semester 2014/2015 were collected from reflective journals written by students. Each year, all students were asked to produce four reflective journals throughout the semesters. The reflective journal was written at Week 6, Week 10 and then in Week 13. At the end of the semester, the students were asked to write an overall reflective journal to look back at their learning experience throughout the whole semester. They were briefed the format of a reflective journal for the purpose of reflecting their learning through various teaching and learning activities in the class.

After all the reflective were collected at the end of the semester, a qualitative data analysis technique recommended by Miles and Huberman (1994) was employed. A qualitative data analysis technique consists of data reduction, data display, conclusion drawing and verification. The first step of data analysis was to reduce the data in to a manageable volume to answer the research questions. By focusing on the research questions, information that was not important can be put aside. Keywords and phrases that could answer the research questions were highlighted.

## 4. Results and Discussion

This paper explores the enhancement of professional skills that students develop in the Introduction to Engineering course, which integrated various learning approaches. Table 1 shows the four generic professional skills most often mentioned in the students' reflective journals that were written in Week 6, Week 10, Week 13 and at the end of the semester. The number given in the table shows the number of students who mentioned the professional skill in the reflective journal of three semesters.

*Table 1: Professional skills found and the number in reflective journals of three semesters*

Professional Skills	Semester 2012/2013	Semester 2013/2014	Semester 2015/2016
Team Working	24	26	18
Communication Skill	26	24	29
Problem Solving Skill	19	27	23
Time Management	19	15	21

From the skills shown in Table 1, the reflection journal of each semester from one of the students that mentioned the skill was taken to provide a snapshot of his/her perception during the course. From the reflection journals that have been collected, it can be observed that there are four professional skills developed through learning activities by the first-year students; namely team working, communication, problem-solving and time management skills. Table 2 shows some sample quotes for each of the professional skills.

Students recognised the crucial importance of every team member's contribution and commitment to the success of the given task. For instance, the peer teaching activities in CPBL provides an environment in which students are encourage to teach each other and to share skills and knowledge. They also learnt that a team requires working together concurrently to success, while disparate functioning of team members adversely affects the attainment of learning objectives. The students demonstrate the ability to work with people who are difference from themselves. Managing conflict is another issue that have been highlighted in their reflective journals. According to Thomas and Clare (2011), bringing students together in engineering teams at a very early stage in their university life through working in groups provides an opportunity for the development of peer interaction and collaborative learning relationships. Compared to students taught traditionally, students taught in a manner that incorporates small-group learning learn at a deeper level, retain information longer, acquire greater teamwork skills, and gain a better understanding of the environment in which they will be working as professionals (Barbara et al., 2004).

Table 2: Example of quotation for skills found in reflective journal of three semesters

Professional Skills	Semester	Example of quotations from the reflective journals
Team Working	2012/2013	It is normal thing in team that we have problems with team members along the project is execute but then as a team we should try to communicate among members and try to overcome all the problem that we face.
	2013/2014	I learnt how to work with others, working with someone I don't familiar with different races. Working in the group teaches me to give and accept others' ideas without condemning it. We will not always have brilliant ideas so hearing others' opinion can help make us open to different thought and perspective. Other than that, working in a group helps us to be more tolerate with each other.
	2014/2015	Group research project instilled the value of teamwork in each team members as we know that engineers did not work as individual, instead work in team.
Communication Skill	2012/2013	It really suits me working in this environment for near future. It's really improve myself confidences well as my communication skills I hope that in years to come, there is a lot of programmed like this so that we can really learn something useful in our university life.
	2013/2014	Unexpectedly, I am bravely volunteer myself to explain about food waste. I am shocked with my improvement on my communication skills. Before this, I will make sure that I will be the one that can escape from explaining section. I had improved my leadership skills. I am proud with my new attitude and I will make sure that I will not change to my old self.
	2014/2015	My communication skill has been improved as well as throughout all the discussion that we had done. I become more confident and excited on presenting my part. I succeed to attract the attention of the people by my body language and loudness of voice.
Problem Solving Skill	2012/2013	Honestly, I am very happy with the report as each of us gives full commitment to complete it. All these works are not easy as abc as each of us need to brainstorm like a half dead person to come out with a good report. However, it taught me to be patient and don't give up even though the challenges are big.
	2013/2014	I faced difficulty in interpreting and list down information because I found the question of stage 3 as a complicated task. However, I managed to write it within the allocated time after think sharply for few minutes and after read the instructions few times. I highlighted the important points in the instruction sheet in order to make me understand the problem very well.
	2014/2015	The project involved a lot of critical thinking and team working skills; it may help us to increase our creativity in solving the problems.
Time Management	2012/2013	PBL was very beneficial for me as a first-year student. It had given me lots of exposure about university life. It also helped me to develop my soft skills especially time management which will be useful for me in the future. This kind of problem will equip me to become a better engineer in future.
	2013/2014	That's a lot of thing to do at once. It's quite hectic for all of us. From there, we learn on how to manage our time well and not to procrastinate our work.
	2014/2015	I learned time management skill. We had given few tasks in a limited time. This tests our skills to distribute our time according the priority of works.

The art of communication is important for engineering graduate (George et al., 2007). From the analysis of student's reflective journals, the majority of the students claimed that a communication skill is valuable for their academic endeavours. In their learning process, students learn how to analyse the unstructured problem given among the small group members and develop an idea into the discussion. Through these activities, students acquire communication skills in generating the ideas. They claimed that the four presentations made for CPBL project in ITE course provides students opportunity to practice and acquire the ability for oral communication. Students reflected that the practice was helpful and that they feel that they have the skills and more confidence to speak in public. The role of this learning approach was successful in enhancing the capability of communication skills among students. The students, in their reflective journals, also focused on the multicultural communication and reflected about how it helped them to understand people from other cultures and how they learnt to work with other people.

The problem-solving approach in this course has been strength of chemical engineering education. The CPBL is where the problem drives the learning. In this course, the problems were posed so that the students discover that they need to acquire some new knowledge before they can solve the problems. Students reflected the importance of problem solving skills that are in great demand by employers. The skills developed are consistent with studies on students who had undergone PBL for developing problem solving skills (Syed Ahmad et al., 2011). Problem solving has been defined as higher-order cognitive process that requires certain pedagogical ways to improve. The real big challenge of engineering education today is not only to produce expert in engineering disciplines, but also to produce knowledgeable students who are able to integrate and develop scientific knowledge in problem solving process.

Another aspect that surface out through the reflective journal is on time management skills. Time management is an important life skill and one that is vital to engineering student success in higher education. Time management is a process of determining needs, setting goals to achieve those needs, planning the tasks required, and prioritising them. Students reflected the need to learn to prioritise duties and tasks to get everything important done. The students demonstrate the ability to planning in advance, prioritising the work, and adhering to the present schedules. While the literature reflects support for the value of time management skills in academic success, this study provides exploratory for introductory engineering course as an aid in the development or enhancement of students' self-regulatory skills, specifically time management. A limitation of the reported results from the reflection journals is that actual improvement in time management skill was not measured; rather, the students' perception of improvement was measured. Therefore, further study with measures of actual time management skills is warranted.

The multi-year study of this paper explores students' skills of the 21<sup>st</sup> century that are needed for the modern graduate engineer. In today's global economy, communication, collaborative team working, critical thinking, problem solving and decision-making are key competencies necessary for an engineer. The Introduction to Engineering course focuses strongly on collaborative and problem based learning, tasks and assignments. Such activities required students to be involved in active learning strategies, be engaged in high-level problem-solving skills and be able to participate in team activities and forge collaborative partnerships amongst multi teams in class. This study also shows that active learning benefits student engagement; collaborative work is found to enhance academic achievement of students, their attitudes towards learning, and retention of students to the programme. Students' reflection journals indicate that students in the introductory course learn best through active activities conducted in small-group settings. Active learning involves students in meaningful learning activities and gets them to be reflective of their experience, thus deepening their understanding.

## 5. Conclusions

Globalisation of the engineering profession is forcing us to reconsider the role of future engineering graduates and the education required to meet that role. The Introduction to Engineering at UTM has adopted instructional and assessment approaches that encourage active, collaborative and problem-based learning. It would seem that the ITE course was successful in helping students to learn technical knowledge and professional skills that they need. This study shows that first year engineering students who went through the activities in the course were able to develop problem solving, team working, communication and time management skills. We believe that mastering these skills will be a major determinant of the future competitiveness of engineering graduates, enabling them to become highly innovative global "problem solvers". Looking to the future, the Chemical Engineering Department in Universiti Teknologi Malaysia plans to continue to run the course in the present form and to carefully monitor the feedback. ITE course alone cannot be effective on its own. Every other course in the curriculum needs to foster and assess these skills, integrating into their outcomes and assessment.

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