Project Based Learning Symposium: Preparing Students for the Workplace

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Project Based Learning Symposium: Preparing Students for the Workplace

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Martin Jaeger (Ed.)

Content

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Project Based Learning Symposium: Preparing Students for the Workplace

Introduction

Project Based Learning has received a lot of attention among educators around the world over the last decades. Different variations, models, and perspectives on Problem and Project Based Learning have emerged and led to approaches such as “Problem-Oriented and Project-Based Learning” and “Problem-Based Project-Organized Learning”. The common focus of the different Project Based Learning variations and models is triggering the students’ learning process by a more or less vague project scenario taken from a real life situation or similar to situations students will find at the workplace. This supports active and student centered learning based on challenges rather than learning discrete subjects.

The “Project Based Learning Symposium: Preparing Students for the Workplace” was an initiative of the Center for Project Based Learning in the School of Engineering at the Australian College of Kuwait. The symposium aimed at bringing together engineering educators, industrial employers and engineering students in order to exchange experiences and perspectives on Project Based Learning.

The Australian College of Kuwait is one of the leading institutions of higher education in the Middle East that utilizes a Project Based Learning approach in Engineering Education. Although Project Based Learning approaches have been applied for a long time in various disciplines and different geographic regions, Project Based Learning is still a new learning approach in the Middle East. Project Based Learning in the School of Engineering at the Australian College of Kuwait has been continually adjusted over the last years, in order to accommodate for the local and regional needs. The accumulated insights gained are based on both research related to active learning and practical experience with the Project Based Learning approach.

The papers of this proceeding were presented during the symposium and allowed insights into the practical application of Project Based Learning to various undergraduate engineering courses (seven papers), the relationship between industrial entrepreneurial skills and Project Based Learning (two papers), an institutional approach to ensure continual improvement of a Project Based Learning model (one paper), and the challenges involved in Project Based Learning team formations (one paper).

I hope these papers will inspire the reader and contribute to further and fruitful reflections on Project Based Learning in the Middle East and beyond.
THE APPLICATION OF PROJECT BASED LEARNING (PBL) IN FLUID AND ELECTRICAL DRIVE SYSTEMS

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Abstract
In this paper, the application of PBL in the fluid and electrical drive systems unit is presented. Two project briefs given to students are listed and examples of output work of students through two semesters are presented for the students in the Mechanical Engineering department of the School of Engineering at the Australian College of Kuwait (ACK). The aim was to expose the students to real world engineering problems. Based on restrictions that each engineer will face in real life work, the students had access only to pneumatic facilities available at the mechanical engineering lab at ACK for the fluid drive part of their learning outcomes and also learnt through their journey from simple electrical devices to application of micro processing tools. The goal of the projects was to acquaint students with concepts of robotics and automation. It was found that the students were able to design and build such mechatronic systems with a fixed amount of budget by the end of their semester with sufficient learning reflected in their portfolios.

Keywords  Automation, electrical drive system, fluid drive system, Project Based Learning

Introduction
PBL (Problem Based Learning) was initiated by McMaster University (De Graaff & Kolmos, 2007) and the idea was applied in many contexts from nursery schools to being used by medical students and others (Schweinhart & Weikart, 1997; Van der Vleuten et al., 1991; Sang, 2001; Schmidt, 1993). The implementation of Project Based Learning was extended later to engineering students (De Graaff & Bouhuijs, 1993; De Graaff et al., 2006). In the PBL environment, the instructor function is better described as “facilitating” rather than general lecturing (Jaeger & Adair, 2015). Students should imagine their instructor as the manager (or boss), their classrooms as the workplace, and their workbook and reflective
journals as their tools for the PBL environment. However, the students will be assured that they will not be fired (as it happens in real work) if their end product fails, but they have to satisfy the learning outcomes of the unit.

2. The Unit of Fluid and Electric Drive Systems

The unit of fluid and electric drive systems introduces fluid and electrical drives and the design of integrated drive systems for use in industry. It covers comparison of characteristics, construction, selection, design and operation of fluid and electric drives and drive systems, use of mathematical models to analyze performance, machine protection and control schemes, and evaluation of drive system performance. Students apply formulas and explain and record calculations. They adopt professional approaches to work in teams and learn collaboratively to manage and complete projects. In addition, they manage their own learning, and communicate professionally using discipline language to investigate, design and check work, and present designs and problem solutions, and using suitable software to develop their prototypes.

The course objectives and student learning outcomes of this unit are listed as:

1. Describe and explain characteristics of fluid drive and electric drive systems, design industrial drive applications to meet performance specifications, and justify selections made and designs approaches;

2. Compare construction and operational characteristics of DC and AC electrical machines and fluid drive machines;

3. Design and explain mathematical models to analyze drive performance;

4. Design and explain machine protection and control schemes for electric and fluid drives in typical industrial applications;

5. Evaluate the performance of the drive systems using appropriate assumptions, non-linear models, solution techniques and simulation software;

6. Describe and explain DC and AC electrical energy and generation and uses in a sustainable development environment;

7. Apply formulas and record and explain processes used to calculate solutions related to electrical power and energy and their conversions;
8. Work and learn demonstrating professional approaches to teamwork, management and completion of projects, and collaborative learning;

9. Apply professional self-management principles and independent learning approaches to ensure competence and experience is gained in all content areas; and,

10. Communicate effectively using terminology, symbols and diagrams related to electric and fluid drives and use professional approaches to investigate problems, justify and check designs and present solutions.

3. Case Studies

Two case studies listed here were conducted in the Department of Mechanical Engineering at the Australian College of Kuwait in 2015. The project briefs of these case studies are listed below.

**Case study 1: Automatic glassware handler in packing line**

**Project Brief:**

As a team of engineers, you are requested to design and implement a mechanical system with fluid and electrical drive systems to grab and pick up safely chosen glassware and transfer it to a packing box. At the end of semester all products will be evaluated based on the product evaluation criteria and the best product will be awarded with an official “ACK best automatic glassware handler in packing line” and allowed to attend a graduation exhibition. On the other hand, you will be evaluated 100% on portfolios with respect to the 10 learning outcomes listed in your unit outlines. A criteria sheet provided suggest four categories of Unacceptable, Acceptable, Good, and Excellent for your portfolio evaluations. Based on the provided grading rubric, your overall mark in this PBL unit will be calculated.

Your design should fulfill the following:

1. Consideration of relevant codes and standards, as well as industry practices;
2. Required material needs to be available in Kuwait;
3. Assumption of all missing information;
4. Available budget: maximum 50 KD; teams should buy only materials not available at ACK;
5. Preliminary presentation of the design should be given at the beginning of week 6 by student teams;
6. All implementation and building work must be conducted in ACK under supervision of the course instructor and lab or workshop technicians; and,
7. Management of the design/production processes (including submission of design, quality control, time monitoring, budget control, organizing meetings, project management, etc.).

Your product should fulfill the following criteria:
1. Satisfying the seven requirements listed above;
2. Demonstration of creativity, innovation, and novelty;
3. Demonstration of actual operation on handling glass;
4. Stability and uniformity of precise operation in real work conditions;
5. Automatic operation and demonstration for one working cycle; and,
6. Quality of the manufactured product.

**Case study 2: Automatic 3D drilling around an object**

**Project Brief:**

As a team of engineers, you are required to design and build an automated machine capable of drilling at different positions and angles in a factory using electrical and pneumatic drive systems. Examples of such objects are shown in Figure 1.

![Figure 1 Examples of objects for operation under the 3D drilling machine](image)

The design and implementation phases require the following:
1. Consideration of relevant codes and standards, as well as industry practices;
2. Required material needs to be available in Kuwait;
3. Assumption of all missing information;
4. Available budget: maximum 50 KD, teams should buy only materials not available at ACK;
5. Preliminary presentation of the design should be given at the beginning of week 6 by student teams; and,
6. Management of the design/production processes (including submission of design, quality control, time monitoring, budget control, organizing meetings, project management, etc.).

Your design should fulfill the following:
1. Meeting requirements as stated above;
2. Stability and uniformity of operating machine;
3. Uniform movement and rotations;
4. Precise localizing and drilling; and,
5. Quality of the finished product.

Methodology

Students in the PBL unit were introduced to the project briefs. They were allowed to form teams of a maximum of 5 members. The students had two sessions of two hours with the instructor and one session of two hours in the pneumatic laboratory each week. Students were provided with short lectures in pneumatic and electrical systems and their regular meetings and entries in their workbooks and reflective journals were monitored weekly or bi-weekly. By week six, students had produced a reflective paper on AC and DC machines preferably by consulting industrial practitioners. Their developed design systems were presented in week 6 and the students received feedback from an internal examiner, lab instructor, the course instructor, and also other teams in the class. After week six, the implementation phases were fully supervised by ACK faculty staff in labs, the workshop, and other internal or external advisors. The students had to familiarize themselves with automation and application of micro-processing programming and other software to design, analyze, and test their manufactured machine. By week 12, all projects had to be completed, tested and evaluated by the course instructor and the internal committee of one or two faculty members. Portfolios were submitted in week 13 and evaluated by the course instructor. In weeks 14 or 15, the
final presentation of teams and their poster were presented and individual viva-voce carried out in front of an examiner committee of two or more faculty members holding a PhD degree. The evaluation was based on satisfying 10 learning outcomes. If one learning outcome was unacceptable and the attendance of a student was below 80% then the student had to repeat the unit.

Results and Discussion

Case Study 1:
Team 1 had designed a robotic arm with a gripper to hold and release the glass. A linear pneumatic actuator was used to lift up or move down the glass and a semi-rotary actuator was used to transfer the glass object from the production line to the packing line. Team 1 had used a microcontroller with its relay module to control the system.

Figure 2 shows the manufactured robotic arm. The mechanical design was stable although it has a small overshoot when it reaches the end strokes.

![Figure 2](image)

Figure 2 Three views of the manufactured robotic arm glass handler

Figure 3 shows the pneumatic and electrical circuits used by Team 1 in their design. The circuits were demonstrated as operational during a cycle of glass delivery by the robot arm. Students in Team 1 demonstrated competency in their learning outcomes.
Case Study 2:

Team 2 was started by an idea of using a mouse trap for the drilling machine. The idea was very nicely developed and the students demonstrated strong ability on developing the idea into an end product. The mechanical design is demonstrated in Figure 4. The system uses a rotating table (using a windshield wiper electric motor) and the mouse trap idea for moving around the drilling object using a pneumatic system.
Figure 4: Three views of the manufactured robotic arm glass handler

Figure 5 shows the Arduino Circuit Drawing of the electrical circuit used by Team 2 to control their machine movement. A pneumatic drill was used.

Figure 5: The electrical Arduino Circuit for the drilling machine

All team members worked professionally and achieved their best in this team work.

6. Conclusions and Recommendations

The PBL unit of fluid and electrical drive systems was developed based on the available facilities in ACK and also the restriction imposed on students due to budget limitation, time frame, and limited access to the ACK workshop during the semester. Feedback received from
students has helped considerably on how to assist students to achieve their best. From the feedback, the number of lectures was reduced, instead more examples of previous work, facilities used, and developed knowledge were shared. Examples of what entries are expected in the workbooks and reflective journals were explained. Students were provided with assembly of pneumatic circuits in the lab, introduced to software FluidSim to simulate their pneumatic circuits, and five extra lab activities were added to introduce students to programming in Arduino. These changes, together with the eagerness of ACK students to learn and to have hands on work experience, are promising. Most of the successful students in the degree program are planning to continue their education with Master or PhD programs abroad.

References


A PRACTICAL DEMONSTRATION OF PROJECT-BASED LEARNING (PBL) APPROACH IN AN INDUSTRIAL ENGINEERING COURSE

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Abstract
This paper explains how the PBL approach was utilized in an elective course (Product Analysis and Design) taught in the Industrial Engineering Department at An-Najah National University (ANU) in Palestine. It shows how the course was developed based on PBL and it discusses the perceptions and attitudes of the students that have participated in the course. In this course, students were split into groups of 4-5 each and were asked to create a physical product as part of a project. An on-line questionnaire was used to capture the students’ learning experience for this purpose in addition to formal and informal feedback and observation. This study revealed that PBL is a powerful process to motivate students to identify and apply course concepts and methods discussed in the class. It enhanced the ability of the students to work collaboratively and communicate effectively during and after the course. The course concluded by organizing a Design Fair where all the students had the opportunity to present their products and they were assessed by external assessors from academia and industry.

Keywords Project-Based Learning, experiential learning, constructive alignment, formative assessment

Introduction and Background
Practices associated with the teacher-centered model in the Palestinian higher education institutions appear to prevail based on a study published in 2009 by AMIDEAST (Cristillo, 2009). Although the academic institutions there are growing rapidly in terms of quantity, the quality of teaching practices is yet to be advanced. The teaching is mostly focused on communicating, informing and transferring experiences through traditional methods. The effort towards addressing high level learning that tackles application, analysis, synthesis, and evaluation is still lacking.
A Project-based Learning (PBL) approach can contribute to restructuring teaching methods by designing projects that are hands-on exercises that address challenging problems which involve the students in design of the problem and give them the opportunity to work together to address the problem and generate realistic results (Jones et al., 1997). In our project, the scenario was to create a new physical product employing the tools they learned in the class for product design and development.

In PBL, students first encounter a problem, followed by a student-centered inquiry process where the students learn to think critically, apply knowledge, and communicate effectively (Boud and Feletti, 1998). This has been achieved by designing the teaching method (project-based) to be aligned with the intended learning outcomes and the assessment method used. Therefore, a learning environment was provided to support appropriate learning activities to achieve the desired learning outcomes (Biggs, 2003).

**Methodology**

The purpose of this study is to investigate the impact of using PBL on the learning experience of the students when constructive alignment is employed. The theme of this study is organized and based on Fink’s (2003) framework with regard to constructive alignment for course design (see Figure 1). Fink’s idea of the Integrated Course Design (ICD) is that the course should not simply be developed based on the contents full of information that need to be conveyed to the students, instead the course should be designed based on a learning-centered approach where the students are learning by doing.

Driven by the Intended Learning Outcomes (ILOs), the teaching methods were crafted to serve the ILOs effectively. Hence, the assessment method was modified from the traditional system used to ensure consistent alignment is achieved and supports the ILOs and the teaching methods. The PBL was designed to be an elemental approach and it was intended to facilitate the learning experience and to achieve the ILOs. Moreover, the assessment didn’t follow the traditional approach used at where sitting exams is the usual case. Instead, poster sessions, presentations, and report writing was utilized and the students were assessed accordingly.
The assessment of the students’ learning experience was accomplished through the Student Course Experience Questionnaire (SCEQ) which was developed by the University of Sydney to measure students’ perception of their experience (Ginns et al., 2007). SCEQ is an adaptation for the Course Experience Questionnaire (CEQ) which is based on the student-centered view of learning, and it was developed as part of the Australian government’s emerging national higher education quality assurance strategy to incorporate data from a survey of graduates on their experiences of university (Prosser & Barrie, 2003).

In addition to the formal assessment conducted according to the current university system, a formative assessment was utilized during the course delivery using various ways ranging from informal observation to using social media and evaluation forms. Both qualitative and quantitative collected data were gathered using questionnaires, written comments, and observation. Therefore, qualitative analysis was used in addition to the descriptive and inferential statistical analysis.

**Discussion and Analysis**

The students’ learning experience was captured quantitatively and qualitatively. The quantitative method used was via an online questionnaire for students including 17 items and using Likert approach which consisted of a five-point scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 =Agree, 5 = Strongly Agree). Four themes were the basis of the questionnaire in addition to the overall satisfaction item. The selected items are the ones that deemed to be more relevant to this study which focuses on the teaching method and assessment methods. These items are numbered according to the order in the questionnaire.
The themes included good teaching, appropriate assessment, appropriate workload and generic skills.

The focus of the questionnaire analysis was on the students’ perception with regard to the teaching methods and the assessment, since these issues were the areas of concerns for ANU. The students were not asked about how clear are the goals of the course, as this study measured the course goals practically through the achievement of the students on each ILO identified in the beginning of the class according the guidelines of the Accreditation Board for Engineering and Technology (ABET). Moreover, further assessment was obtained from the formal ANU course evaluation with regard to the students’ satisfaction of the course and the lecturer.

The qualitative data as part of assessing students’ learning experience was the output from the optional open question in the questionnaire in addition to the comments generated by documenting the observations and the comments on the secure Facebook page which was dedicated to the course in study. Facebook was used after failing to motivate the students to use other formal education tools due to lack of stimulus when compared with the already familiar social media system. Moreover, the advantage of using Facebook was to maintain the community that has been created as a result of this course. In fact, the page is currently active and the students are contributing till the time of writing this paper, although the course has been completed.

The course was taught in the first semester 2011/12 and 55 students were enrolled. The questionnaire was designed based on an on-line platform and the link of the questionnaire was shared on the Facebook page two weeks after the class was finished. The response rate was 51% (28 out of 55) which is a good response rate considering that it was a voluntary questionnaire and well after the course was completed. The other evidence of the credibility of the questionnaire is that most students gave narrative written feedback in the open question.

The overall satisfaction score was 4.2 which represents a positive perception. The rest of the themes discussed are shown in Table 1 which depicts positive perception with regard to good teaching and generic skills. However, the work load and the assessment seem to be lacking according to students’ opinion. This is due to the fact that the students still had to go through two exams (midterm and final) which are equivalent to 60% of the total marks of the course. Moreover, the
students are not used to this approach in terms of managing their time since they had to do a large project during the course which consumed a lot of their time. The students had to design a product starting from the initial stage of idea generation and going through evaluation and market/customer analysis before developing a physical presentable working prototype at the final stage.

Table 1  Comparison of the average score of each theme investigated in the study

<table>
<thead>
<tr>
<th>Theme</th>
<th>Average score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic skills</td>
<td>4.1</td>
</tr>
<tr>
<td>Good teaching</td>
<td>4.3</td>
</tr>
<tr>
<td>Appropriate load</td>
<td>3.0</td>
</tr>
<tr>
<td>Appropriate assessment</td>
<td>3.1</td>
</tr>
</tbody>
</table>

The detailed analysis of the responses of all items in the questionnaire is shown in Figure 1. Considering the selected themes, the average positive responses with regard generic skills and good teaching were 72% and 76% respectively, while the appropriateness of load and the assessments were relatively low as they were 26% and 28%, respectively. The highest average positive responses with regard to generic skills were the ability to develop an independent learner (item 16).

The results showed that the course helped the students to develop problem-solving skills, sharpen analytic skills, team work, confidence to tackle unfamiliar problems, and improved written communication skills. All the statements related to the lecturer were positive except the two statements that were related to memorizing (item 9 and 11). This also emphasizes the role of the lecturer and not just the teaching method used in the course.

It is worth mentioning that the course assessment conducted by ANU at the end of each course was 4.59 out of 5. This figure, when compared with other courses taught by the same lecturer, makes it one of the top three courses out of 9 courses taught recently, although none of the student received distinction (i.e. mark above 90%) compared with the other courses where few students have scored above 90%. 
The qualitative data confirmed the results obtained in the quantitative analysis where the students commented on the importance of applying the knowledge learned in the class directly in real life. The students think that the load of work is still an issue when compared to the mark associated with it.

Additional direct feedback was obtained from the current procedure of assessing students’ achievements of the ILOs according to ABET guidelines. The course project, as a teaching method, was employed to address two specific ILOs that were “become confident in own abilities to create a new product” and “able to coordinate and communicate students own ideas and thoughts”. These ILOs were assessed based on the course project contents and delivery. This way the teaching activities and assessment were aligned with the learning goals. The achievements on these ILOs (which is measured based on the marks of the students on this task) were 86% and 73% respectively, which represent a good achievement.
The relationship between perceived quality of the course (as measured by item 14) and the motivation and feedback given by the teacher (as measured by items 2 and 13) was investigated using the Pearson product-moment correlation coefficient. Preliminary analysis was performed to ensure the assumptions of normality and linearity were not violated. There was a strong (according to Cohen, 1988), positive correlation between the two variables, $r = 0.503$ for motivation and $r = 0.607$ for feedback with perceived quality of the course, and both showed significant correlation at the 0.01 level (2-tailed).

**Effective Supporting Activities**

Several activities supported the course to succeed in its innovative form in this context as shown in Figure 3. A mini project was requested from each student at the beginning of the course in preparation to the main project and several examples of product designs captured by the lecturer’s personal camera to simulate students to do the same and select a product from their personal life. The students were then asked to present to the class demonstrating their reflection on the pros/cons of the good/bad design of the product in terms of function and form.

A formative assessment was conducted using a simple form asking about the best thing, worse thing and corrective/improvement actions. This proved to be useful in capturing the concerns of the students from commencing a practical project and unfamiliar problem.

Two external speakers were brought to the class to explain relevant technical topics. The course was concluded with the ‘Design Fair’ which was one of the most important factors that drove the students to excel on their tasks and enjoy presenting their final outputs (physical products) in public. A local industrial firm sponsored the Design Fair and provided three monetary prizes to the top three products based on the evaluation of the external judges who were mainly industrialists. Major local TV associations covered this event and the students were pleased to communicate their effort to the public. Some students invited even their family to share with them the whole experience.
Conclusion and Recommendation

Based on the analysis presented in the previous section, it is evident that PBL can leverage the learning experience and motivate students to become able to work independently and improve generic skills such as effective communication, problem solving, working in teams, and analytical skills. The correct course design that ensures constructive alignment between the course objectives, teaching methods, and the assessment is the main enabler to a successful learning experience.

The result of this study recommends incorporating such experiential learning into a broader range of university courses and not just the Faculty of Engineering, since a PBL approach engages students to excel in deep learning. An important conclusion from this course was deduced by the author considering the various feedback received that students consider three criteria to assess their learning experience. These are the learning environments in the class, the lecturer style, and the assessment criteria.

Further evaluation will allow us to determine the strengths and opportunities in a PBL approach and at the Faculty of Engineering in general by converting other types of courses that are not inherently practical.
References


THE ACK PBL MODEL APPLIED TO THE ACQUISITION
OF BASIC C++ PROGRAMING SKILLS

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Abstract
Project Based Learning (PBL) is an interactive classroom approach in which students are explicitly confronted with real-world problems and challenges in order to increase their motivation to learning and as a consequence acquire a deeper knowledge. With a vision of “Enabling Human Potential within a Culture of Care”, the Australian College of Kuwait – ACK – has adopted a PBL approach in its School of Engineering programs. Particularly, its Bachelor of Engineering Technologies (Electronics and Control Degree Program) students are acquiring their first C++ programing skills using a PBL approach. In this paper, the ACK PBL model is applied to the delivery of “Introduction to computing with C++” at ACK with an emphasis on project design and student evaluation. Real life evidence from students’ work is analyzed and finally the success of the adopted PBL approach and challenges confronting the students and facilitator are discussed.

Keywords  Project Based Learning, PBL, programing

Introduction
Project Based Learning – PBL – is an alternative instructional method centered on the learner that organizes learning around projects (Thomas, 2000). Unlike the “traditional” way of teaching where the lecturer follows rigid delivery and lesson plans in order to direct the learner toward specific learning outcomes and objectives, the PBL approach revolves around a real life project which drives the learner to self-accomplish these learning outcomes implicitly by performing all project related tasks (Harris & Katz, 2011). Although the learner is still acquiring the same rigid learning outcomes defined for a traditional learning approach, when PBL is appropriately implemented, the learner enjoys learning as it is driven by projects issued from our daily life problems. In other words, PBL frees the hands of the learner and transforms him from a passive learner spoon fed by the instructor into an active
one who is highly motivated to self-learn in order to accomplish the assigned real-life tasks. Studies have proven that when implemented appropriately, PBL increases the student motivation to learning, promotes their abilities, cuts absenteeism, improves academic performance, and develops lifelong learning skills (Vega, 2015).

PBL is nowadays infused with technology which may lead to the conclusion considering it as this century’s idea although it is built on a venerable foundation (Tretten & Zachariou, 1995), (Jones, Rasmussen, & Moffitt, 1997). However, as fully compatible with the rapid growth of technology it is nowadays more immersive.

As part of its vision of “Enabling Human Potential within a Culture of Care”, the Australian College of Kuwait – ACK – has adopted a Project Based Learning approach in its School of Engineering programs. Particularly, its Bachelor of Engineering Technologies (Electronics and Control Degree Program) students are acquiring their first C++ programming skills using a PBL approach. In this paper, the ACK PBL model is applied to the delivery of “Introduction to computing with C++” at ACK with an emphasis on project design and student evaluation. Real life evidence from students’ work is analyzed and finally the success of the adopted PBL approach and challenges confronting the students and facilitator are discussed.

**C++ unit at ACK**

C++ unit is intended for ACK students enrolled in the first semester of the Bachelor of Engineering Technologies (Electronics and Control Degree Program). Students of this unit meet three times per week, two hours each, to work on a well-designed real life C++ project that is supposed to cover certain learning outcomes (LO), as presented next:

- **LO1**: Design, implement, test and debug C++ programs including simple arithmetic, increment, decrement, assignment, equality and logical operators, input/output;
- **LO2**: Design, implement, test and debug C++ programs including selection and repetition control structures: if, if/else, switch, while, do/while, for;
- **LO3**: Design, implement, test and debug C++ programs including standard libraries, pre-defined functions and user-defined functions;
- **LO4**: Design, implement, test and debug C++ programs that deal with structs, arrays and strings;
- **LO5**: Design, implement, test and debug C++ programs for applications in real life;
- LO6: Break down/analyze basic C++ programs; determine whether a C++ program runs flawlessly; and make judgments / evaluations / comparisons of a given program;
- LO7: Document and present the algorithms, flowcharts and programs in form of user-manuals;
- LO8: Articulate and demonstrate personal application and development of the practice of professional engineering, including a professional attitude, problem solving skills, relevant technical knowledge and productive work practices and a commitment to lifelong learning; and,
- LO9: Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams.

One can notice here that the first six learning outcomes (i.e. LO1 till LO6) are purely technical in relation to basic concepts of C++ programming; unlike LO7, 8 and 9, which are more related to professional behavior and project documentation.

**Adopted PBL Approach**

The PBL approach adopted for the delivery of C++ unit at ACK is inspired by the Aalborg PBL Model (Barge, 2010) and can be summarized as follows:

*Pre-PBL:* Before the start of the semester, a real-life project which is supposed to cover all the unit learning outcomes is defined by the C++ PBL facilitator who is an expert in C++ programming and software development. Simultaneously, students are introduced by ACK’s PBL center to the PBL approach.

*PBL Groups:* At the beginning of the course, students are supposed to be aware of the learning outcomes of the unit. These outcomes are well detailed in the unit outline which is made available to the students on the unit’s page of ACK’s Learning Management System before the start of the course. For surety reasons, it is also explained during the first C++ PBL “class”. Moreover, a project fully based on a real-life scenario along with its specifications is presented. Students are then divided into groups of three to four members. All groups meet on a regular basis during the regular class times throughout the semester. Members of each group are supposed to work equally together in order to perform all the project tasks.

*PBL facilitation:* Throughout the semester, the PBL facilitator guides the students and ensures that they cover all the unit’s learning outcomes. The golden rule to do so is by asking probing questions such as “what next”, “what do you think”, “how can we know”, “did you
try all possible alternatives”, etc. Such questions promote the challenging aspect of PBL and motivate the students to elaborate more on/explore other alternatives and hence complete and enhance the level of achievement of all the unit’s learning outcomes.

We note here that the level of “knowledge” provided to the students within such probing questions depends on the performance of the students. For instance, to guide a student toward the conclusion that there is an alternative for a “nested if-else” statement in a C++ program the facilitator would ask: “are you sure that a nested if-else is the best choice here?” or “are you sure there are no alternatives for the nested if-else you used here?” or “Do you know what is the difference between the One-Way and the Two-ways selection?” or “did you try switch-case instead of the nested if-else you used here?” Although the four previous questions lead to the same conclusion, the first question is the most challenging one as it guides the student to evaluate his or her current program and try alternatives. Obviously, such questions would be addressed to a student who showed a full comprehension of what selection statements are. On the other hand, the last question is the least challenging as the facilitator is explicitly guiding the student to learn about a new selection statement called switch-case. Trivially, such questions would be asked to a student who is feeling lost, have difficulties in finding alternatives and their learning achievements are far too late compared to his or her classmates.

**Documentation of learning evidence:** Throughout the semester, each student is required to collect learning evidence and document them in the form of what is called “unit portfolio”. Examples of documents in a unit portfolio are: preliminary programs, debugging evidence, student reflections, meeting minutes, assignments, research summaries, etc. The unit portfolio is continuously checked by the PBL facilitator as to formatively assess the student from one side and to give them feedback and advice for improvements from the other side. The contents of the unit portfolio will be detailed further in the “Unit Portfolio” section.

**Student Evaluation:** In addition to the formative assessment throughout the semester, the last version of the student’s unit portfolio is checked by the instructor after its official submission and a viva-voce verbal examination is scheduled with the student to double check his or her understanding of what they included in their portfolio. Accordingly, the level of achievement of each learning outcome is evaluated and a final grade is consecutively calculated. The assessment technique used for student evaluation will be described further in the “Student Evaluation” section.
C++ PBL Projects at ACK

According to many researchers, the design of the project plays a key role in the success of the PBL implementation. A project should be built with complex tasks and challenging questions or problems that involve students in various self-learning activities such as design, problem-solving, and decision making. It should give students the opportunity to work relatively autonomously over extended periods of time (Jones, Rasmussen, & Moffitt, 1997) (Thomas & Mergendoller, 2000).

A design framework that enables facilitators to think through the many levels of standards, skills, and other course objectives that their PBL experience will address is also found in the literature. The so-called simultaneous outcomes framework described in Figure 1 below shows “how teachers can create projects that operate on several levels at the same time. The best projects skillfully weave together opportunities for students to engage in classroom activities (Level 1), address content standards (Level 2), while encouraging students to develop habits of mind (Level 3) and the ability to take responsibility of their own learning (Level 4).” (Foundation, 2014).

![Figure 4 The Simultaneous Outcomes Framework (Foundation, 2014)](image)

At ACK, a similar framework is adopted when designing PBL C++ projects. Indeed, as per self-directed learning (level 4), a real life scenario is used to prepare students for the expected professional behavior during the preparation of their project. For instance, Figure 2 shows a snapshot of a C++ PBL project where the student is pushed in the context of being an employee in a well-known company facing financial problems and supposed to be the leader of the saver project. It also shows examples of skills the student can transfer to all aspects of
their life which are: facing challenges bravely, self-management, recording meetings in the form of meeting minutes, etc.

As per habits of mind (level 3), the real life scenario addressed previously also suggests for students some intelligent behaviors. For instance, Figure 2 shows how the context of the project prepares the student to be a self-learner (metacognition habit of mind) and encourages him or her to persist until the successful achievement of the project.

As per content standards (level 2), the C++ PBL project is designed in such a way that when well designed, implemented, debugged, tested and documented, all the unit’s learning outcomes are implicitly completed at least at an acceptable level. For instance, under the same pre-defined example of context, Figure 3 shows a snapshot taken from “the minutes of the meeting with Dr. Hassan, the representative of the company requesting the C++ program”. It shows clearly how the learning outcomes are incorporated within the context in the form of “program requirements”.

Figure 5  Scenario for C++ PBL Project: self-directed learning and intelligent habits of mind
As per classroom activities (level 1), PBL units are conducted in special PBL classrooms which are designed to facilitate group work and are fully equipped with internet enabled computers to facilitate students’ learning and the access to online resources. Visual studio is also installed on those computers to enable the students to live-test their learning and implement C++ programs, from the most basic programs to the relatively sophisticated ones (such as the one of their project). As such, classroom activities vary between conducting research, group discussions, designing, implementing, debugging and testing C++ programs, as well as preparing required documentations for the portfolio. Figure 4 shows a photo of C++ students working on their projects during a regular PBL C++ session.
C++ Unit Portfolio

As introduced previously, ACK C++ PBL students are required to prepare a unit portfolio which groups and documents the student’s learning evidence. The unit portfolio is an assessment tool used to evaluate the student’s learning, be it a formative or summative evaluation. It is an indexed file (e.g. clip file) that groups documented evidence of completing all LOs covered by the project. It must include three compulsory items and should be prepared individually by each student. The three compulsory items are: The workbook, the reflective journal and the user manual. A description of each item is given as follows:

**Workbook**: A day-to-day workbook used by the student to take all learning/project related notes. It is a workbook created by the student to keep track of all project related tasks. It shows the chronological progress of the student’s learning and helps the facilitator in performing the formative assessment and giving continuous feedback to the student. A workbook might include:

- Referenced research summaries;
- Notes taken from lectures (if any);
- Hands on algorithms /flowcharts and C++ programs;
- Snapshots of programs implemented by the student with hand written comments about the code, its output, debugging, etc.;
- Assignments; and,
- Copies of meetings minutes.

The workbook is an essential tool for the evaluation of student learning as it shows their chronological improvement throughout the semester. For example, Figure 5 shows two snapshots taken from a C++ PBL student’s workbook. It shows how the student is learning the difference between a post-fix and a pre-fix increment. The student started his or her learning with research about post and pre-fix, and then implemented a simple C++ program incorporating them. The student also wrote comments on the program they implemented. Although the student made efforts in understanding such concepts, the facilitator can easily notice that the code as well as its output do not show clearly the difference between post and pre increment. As such, the facilitator would ask the student probing questions to guide them and encourage them to elaborate more on such concepts.
Figure 8 Snapshots from a student workbook: (a) Research Summary on post/pre fix operators; (b) Program incorporating post/pre fix operators.

**Reflective Journal**: It is a document in which students reflect on their learning on a regular basis. It is a document mainly used by students to self-assess their learning. Students might reflect on a new learned topic or concept, the contribution of group members, the strength and weakness of the group, difficulties they are facing, potential solutions, etc.

**User Manual**: It is a user manual for the student’s final project program. It is an official document mainly used to assess the 7th learning outcome (i.e. LO7). In the user manual the student includes an explanation of the aim of the program, its flowchart, a user guide
illustrating how to use it with explanatory output snapshots and its C++ code including detailed comments about the role of each part.

**Student Evaluation**

The evaluation of a C++ PBL student work is based on three different yet complementary types of assessments: Formative assessment, pre-evaluation, viva-voce (Figure 6). 

During the formative assessment, the workbook and reflective journal of each student are checked by the facilitator and feedback is given accordingly. The facilitator ensures to provide the student with feedback on the achievement of each of the nine learning outcomes. Comments on the student’s improvements are also noted by the facilitator to facilitate realization of the next assessment step, which is the pre-evaluation.

By the end of the semester, the student submits their portfolio which should include their workbook, reflective journal and user manual. The facilitator makes use of their notes taken during the formative assessment, then double checks the evidence provided by the student in his or her portfolio to finally give a pre-evaluation for each learning outcome be it “unacceptable”, “acceptable”, “good” or “excellent.” In case the level of achievement of a particular learning outcome is questionable, questions for the next assessment step, the viva-voce, are prepared.

At the third and last step of assessment, the student is supposed to give answers to all questions prepared by the evaluator during the pre-evaluation phase. This occurs during what
is called viva-voce which is a form of face-to-face verbal examination. A final decision on the level of achievement of each learning outcome is taken afterwards.

For all types of assessments, a formal criteria sheet is used to evaluate the level of achievement of the learning outcomes. A criteria sheet shows how each learning outcome may be achieved in an “acceptable”, “good”, “excellent”, or “unacceptable” manner. A snapshot taken from the criteria sheet of the C++ PBL unit is shown on Figure 7. For instance, to achieve a good level in LO1, the student must satisfy all criteria of “acceptable” in addition to the majority of those of “good.”

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Unacceptable</th>
<th>Acceptable</th>
<th>Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO1: Design, implement, test and debug C++ programs including simple arithmetic, increment, decrement, assignment, equality and logical operators, input/output.</td>
<td>No evidence of simple arithmetic, increment, decrement, assignment, equality and logical operators, input/output programs.</td>
<td>Identifies different types of data variables.</td>
<td>Demonstrates an understanding of different types of data variable and the ability to select the best type in a particular context.</td>
<td>Differentiates between a local and a global variable.</td>
</tr>
<tr>
<td></td>
<td>Inability to articulate the role of a basic arithmetic, increment, decrement, assignment, equality, logical operators and input/output instruction within a program.</td>
<td>Articulates understanding of the role of a basic arithmetic, increment, decrement, assignment, equality, logical operators and input/output instruction within a program.</td>
<td>Demonstrates the ability to implement and run a basic program output program.</td>
<td>Demonstrates the ability to design, implement, test and debug an input/output program incorporating simple arithmetic.</td>
</tr>
<tr>
<td>LO2: Design, implement, test and debug C++ programs including selection and repetition control structures: if/else, switch, while, do/while, for.</td>
<td>No evidence of programs including selection and repetition control structures.</td>
<td>Identifies different types of selection structures.</td>
<td>Demonstrates the capacity to design, implement, test and debug a program combining selection/repetition structures.</td>
<td>Shows development of own perception.</td>
</tr>
<tr>
<td></td>
<td>Inability to articulate the role of a selection or a repetition structure.</td>
<td>Identifies different types of selection structures.</td>
<td>Demonstrates the capacity to implement and run a program including at least one selection structure.</td>
<td>Demonstrates the ability to select the best selection/repetition structure within a program.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demonstrates the capacity to implement and run a program including at least one repetition structure.</td>
<td>Demonstrates the capacity to design, implement, test and debug a program incorporating nested selection/repetitions.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 10 Criteria sheet: Example of criteria for C++ PBL LO1 and LO2 evaluation.

Finally, a simple formula is used to derive the final letter grade of the student. For instance, 10 scores for each “excellent” Learning Outcome, 8 scores for each “good” Learning Outcome, 6 scores for each “acceptable” Learning Outcome. The average gives the final grade of the student. We note here that unacceptable learning outcomes lead to failing the unit, which gives extreme importance of the formative assessment and feedback given to the student during the semester.
Success and Challenges

The key element behind the success of the PBL delivery method described above is transparency. Indeed, the delivery method, the unit outline, the learning outcomes, the evaluation method and criteria sheet are all made available to the students on the Learning Management System from the beginning of the semester. The continuous feedback given to students throughout the semester as part of the formative assessment plays also a key role in awakening the awareness of the students on their performance and on the importance of continuous self-evaluation. As such, the students are hence able to expect relatively authentically their final grade by the end of the semester.

In the end, one can conclude that the performance of the students varies with respect to their commitment to learning. Committed students usually go beyond the unit’s learning outcomes, continuously update their project each time they discover new C++ concepts or codes and always reflect on their learning. Those students take into account the facilitator feedback and improve their learning consequently.

Although transparency is the key element behind the success of the C++ PBL delivery, it is a double-edged sword as it is also the main challenge confronting facilitators and students. Indeed, as the evaluation criteria sheet is made available to students since the start of the course, students who are less committed to learning usually consider it as a check list. They would be convinced that spending minimum efforts would allow them to pass the unit and even getting a high grade. This illusion usually occurs at the beginning of the semester. A wise facilitator is the one who is able to identify these students as soon as possible, show them how much information they are lacking and warn them of the severe consequences of applying such “technique” (e.g. the student would fail LO8 which is related to commitment to lifelong learning).

Conclusion

In this paper, the ACK PBL delivery model is applied to the “Introduction to computing with C++” unit which is dedicated for students enrolled in the first semester of the Bachelor of Engineering Technologies (Electronics and Control Degree Program). The main steps of the adopted PBL delivery approach were defined and the design stages a C++ PBL project passes through were emphasized. Then, the student evaluation procedure with real life examples
were presented and discussed and finally a conclusion on the success of the ACK delivery method and the challenges facing it were driven.

References


APPLYING PBL TO DIFFERENTIAL CALCULUS
CASE STUDY ON ENGINEERING STUDENTS AT THE AUSTRALIAN COLLEGE OF KUWAIT

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Abstract
This is a pilot study to implement PBL in a course for Civil Engineering students in the Department of Mathematics. The course will be essentially taught utilizing a hybrid teaching approach. In the first part, the course will be taught using lectures, before students will have their conventional written assessments. Students will evaluate their learning experience in the first part of the course based on a questionnaire survey. In the second part of the course, the instructor will assign the students a project and a PBL approach will be followed for the remainder of the course. Here, the instructor shares his observations and conclusions from this experiment.

Introduction
PBL is originally traced to the works of John Dewey (1916). The main idea of PBL is that it starts the learning process by a problem or a puzzle that the learner wants to solve (Boud & Feletti, 1997). PBL is an active learning process which encourages application in a real context (Lilian, Lan, & Leng, 2007). It was suggested by Lee and Jang (2012), that in order to apply PBL in mathematics, teachers need to be aware of the following phases:

Phase I: identifying the problem (understanding);
Phase II: investigation process for solving (concepts and curriculum); and,
Phase III: problem solving (choosing the best method).

Some encourage the role of tutors in PBL which highlights that information literacy and mathematical thinking must be kept in mind before self-directed learning can take place (Lilian, Lan, & Leng, 2007). Ben-Naoum presented some main ideas that need to be kept in mind when designing a PBL problem for a mathematics course (Ben-Naoum & Wertz, 2002).
Ben-Naoum also argued against those who claim that Active Learning (AL) is only for applied fields. He showed that AL is also possible in theoretical fields such as mathematics (Ben-Naoum & Wertz, 2002).

Main Characteristics of a Mathematical Problem in an Engineering Situation

Ben-Naoum suggested that real-life problems are used to teach mathematical concepts. However, he emphasized that only the parts that encourage students to learn the mathematical concepts should be focused on by instructors. He suggested that “concrete application” can be used in a mathematics PBL course, but the core focus should be steered towards the mathematical concepts.

Another approach Ben-Naoum suggested is that no “concrete application” is required. In this case, the main focus is shifted, instead, to the numerical results. Yet another approach is to introduce the problem as a game (Ben-Naoum & Wertz, 2002).

Some competencies expected from students are according to Ben-Naoum:

- Capture the sense and need for rigor;
- Grasp the need for abstraction and use it appropriately;
- Prove, generalize, and criticize results;
- Model different situations by using the appropriate mathematical tools; and,
- Interpret and assess results.

According to Ben-Naoum, the main characteristics of a problem are:

- A complex task;
- Requires several competencies;
- No direct solution;
- Requires the student’s involvement and initiative; and,
- A learning obstacle.

According to Ben-Naoum, the difficulty of implementing PBL in mathematics is that some direction must be involved which contradicts with the previous requirement of “student’s initiative”. This is justified in that it will help students to know how to use these mathematical tools. Instructors are encouraged in this case to only give key words to guide the students.

According to Ben-Naoum, there are four axes to analyze a problem:
• Type of context;
• Level of information given;
• Task or production required; and,
• Obstacle.

Aims and Implementation of a Project
In their experiment, Lilian et al. included PBL in all their mathematics courses with a weight of 5% of the overall grade (Lilian, Lan, & Leng, 2007). Their module was intended to achieve the following:

• To help students develop confidence in solving complex real-life application problems;
• To strengthen their mathematical thinking and reasoning skills; and,
• To find out how well they could apply what they have learned in PBL to solve similar problems in the future.

Case Study
In Differential Calculus, a course offered by the Australian College of Kuwait, a problem will be distributed to students at the beginning of the semester. The instructor will be in charge of providing supplementary information and theoretical background with minimal direction towards the solution. Students are grouped into teams of 4-5 members. The instructor will meet with the groups at different times of the semester. Later, each group will have to submit a final report which will account for 10% of the students’ overall grade.

Problem Design
The instructor referred to the Engineering Mathematics book by John Bird (2003) and selected one of the word problems in differentiation.

The problem was initially formulated as follows:

A rectangular sheet of metal having dimensions 20cm by 12cm has squares removed from each of the four corners and the sides bent upwards to form an open box. Determine the maximum possible volume of the box. (Bird, 2003, problem 16)
The instructor reworded this problem and converted it into the following format:

*Using a rectangular paper, design a water container that contains as much water as possible.*

The process was based on changing wording of the problem. Some words were removed to make the problem more challenging. Some concepts such as volume were removed and expressed in a vaguer manner so that it stimulated the student’s thinking process. Students reached a solution to the problem experimentally without using calculus.

Students presented their experimental data in tables, such as Table 1.

Table 2 Experimental data

<table>
<thead>
<tr>
<th>No. of box</th>
<th>Length &amp; width for paper</th>
<th>Size of small box</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Volume L x W x H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.6x21</td>
<td>1x1</td>
<td>27.6</td>
<td>19</td>
<td>1</td>
<td>524.4</td>
</tr>
<tr>
<td>2</td>
<td>29.6x21</td>
<td>2x2</td>
<td>25.6</td>
<td>17</td>
<td>2</td>
<td>870.4</td>
</tr>
<tr>
<td>3</td>
<td>29.6x21</td>
<td>3x3</td>
<td>23.6</td>
<td>15</td>
<td>3</td>
<td>1062</td>
</tr>
<tr>
<td>4</td>
<td>29.6x21</td>
<td>4x4</td>
<td>21.6</td>
<td>13</td>
<td>4</td>
<td>1123.2</td>
</tr>
<tr>
<td>5</td>
<td>29.6x21</td>
<td>5x5</td>
<td>19.6</td>
<td>11</td>
<td>5</td>
<td>1078</td>
</tr>
<tr>
<td>6</td>
<td>29.6x21</td>
<td>6x6</td>
<td>17.6</td>
<td>9</td>
<td>6</td>
<td>950.4</td>
</tr>
<tr>
<td>7</td>
<td>29.6x21</td>
<td>7x7</td>
<td>15.6</td>
<td>7</td>
<td>7</td>
<td>764.4</td>
</tr>
<tr>
<td>8</td>
<td>29.6x21</td>
<td>8x8</td>
<td>13.6</td>
<td>5</td>
<td>8</td>
<td>544</td>
</tr>
</tbody>
</table>

Students visualized their data as shown on Figure 1.

Figure 11 Volume and height

Some of the students were creative about presenting their work and used images and videos, such as the photograph shown on Figure 2.
Then, the conventional solution was compared with the experimental solution. Students were able to compare and understand where differentiation helped to save them from long experimentation time.

**Conclusion**

In conclusion, students enjoyed the PBL approach of solving the problem. The PBL approach allowed them to develop more critical thinking skills. Furthermore, it provided room for creativity.

It also enhanced students’ understanding of the underlying concepts. Through this project, students learned to appreciate concepts such as differentiation in reaching the optimal solution in less time.
References


PROBLEM BASED LEARNING (PBL) AND ENTREPRENEURSHIP

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Abstract
Problem-based learning (PBL) is one of the most innovative educational methods to date. PBL focuses on creative thinking and problem solving as well as promoting self-directed learning and collaborative learning in small groups. Teachers act as facilitators rather than instructors, a radically different approach from traditional instructional methods. PBL is not intended to replace traditional methods of instruction, but rather complement them.

The aim of this paper is to give an overview of PBL and show some highlights of the PBL implementation experience in the School of Engineering at the Australian College of Kuwait.

Keywords  Project Based Learning, entrepreneurship, Problem Based Learning, PBL

Introduction
Universities have been established to serve society and improve quality of life by building a skilled workforce, conducting research and championing innovation. Fields such as science and engineering play a major role in shaping the technological advances of nations. Colleges are expected to lead when it comes to invention and innovation. However, over the years, most educational institutions have fallen behind the technology curve, becoming relatively isolated and disconnected from solving real-life problems. In fact, the primary source of creativity and innovation shifted to the private sector where cutting-edge science and technology were developed and introduced to the market.

In traditional teaching methods, the quality of education students receive is highly dependent upon the quality of their instructors – namely, their ability to deliver information and transfer knowledge. When solving problems that relate to engineering, professors present classical problems that were applicable years ago, with little or no relevance to the challenges of today. As a result, recent engineering graduates from some universities often struggle when
they face real-life problems and require extensive training to perform well in entry level jobs. As a result, it is now commonplace for corporations to offer extensive training to all recent graduates to bridge the gap and bring new hires to the required level of skills. Problem-Based Learning (PBL) is a method of instruction introduced to improve the education system, allowing students to work in teams where they collaborate to explore solutions for real-life problems — much as they would upon entering the work force.

2. Problem-Based Learning (PBL)

Problem-based learning (PBL) methodology is an instructional approach to learning and solving real-life problems. Sometimes, it is referred to as Project-Based Learning. The primary goal of PBL is to introduce students, early on, to the practice of exploring existing problems and to enhance their learning by requiring them to solve these problems. Problem-Based Learning was introduced in the 1950s to prepare medical students for solving problems in clinical settings (Hung et al., 2008). By the 1970s, medical schools such as McMaster University in Canada, Michigan State University in the United States, Maastricht University in the Netherlands, and Newcastle University in Australia were also involved in developing problem-based learning curricula (Barrows, 1996). In the 1980s, a report came out of the General Professional Education of the Physician (GPEP) and College Preparation for Medicine recommending reduction in lecture times and promoting independent learning and problem-solving techniques and the report was sponsored by the Association of American Medical Colleges (Muller, 1984). Consequently, the recommendations from this report helped PBL spread in the United States especially in medical schools to prepare doctors for the workplace. As the PBL approach grew in popularity, more universities implemented the methodology in various fields, including Engineering, to prepare students and equip them with critical problem-solving and lifelong learning skills. PBL enhances and facilitates self-directed learning and problem-solving skills, as well as team work and collaboration, which is much more effective in developing innovation skills than conventional learning (Barrows, 1980; Schmidt, 1983).

In traditional teaching methods, students study content knowledge first - prior to practicing classical problems. PBL is considerably different from traditional teaching methods and inevitably leads to a direct, and very positive, impact on team dynamics and relationships between instructors and students. PBL projects are not the same as graduation or capstone projects. They are problem focused and designed to stimulate higher thinking. Roles and
responsibilities change. Students, individually and collectively, are expected to take responsibility for their learning via monitoring, evaluation and reflection. The instructor role is that of a facilitator rather than a teacher, encouraging creative thinking. Instructors do not often provide full, or even partial, solutions. They may not even provide direct answers to questions. Instead, they encourage students to take steps to generate their own ideas, make decisions and accept reasonable risks. This approach facilitates higher order thinking and problem-solving skills.

There are many benefits of implementing PBL. Several studies have shown PBL is essential to prepare students for the workplace, having greater positive impact on students in terms of utilizing basic information to solve complex problems in the workplace. Several studies have shown that new graduates who have exposure to PBL illustrated rapid development of expertise and required very little on-the-job training to solve problems independently, where new employees that have no exposure to PBL required 1 to 1-1/2 years of training. In one study, employers were very pleased with the outstanding problem-solving skills and job performance of the McMaster University’s PBL chemical engineering graduates (Woods, 1996). For that reason, PBL became popular not only in the medical field, but also in engineering because critical reasoning and solving problems on the job require more than memorization of factual knowledge. PBL Students usually gain many skills including the following:

1. Creative thinking and real-life/ill-defined problem solving;
2. Higher order thinking through Reflective thinking;
3. Independent knowledge acquisition;
4. Research and development;
5. Learning by doing;
6. Long term retention of content;
7. Life-long learning;
8. Self-confidence;
9. Collaboration and documentation (i.e. meeting agendas, meeting minutes, reflective journals, etc.);
10. Technical writing;
11. Project planning; and,

12. Team work.

3. PBL and Entrepreneurship

Entrepreneurship has had many definitions over the years. Joseph Schumpeter (1942) defined entrepreneurship as creative destruction, which refers to the continuous product and process innovation mechanism by which new innovative products replace outdated ones (Bygrave and Zacharakis, 2009). Others define it as managing resources. Regardless of its definition, entrepreneurship is critical to improving quality of life. Radical innovations and breakthrough technologies result from effective management of resources and often change our lives for the better. It also helps fuel the economy and sustains long-term economic growth.

It is self-evident that radical innovation has been the single, most important component of long-term economic growth. To demonstrate an example of how a strong economy is fueled by innovation, consider the invention of mobile devices. In 1983, when AT&T was being divested in an anti-trust suit, it was considering whether it should attempt to retain the frequencies that would be essential for the operation of mobile phones. As a result, AT&T hired one of America’s best-known consulting firms to forecast the likely number of American subscribers for mobile phones by the year 1999. The forecast that was given to AT&T was that there might be as many as one million subscribers. It turned out that the number exceeded 70 million subscribers in that year (Rosenberg, 2004). In fact, the number of mobile phones sold around the world in late 2010 exceeded 5 billion units (BBC, 2010).

To have more appreciation for innovation, imagine how life would have been now if AT&T had not relied on innovation to pursue the development of mobile phones. Where would the economy be if we had not seen the contribution of companies like IBM, Google, Yahoo, eBay, Apple, Microsoft and other technology giants? Also, if the United States government had not created an innovative environment, would not the outcome have been completely different? Also, there is a direct link between innovation and the strength of the economy. To keep pace with the number of people entering the work force for the first time back in 2000, the U.S. economy would have had to generate 21 million jobs. As it turned out, 23.5 million new jobs were created. It is estimated that small businesses and the entrepreneurs who run them accounted for more than two thirds of those new jobs. Today, U.S. small businesses (firms with 500 workers or fewer) employ more than 50% of the labor force and generate
approximately one-half of the nonfarm private gross domestic product (GDP) (Bygrave and Zacharakis, 2009).

Universities with strength in research have the ability to discover innovative technologies and prove their affectivity in the laboratory. However, most universities lack the ability to develop those innovations or to validate technologies in the market place. There are many early- and mid-stage academic discoveries that have worked well in the lab, but never successfully made it to the market place. In order for a technology to survive in a market place, it has to meet a specific need or fulfill a poorly addressed application. Success with any innovation requires a good understanding of the technical and business fundamentals that govern its application. Even then, the risk of falling under the term “Technical success and Commercial Failure” is still high. According to Greg Stevens, president of WinOvations, a new product research and consulting firm in Midland, Michigan, only 2 products are launched out of every 3,000 ideas, and only one of those succeeds (Stevens et al., 1997). The challenge, always, is how to reduce the risk of failure and ensure technological innovations become a successful “market ready” technology. This is where the private sector can play a major role by bridging the gap and developing the new discoveries. This is sometimes done through establishing a relationship with the university, where the students work in teams to develop these early stage inventions through the PBL process.

It has been proven that the best resources are human resources and the best way to achieve increased output from human resources is to form effective teams. Research has also shown that when teams are established properly, their collective IQ is higher than the highest member IQ (Rice, 2012).

4. Implementation of PBL at ACK

The Australian College of Kuwait (ACK) is the primary institute in Kuwait for PBL. It uses a Project Based Learning model. Although the PBL program at ACK is relatively new (less than 5 years old), much progress has been made and significant impact has been noticed with recent graduates. One of the best attributes of PBL is the early exposure of working with teams. Students also learn how to reflect on their learning and assess themselves and their team members through self-assessment and peer-assessment. ACK implemented PBL primarily to degree students, but 2-year diploma students also take one PBL course prior to graduation, gaining early exposure to individual and collective problem solving skills.
Students also monitor and evaluate their learning and reflect on their learning via a reflective journal. The PBL learning process at ACK normally involves the following steps:

1. Students are assigned a set of learning outcomes to be met. Some are technical in nature while others focus on soft skills such as professionalism, teamwork, and ethics. Students are required to articulate and demonstrate personal application and development of the practice of professional engineering, including a professional attitude, problem solving skills and commitment to lifelong learning.

2. Students are assigned to groups (mostly interdisciplinary, with three to six members for each team) and they are required to solve a technical problem and/or achieve a certain outcome. The problem is usually ill-defined, requiring the students to work in teams, utilizing all available resources to identify what they know and learn new skills to understand all dimensions of the problem in order to provide a viable solution.

3. For 14-15 weeks, students work and learn in teams and, as necessary, lectures support their learning and help students to achieve their learning outcomes. These topics may include, project planning, risk assessments, stakeholder analysis, and decision making. Other topics also include team dynamics and how to establish and manage winning teams. Teamwork sessions are mainly used by the learning facilitator to review the students’ work and check progress. All work is documented through individual workbooks and reflective journals.

4. At the end of the learning period (usually beginning one week prior), students summarize and integrate their learning, presenting it to the facilitator in a form of a portfolio. The students then deliver a team presentation and an individual viva-voce, where each team member explains and defends their work and their findings. Each portfolio includes, at minimum, an individual workbook, individual reflective journal, group technical report, as well as self and peer assessment.

One example of intended learning outcomes for a PBL course at ACK includes the following:

1. Discuss the role of a professional engineer within a business environment, showing an appreciation of the interaction between the technical aspects of the role and the social, cultural, environmental, economic and political contexts.

2. Investigate and select materials and processes for engineering applications and justify decisions made.
3. Apply information literacy skills and information technology skills to engineering projects.

4. Use drawing, modeling and simulation tools to analyze and present project outcomes.

5. Describe, apply and justify risk assessment and workplace health and safety in engineering activities.

6. Design, conduct and report on practical activities; including, devising appropriate measurements and procedures, analyzing and interpreting data and forming reliable conclusions.

7. Articulate an appreciation of the complex nature of engineering activities including ill-defined situations and problems involving uncertainty, imprecise information, and conflicting technical and non-technical factors.

8. Articulate and demonstrate personal application and development of the practice of professional engineering, including a professional attitude, problem solving skills, relevant technical knowledge, productive work practices and a commitment to lifelong learning.

9. Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams.

10. Demonstrate professional oral skills during the presentation and viva-voce.

5. Challenges of PBL

Students tend to be confused at the beginning when they take their first PBL course. Some of the common difficulties they face are thinking and making decisions on their own, reflections, self-learning, and searching and finding answers. Unlike traditional methods, PBL problems often have many ways to approach and solve the problem - and there is usually more than one good answer. Students sometimes struggle with determining the best possible answer. Other challenges include team member selection and integration of different genders and majors. Not all teams have members with the same level of competence, so some teams may have advantages over others. Also, lack of commitment from some students tends to discourage other members of the team. Finally, measuring performance and grading of PBL courses are not the same as traditional courses. Since there are different ways to meet the learning outcomes, there is usually a grey line between different performance criteria.
When grading students, it can be challenging to determine how much each member actually contributed to the success of the project. Grades are often based on the students’ ability to prove how well they met the learning outcomes, self and peer assessments, as well as their performance on the viva-voce.

In spite of all of these challenges, students with PBL experience show higher confidence in working with teams and solving new problems.

6. Conclusion and Recommendations

New fields of study emerge as a result of breakthrough inventions. These innovations are usually as a result of effective management of resources. Effective teams have a higher collective IQ than the highest IQ of any member. Teaching students to think on their own early on and exposing them to team work leads to better performance (HBS Press, 2004). According to results from surveys conducted with new workers that graduated from the Australian College of Kuwait, recent graduates have shown to perform better on tasks that require problem solving, team work and documentation. Even small tasks such as organizing and documenting meeting minutes tend be much easier for ACK’s graduates than others. ACK has produced graduates with strong skills that significantly improve their employability across industries.

References


AN OVERVIEW OF SKILLS EXPECTED FROM YOUNG PROFESSIONAL JOB SEEKERS BY THE ENGINEERING INDUSTRY
A CUSTOMIZED EXPERIENCE-BASED PROFESSIONAL OPINION FOR CURRENT GULF REGION MARKET CONDITIONS

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Abstract
To be an effective engineer there are a number of soft and hard technical skills that are expected to be met. Employers and managers do not expect all employees to completely master each of these qualities and skills. The successful engineer should, however, be well-rounded and knowledgeable and be able to recognize those expectations and work towards improving on them with time. Typically, it is enough for a job seeker to acknowledge them and express interest in improvement in order for an employer or manager to be convinced to take a chance on them. Eventually with time, those key skills become second nature and can more easily be applied appropriately and effectively when needed. It will typically take some effort on the young professional’s part to develop them. However, by recognizing those skills and working on improving them one can contribute towards personal and professional growth and make a bigger impact on the team and projects. Furthermore, one can secure one’s value within a business making it important to be retained and appropriately compensated, increasing one’s marketability.

This paper discusses the general status of engineering education around the world, in the US, and in the Gulf Cooperation Council (GCC) region and their relationship to employability. The paper goes on to briefly discuss the effects of economic and market performances on employability and concludes with a list of industry expectations of soft and hard skills which are vital to young engineers and could help with their professional growth.

Keywords  Engineering education, industry expectations, GCC, Gulf Cooperation Council, skills
Introduction

Technical excellence alone is insufficient for success in a career in engineering. Soft skills play an increasingly important role in differentiating STEM (Science, Technology, Engineering, and Mathematics) professionals for employment and advancement.

In the day-to-day work of engineers and technical specialists, soft skills are as important as technical skills. These soft skills are sometimes correlated with emotional intelligence, along with other forms of non-technical intelligence such as cultural intelligence (‘Soft skills’, 2016). Soft skills are often not learned in school and are seen as tools that assist professionals to navigate smoothly and effectively through a wide variety of social and professional situations and networks. Such skills include communication, cooperation, creativity, leadership, and organization. With diverse cultures living and working together, these skills are even more important to ensure efficient work flow and effective project delivery. This paper will present a discussion of the general status of engineering education around the world, in the US, and in the Gulf Cooperation Council (GCC) region and their relationship to employability. The paper goes on to briefly discuss the effects of economic and market performances on employability and concludes with a list of industry expectations of soft and hard skills which are vital to young engineers and could help with their professional growth.

After years of experience in both academia and industry I have personally built a strong understanding of the expectations and limitations of both entities. Although they are both expected to be complementary with academia being the pathway to preparing students for a professional career, there often seems to be an apparent disconnect. Academic institutions are typically preparing and building the engineering students’ skills and knowledge pertaining to theoretical fundamentals of engineering. However, industry typically runs on more practical and time-efficient simplified summaries of those theories. Time is money in the business world and projects could be quite complicated with multiple involved disciplines. Considering one cannot be an expert in everything, the expectation becomes more centered on working within a team of professionals and understanding the simple methodology behind the engineering theory with the bigger emphasis being placed on quick access and efficient management of that knowledge. In order to be able to achieve that target soft skills are crucial; that’s where the disconnect arises.

Engineering is perceived by many as one of the prestigious and financially secure professional paths that young people can follow. It is typically very highly sought after as a career in the Middle East and around the world (Weintraub, 2014). However, it is also considered one of the most demanding professions in terms of gaining the knowledge and
skills required to be part of the industry with a high technical learning curve. Similar to many other specialized science and technology professions, the path into the industry is slightly more rigid.

In this day and age most leading international engineering firms, such WSP | Parsons Brinckerhoff, ATKINS, and AECOM, are looking to secure well-rounded individuals who not only possess relevant qualifications but also display evidence that they possess other skills, which can be more difficult to quantify. These criteria have developed over years of project performance observations and lessons-learned. Engineering firms seek those “top” engineers who bring different strengths to their teams and projects while having the tools to manage their weaknesses and unexpected surprises. Thus, it is essential for employers to ensure their employees are technically apt, can grow with time and experience, and can work within the bigger picture of day-to-day business function regardless of geography or discipline. Good technical skills are essential, however, engineering jobs are typically seen as dynamic in nature and need people who can simultaneously work across various disciplines, collaborate with other individuals and entities, and easily handle new challenges.

**Engineering Education and Employability**

On average, around 20 percent of university graduates worldwide embark on a career in STEM each year. In order for local graduating students to have a competitive advantage over other local and international candidates in this highly competitive market, it is important that the necessary skills and qualities that engineering employers desire are better clarified and developed for all graduating engineering students. This paper later lists and discusses some of those common sets of intangible soft skills, technical hard skills, and other recommendations which engineering employers typically desire across various engineering disciplines.

Typically, working in the engineering industry involves an array of job types and disciplines. The industry can accommodate various applicants’ interests, personalities, levels of expertise, levels of academic achievement, technical expertise, and accumulated professional experiences. Many companies look to hire high performing fresh graduates to ensure they have secured the elite talents within the market giving them a competitive edge in the long run. This also allows them to custom train those engineers on business procedures and office culture thus increasing the chances of success. Fresh graduates are also considered to be in a lower salary bracket than more experienced engineers and could provide a lucrative source of manpower for project managers.
Professional engineers and technicians need to have a high level of attention to detail, cognitive ability, skills and knowledge to design elements and sometimes managerial skills to lead tasks and other personnel. Other types of engineering position are more hands-on requiring craft-workers and operators with basic mathematical abilities, manual skills, and interest in outdoor supervision work. Regardless which position title in engineering one is being hired for, employers are looking for evidence that the candidate is well-rounded, sufficiently understands the industry, has an active interest in the discipline specifics, and has the motivation, drive and ambition to contribute to the business and the project to make a noticeable impact.

It is evident from the US Bureau of Labor Statistics (BLS) that unemployment rates are inversely proportional to the educational level of the work force (BLS-CLM, 2016). This trend is observed in other parts of the world and explains the increased trend of spending by governments and individuals on higher education in hopes of better future opportunities (EIU, 2009).

![Figure 1  US Unemployment Rates for persons 25 years and older by Education Attainment (BLS-CLM, 2016)
Overview of GCC Engineering Education Status and Employability

The number of GCC students studying abroad is evident from the UNESCO Institute for Statistics. Kuwait alone has over 16,000 mobile students studying abroad. However, recently “the share of mobile students studying within the region increased from 12% to 30% between 1999 and 2013” (UNESCO, 2016). For example, academic institutions such Kuwait University and research institutions such as Kuwait Institute for Scientific Research (KISR) are now attracting more local and regional students and regional research projects (UNESCO, 2015). With an increasing private engineering university trend in Kuwait in the last decade with institutions such as the Australian College of Kuwait (ACK) and Gulf University of Science and Technology (GUST), students can now have a choice between private and public education. This rise in supply of and demand for local engineering education could be attributed to political instability in adjacent regional countries, such as Egypt, Syria and Lebanon, which have historically been considered education attractions for GCC nationals and GCC expats.

According to the Organization for Economic Co-operation and Development (OECD), for example, the average percentage of STEM students in Saudi Arabia is about 20% and falls within the typical range for many developed countries around the world, which varies between 15% and 37% (OECD 2016).

<table>
<thead>
<tr>
<th>Country</th>
<th>% of Students Majoring in Engineering or the Sciences (Source: OECD)</th>
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<tbody>
<tr>
<td>Australia</td>
<td>21%</td>
</tr>
<tr>
<td>Canada</td>
<td>18%</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>24%</td>
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<tr>
<td>Finland</td>
<td>29%</td>
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<tr>
<td>Germany</td>
<td>28%</td>
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<tr>
<td>Iceland</td>
<td>15%</td>
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<tr>
<td>Japan</td>
<td>24%</td>
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<tr>
<td>Korea</td>
<td>37%</td>
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<td>Mexico</td>
<td>25%</td>
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<tr>
<td>Sweden</td>
<td>27%</td>
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<tr>
<td>United Kingdom</td>
<td>23%</td>
</tr>
<tr>
<td>United States</td>
<td>15%</td>
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Figure 2 Percentage of Student Majoring in Engineering and Sciences in Various International Countries (OECD, 2016)

Note. From the Organization for economic co-operation and development, March 2016 (OECD 2016)
This data alone is not a sufficient indication of employability of a fresh graduating engineer especially within the complex demographic structure of the six-nation GCC region (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates). Using USA’s BLS again as an example illustrates this issue where unemployment for 20 to 25 year olds, the age where many young professionals are leaving college and starting their career, is approximately twice as high as 25 to 30 year olds (BLS-LFS, 2016; Larson & Kaplan, 2015).

The population growth in the GCC has been heavily driven by immigration trends, with expatriates making up 42% of the region’s population in 2009, according to Economist Intelligence Unit estimates. “Based on a simple extrapolation from the trends of the past five years, nationals could become a minority of the GCC population by 2021. Under the Economist Intelligence Unit’s core scenario, however, nationals are likely to remain in the majority, as net immigration slows compared to its rate during the recent oil boom. Despite the slowdown, net immigration will remain strongly positive, as the private sector remains heavily dependent on expatriate labor. The gaps of cost and of skills between nationals and expatriates will gradually narrow, but will not close within the next decade.” (EIU, 2009)

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<tbody>
<tr>
<td><strong>Total (m)</strong></td>
<td>29.63</td>
<td>35.08</td>
<td>41.45</td>
<td>47.52</td>
<td>53.41</td>
</tr>
<tr>
<td><strong>Average annual change over previous five years</strong></td>
<td>2.80</td>
<td>3.44</td>
<td>3.40</td>
<td>2.80</td>
<td>2.40</td>
</tr>
<tr>
<td><strong>Saudi Arabia</strong></td>
<td>20.47</td>
<td>23.12</td>
<td>26.18</td>
<td>29.59</td>
<td>33.34</td>
</tr>
<tr>
<td><strong>Kuwait</strong></td>
<td>2.23</td>
<td>2.99</td>
<td>3.58</td>
<td>4.40</td>
<td>5.20</td>
</tr>
<tr>
<td><strong>UAE</strong></td>
<td>3.24</td>
<td>4.61</td>
<td>5.57</td>
<td>6.44</td>
<td>7.06</td>
</tr>
<tr>
<td><strong>Bahrain</strong></td>
<td>0.64</td>
<td>0.89</td>
<td>1.18</td>
<td>1.45</td>
<td>1.66</td>
</tr>
<tr>
<td><strong>Oman</strong></td>
<td>2.40</td>
<td>2.51</td>
<td>3.11</td>
<td>3.32</td>
<td>3.53</td>
</tr>
<tr>
<td><strong>Qatar</strong></td>
<td>0.64</td>
<td>0.97</td>
<td>1.82</td>
<td>2.33</td>
<td>2.79</td>
</tr>
</tbody>
</table>

Sources: IMF: individual country statistical agencies (historical data); Economist Intelligence Unit long-term forecasts. (Our population growth estimates are based on separate projections for each GCC state and population growth is projected to be higher in some of the smaller countries.)

Figure 3  GCC Population by Country - Historical and Future Forecast (EIU, 2009)

**Effect of Economic and Market Performances and Employability**

Markets all over the world felt the pinch of the 2008 economic crash (‘When giants slow down’, 2013). The Middle East, similar to the rest of the world, had to adjust to the world economy. The engineering sector was hit hard with lower private and public sector spending (Torchia, 2015). While the GCC has witnessed an emergence from that era over the last few
years, it was soon hit by a rapid and long term deterioration of the price of crude oil, which contributes to the majority of government revenues in the region (Maceda, 2014). That has had a big effect particularly on government spending. Businesses have been keeping an eye out for future economic forecasting and are trying to act fast to avoid the magnitude of the impact experienced in the post 2008 era. This has been seen with many companies operating in a leaner fashion with lower operating costs and more aggressive marketing methods. Within limited markets, the bulk of financial survival plans is going to be coming from employee redundancies, hiring freezes, and off-shoring which would create a growing pool of labor that may be difficult to absorb into the private sector (Maceda, 2014).

Based on the data mentioned above, fresh graduating engineers of locals and expats are going out into a very competitive market that is saturated with experienced professionals. Businesses are seeking the cream of the crop for the competitive advantage. In order for those young engineers to stand-out, they need to possess some strong technical skills. However, when a junior engineer is hired, the expectation is that technical experience is low; companies are going to be putting more emphasis on the soft skills that would ensure that this employee is going to succeed within their business in the long run. The following is a breakdown of soft and hard skills which most employers are looking for in new engineering graduates. Unfortunately, with the most prevalent higher education models, there is a clear disconnect between the theoretical work being taught in the classrooms and the practical work early career engineers are expected to perform once they enter the professional world. Some skills are acquired with experience and self-reflection which is difficult to teach. However, with a Project Based Learning (PBL) model, the introduction and adoption of those skills is more effective and long term. For example, team work cannot be taught theoretically nor would a student acquire any team work skills when solely exposed to the traditional higher education model. The PBL model and the skills developed using it are elaborated upon within this paper.

For that reason, many academic institutions are increasing collaboration with industry and introducing more PBL projects within their educational system (Larson & Kaplan, 2015; Gallop Perdue, 2014). So in order to build future engineers’ soft skills and kick start their hard skills, many regional universities which have not historically had the internship (cooperative education) model have recently started introducing it similar to what has been proven to work in many of the leading institutions in the US and Europe.
The following is a discussion of some soft and hard skills across a variety of engineering disciplines which employers seek out when hiring young engineering professionals with little hands-on experience.

Soft Skills
Soft skills are defined as “intangible non-technical skills. It is a term which is often associated with a person's "EQ" (Emotional Intelligence Quotient), the cluster of personality traits, social graces, communication, language, personal habits, interpersonal skills, managing people, leadership, etc. that characterize relationships with other people” (‘Soft skills’, 2016). Soft skills contrast hard skills, which are generally easily quantifiable and measurable (e.g. software knowledge, basic plumbing skills). The following are a number of highly desirable soft skills which are typically expected by employers in the Middle East and around the world from newly hired engineers (Monster, 2015; Brightside-What, 2016; Try Engineering, 2015; Butcher, 2013; Riley, 2010).

Soft Skill 1: Communication
To be a successful engineer, young professionals must continuously develop effective communication skills, including both written and spoken. Effective communication ascertains that the intended communication is received as planned. Engineers tend to prioritize technical skills over communication skills not realizing that they are ineffective in their jobs if they are inadequate speakers, writers, and listeners. Yet, it is particularly in the engineering fields that effective communication skills are crucial for success. Clear communication is vital when working with teams and individuals on any project, conveying expectations to team members, and receiving instructions from managers and peers.

Due to the diverse nature of the workforce in the GCC region, communication skills - such as business writing, technical writing, public speaking, and presentation preparation are more crucial for success as engineers work internally and externally with groups from different cultures and with varying understanding from team members of typical common business languages (English and Arabic). The ability to speak both languages in this work environment gives the engineer a very unique advantage.

The interaction between stakeholders, whether it is internal in an organization or external with partners or clients, is land-mined with opportunities for misunderstanding. That is why effective communication also involves listening, which is itself an essential soft skill.
Without actively listening to customers, clients, or project partners, problem-solving becomes much more difficult and time-consuming. There are plenty of simple ways to improve communication including taking a communication skills course. However, the most effective way to develop the skill is to practice. Typically, group activity involvement aids with communication skill improvement.

**Soft Skill 2: Creativity**

The successful engineer should be able to think outside of the box without reinventing the wheel. Due to the complexity of modern standards and liability that lies on the engineer’s shoulders, this should always be done after in-depth knowledge is gained in the available standards and practices or with appropriate research in order to allow the engineer to confidently justify their decisions and choices. Otherwise, the engineer would be considered irresponsible to be making ad hoc decisions. Creativity is arguably the driving force behind innovation. It should not be looked at as a luxury during prosperous times. However, it must be cultivated as though it is capital in current uncertain and challenging economic times. Innovation thrives on “industry leading” mentality, fosters a value engineering culture, and empowers employees to explore new paths. Organizations often depend on big ideas and creative employees to develop innovative products and services that could help with cost-cutting and process improvements. It is important that young professionals continue to show creativity to ensure problems are solved “better, faster and cheaper.” Creative thinking is a soft skill that all STEM disciplines should cultivate in order to become invaluable members of their organizations.

**Soft Skill 3: Adaptability**

Engineers face daily challenges on the job; nonetheless, employers are looking for those people who have the ability to adjust according to the situation at hand to address those issues. The ability to think quickly, assess problems, and formulate a solution within a reasonable time are some of the means in which one can demonstrate flexibility and agility. It is also very important to corporations that engineers have the willingness and motivation to adopt and implement internal policy changes. As a general rule of thumb, employers are looking for people that try to adapt to organizational changes before criticizing them.
Soft Skill 4: Cooperation, Collaboration and Teamwork

Projects are never individually designed or run. It is vital that any engineer can work with other people from different backgrounds and disciplines. The success and efficiency of any project is dependent on the level and quality of collaboration. Typically, participating in course projects (preferably PBL) at university gets future engineers acquainted to the idea and familiar with the requirements of team work. The hope is that those experiences are then built upon throughout the professional career. Additionally, volunteer activities and team sports have also been shown to provide experience of team work, collaboration and cooperation.

Soft Skill 5: Leadership

As an engineer progresses through their career, they will be given more responsibility, perhaps eventually becoming the manager of an entire team. To be successful, they need to possess leadership skills. These might include knowledge about when to step in or back off; how to best utilize a team member’s strengths; how and when to discipline someone and so on. One does not become a top engineer without leading at some point, so possessing and developing these skills is vital. Leadership skills include project management skills: planning, prioritizing, delegating, making decisions and influencing people.

Leadership is typically the combination of a number of skills including the ability to motivate and inspire others to give their best. Leadership for engineers is also about efficiently communicating with colleagues, teams, and clients and collectively agreeing on a unified way forward.

According to the National Society of Professional Engineers (NSPE), and as adapted from the Gordon-MIT Engineering Leadership Program, leadership is the capability and willingness to assess risk, take initiative, and make decisions to overcome obstacles. “These leadership capabilities are essential for the professional practice of engineering and for the protection of public health, safety and welfare.” (Musselman, 2010)

Soft Skill 6: Organization and Time Management Skills

Working in the engineering world is similar to the way that engineering students organize and manage their time while in university to meet their course work and project requirements and deadlines. To do so, one is required to manage available time effectively, to be able to prioritize tasks, and conduct various resource planning exercises.
**Soft Skill 7: Problem Solving**

Engineering is a profession centered on problem solving. Therefore, almost every task needs to be approached with an analytical mind. The solution has to be developed so that it meets all of the requirements with as little risk in the construction process as possible. Some may find this comes naturally, but there are techniques one can learn to make it easier. This might involve experimentation and testing before work actually begins so the budget is not wasted on failed attempts. A systematic way of approaching problems would involve the following:

- **Get specific:** One has to be specific about the problem in order for it to get fixed.
- **Break the problem down:** One big problem might be made up of smaller problems. Smaller problems are easier to consider and tackle.
- **Talk to someone:** Some problems could be complicated or may involve many people or disciplines. Simply restating or explaining the problem to someone else can help clarify the important elements even if that person is from a different discipline. A common industry trend is interoffice mentors that could guide others through certain challenges. In order to improve at problem solving it is most important to observe and practice.

**Soft Skill 8: Attention to Detail**

Engineering projects could be extremely complex. There are numerous details that have to be thought through during the planning and construction processes. Engineers need to possess a high level of attention to detail to ensure nothing important gets forgotten that could potentially impact the project’s schedule, budget, and morale. Accordingly, it is vital for engineers to make it a habit to validate and verify as they are working. Typically asking others to review also helps introduce a new set of eyes and perspective to the issue at hand.

**Soft Skill 9: Desire to Learn: Enthusiasm and Commitment**

Any diligent professional who is passionate about what they do makes an effort to keep abreast of industry changes and developments. It is vital for engineers to take it upon themselves to learn new techniques and learn about state-of-the-art pieces of equipment. This is typically done by reading industry journals and magazines and attending relevant professional meetings and seminars. Knowledge of the anticipated future trends of the industry is a must to keep one’s knowledge and competitive edge ahead of the game.

During any process there must be a sense of commitment to the team, project and profession. Without that, it would be difficult to move ahead and grow. Additionally, learning new skills is part of every engineer’s role, so engineers must be ready to adapt new information,
technologies, policies, procedures, and methodologies with an open mind and enthusiasm. Negative contributions could have a damaging effect on the team and the project. Controlled doses of enthusiasm may also demonstrate and enforce to managers the candidate’s potential level of commitment to the job and project.

**Hard (Technical) Skills**

Technical knowledge is the technical expertise that is vital to the job. They are essential in order to solve practical problems. Engineers must foremost have technical competence. Sufficient technical skills provide the ability to carry out the basic requirements for the position at hand. Although an engineering education provides the foundation of this knowledge, practical knowledge is typically imperative early on in one's career to learn the trade. Later, as technology is constantly advancing, engineers are expected to continue learning throughout their careers. The following are a number of highly desirable hard skills which are typically expected by employers in the Middle East and around the world from newly hired engineers (Monster, 2015; Brightside-What, 2016; Try Engineering, 2015; Butcher, 2013; Riley, 2010).

**Hard Skill 1: A Strong STEM Technical Base**

The core foundation of any engineering degree includes a series of qualifications in STEM (Science, Technology, Engineering, and Mathematics) subjects at any university. Engineering is often seen as a series of mathematical and logistical problems to design an element or manage a certain problem.

Mathematics skills are a key and necessary requirement for any engineering job whether it involves design, supervision, consulting, construction, assessment, or asset management. Mathematics skills do more than just prove that one is qualified to perform the minimum requirements for the job. The skills are an essential element used in every area of an engineering job. Usually, all universities and vocational schools require mathematics as a core requirement and prerequisite for most advanced classes. However, putting in the extra effort to ensure proper understanding of the theory and to have a better grasp of the relevant math’s skills will save the engineer a lot of undue stress in the long run.
**Hard Skill 2: IT Skills**
In this day and age, there are a small number of IT skills which are considered essential for any career. Something as simple as being able to log in to, operate, and perform simple trouble shooting for computers is considered a common expectation. Most universities now provide their students with the opportunities to pick up these skills and in some cases offer free training courses to help students improve on those skills.

As an engineer, IT skills are becoming more of a core requirement. Engineers are now expected to work with more specialized software, such as AutoCAD packages and take notes using tablets. Most recently in the USA, the use of electronic signatures and paperless operations are gaining momentum and being adapted with many private organizations and state DOTs (Departments of Transportation). Engineering young professionals are always highly encouraged to take advantage of any opportunity to learn and use new software as part of their degree to make it easier to understand and pick up new software in the future.

**Hard Skill 3: Office (MS or other equivalent) Products**
Office products have become an essential part of an engineer’s job requirements. The products that are most commonly used are Microsoft’s Word, Excel, and Outlook. However, there have been other suites on the market that offer similar products. As an engineer, it is always encouraged that Excel skills are built up early on in any student’s academic career. Excel is a very powerful and versatile spreadsheet software that could be customized to serve a variety of tasks. It is always recommended that more complex Excel commands are learned and applied on the job. This aids the applicant’s skills to stand out among the pool of other talented engineers.

In addition to the three basic programs, Microsoft also offers Access, OneNote, PowerPoint, and other very useful and practical products. The more proven experience that an applicant can show, the better the chances he or she has in obtaining the position they desire.

**Hard Skill 4: Auto CAD with CIVIL 3D and BIM**
Civil 3D and BIM are the future of engineering design and construction. AutoCAD 2D knowledge and experience are now considered a basic expectation. Many offices do not have the support of specialized CAD technicians to conduct the drafting work. Every engineer is expected to be able to draft or at least edit elements in AutoCAD (or Microstation). Even if an engineer is not directly working with CAD, they need to learn and understand CAD and more recently Building Information Modeling (BIM), in order to better instruct others doing
the work and to have a realistic expectation of outcome, quality, final delivery, and duration needed for the work. Beyond CAD, even if BIM knowledge is still basic, a fresh graduate engineer should try to seek every opportunity to learn more about BIM through personal research, on the job training, or professional development sessions.

**Hard Skill 5: Familiarity with Relevant Standards, Manuals and Guidelines**

Engineering is a rule-based industry. Standards, manuals, and guidelines are developed to facilitate the engineers’ jobs and reduce the amount of liability that could be borne if common standards are followed. Depending on the engineer’s related discipline, it is essential that he or she make themselves acquainted with all relevant standards, manuals and guidelines as soon as possible. All offices typically keep copies of that literature in-house for quick and easy reference. It is essential that engineers familiarize themselves with all relevant and available references such as HCS (TRB), Geometric Design “Green Book” (AASHTO), MUTCD (FHWA), LRFD, ACI Design Manuals, and LRFD Bridge (AASHTO).

**Other Recommendations**

**Recommendation 1: Learn about Individual Strengths and Weaknesses**

If one’s strengths and weaknesses are not known, then simply asking for a 360 assessment from various people around that individual can unveil very important characteristics and traits that could be either helping or hindering their professional advancement. Humility can go a long way in helping explore one’s weaknesses. Once that is done, it is important to identify the means and methods that help each student build on their strengths and manage their weaknesses. There are many resources online which could help with this element. One example is presented on www.brightknowledge.org (Brightside-Learn, 2016) where a variety of motivational recommendations are shared.

**Recommendation 2: Extracurricular Activity, Community Involvement and Volunteering**

Employers appreciate new employees that have an active life outside of work. This typically indicates a healthy well-balanced individual who can multitask and has means to de-stress. Accordingly, it is recommended that responsible extracurricular activities are shared. Community involvement and volunteering are typically highly regarded amongst the professional world.
Recommendation 3: Relevant Professional Organization Involvement
In order to be familiar with the state-of-the-practice in one’s field it is vital that there is involvement in relevant local, regional, and international professional organizations outside of academia and work. This also opens up room for professional discussions and networking with other peers, improves communication skills and increases the marketability of the engineer.

Recommendation 4: Professional Social Media Accounts
With the new era of social media, it has become even more difficult to separate professional and personal life. It is always recommended to be actively responsible on personal social media forums such as Facebook and Twitter. Employers typically shy away from engineers that could exhibit risky behavior which could be indicative of troublesome future behavior. Additionally, it is always recommended to update and maintain a professional looking social media account such as a blog or LinkedIn account. Employers are more commonly now approaching professionals online based on their posted CV. Ensure that the online profile is complete, updated, honest, and error-free to improve on one’s image and keep the most number of opportunities open.

Recommendation 5: Evidence of Continuing Education and Knowledge Growth
Employers like to know that the new applicants are keeping up-to-date on all the new technologies and innovations in their fields. Ability to show that this has been done through attending seminars and knowledge of relevant innovations could be a vital asset.

Recommendation 6: Get Professionally Licensed (registered / chartered engineer status)
Work on a path towards professional licensing to ensure proven advanced credentials and professional excellence within the industry. Usually, professional licensing requirements are quite extensive and vary by discipline and geographical region. Detailed research into local and international certifications and licensing must be done to ensure the student is selecting an appropriate credential that will contribute to their professional growth. Those requirements may sometimes require a combination of multiple exams and a number of years of experience. Early investigation into requirements will help manage expectation and keep focus. Most companies offer some sort of incentive for their engineers to become licensed and also offer pay raises once achieved. Licensing nowadays is considered a vital
qualification which is listed as a job requirement or is highly regarded by the hiring managers.

**Conclusion**

To be an effective engineer there are a number of soft and hard technical skills that are expected to be met. Employers and managers do not expect all employees to completely master each of these qualities and skills. The successful engineer should, however, be well-rounded and knowledgeable to recognize those expectations and work towards improving on them with time. Typically, it is enough to acknowledge them and express interest in improvement in order for an employer or manager to be convinced to take a chance on new talent. Eventually with time, those key skills become second nature and can more easily be applied appropriately and effectively when needed. It will typically take some effort on the young professionals’ part to develop them. However, by recognizing those skills discussed in this paper and working on improving them with time, one can contribute towards personal and professional growth, make a bigger impact on the team and projects, secure ones’ value within a business making it important to be retained and appropriately compensated, and increasing ones’ marketability.
References


INTRODUCING PBL TO A SELECTED TOPIC AND BRINGING IT TO A NEW LEVEL

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Abstract
Project-based learning (PBL) is a dynamic approach to teaching in which students explore real-world problems and challenges. With this type of active and engaged learning, students are inspired to obtain a deeper knowledge of the subjects they are studying.

PBL in the oil industry is a new idea and many people are still against the idea as PBL is still in the developmental stage and there is not sufficient research to state that PBL is a proven alternative to other forms of instruction. The petroleum industry is a practical industry rather than theoretical, therefore, introducing PBL to the oil industry through a unit called “selected topics” as well as with senior projects will prepare students to be well prepared for the industry.

Based on evidence gathered from our students, PBL appears to be an equivalent or slightly better model for producing gains in academic achievement, although results vary with the quality of the project and the level of student engagement. Also, PBL is not appropriate as a method for teaching certain basic skills such as reading or computation; however, it does provide an environment for the application of those skills.

More important, evidence shows that PBL enhances the quality of learning and leads to higher-level cognitive development through students’ engagement with complex, industry problems. It is also clear that PBL teaches students complex processes and procedures such as planning and communicating. Accomplishing these goals, however, requires time for both teachers and students to master the behaviors and strategies necessary for successful PBL.

Keywords PBL, petroleum industry, practical and theoretical courses
Introduction

Project-based learning (PBL) creates new instructional practices that simulate the real work environment. The main concept of such experience is self-learning through carefully designed projects. Instructors act as facilitators rather than lecturers. One of the main advantages of this approach is the ability to select projects that serve certain purposes. For example, a project can be chosen that will require students to go deeper into a certain project, or it can be designed to help the students to acquire other essential knowledge and skills not covered in the curriculum. It is this fact that makes the use of PBL courses attractive in petroleum engineering departments.

Petroleum engineering (PE) curricula are typically designed to cover topics from fundamental sciences to the production phase. This is, for example, reflected in some accreditation requirements. For example, the ABET requirements state that (ABET, 2014):

*The program must prepare graduates to be proficient in mathematics through differential equations, probability and statistics, fluid mechanics, strength of materials, and thermodynamics; design and analysis of well systems and procedures for drilling and completing wells; characterization and evaluation of subsurface geological formations and their resources using geoscientific and engineering methods; design and analysis of systems for producing, injecting, and handling fluids; application of reservoir engineering principles and practices for optimizing resource development and management; the use of project economics and resource valuation methods for design and decision making under conditions of risk and uncertainty.*

This is demonstrated schematically in [Error! Reference source not found.]. Because of the wide range of topics covered within the PE curriculum, it is not always possible to cover some of the practical aspects of the field. An example of this will be discussed later.
Another area where PE students can benefit from horizontal knowledge is the link with downstream operations (refineries and gas plants). There is a close connection between the exploration and production phases and downstream operations. PE curricula usually do not cover downstream production processes. For example, a good understanding of downstream operations can be valuable for those working in the production phase in terms of product quality and limitations.

The above two points highlight an excellent opportunity to use PBL courses to familiarize PE students with topics not traditionally covered. The idea is that PBL courses can be designed such that students will have an opportunity to learn about several topics that complement the core curriculum without having to dedicate specific units for that purpose.

In the following sections, we present a case study where well-control (a topic that is not covered within the current curriculum) is introduced to students through a project. The project is designed such that it connects the different parts of the curriculum (mainly fundamentals and drilling) and practical demonstration of the concepts through simple setup built by the students.

**PBL Courses in the Petroleum Engineering Department at ACK**

In the Petroleum Engineering Department at ACK, PBL courses have been used to complement the current curriculum with important topics. Currently, there are four courses...
utilizing a PBL approach, plus the senior project, that spans the four semesters of the degree program, as shown in Figure 14.

<table>
<thead>
<tr>
<th>Semester 1</th>
<th>Semester 2</th>
<th>Semester 3</th>
<th>Semester 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Programmable Logic Controllers (Department of Electronics Engineering)</td>
<td>• Advance Process Simulation (focus: downstream operations and calculations)</td>
<td>• Selected Topics (focus: unconventional topics in exploration and production)</td>
<td>• Sr. Petroleum Project (focus: practical and research based projects) • Environmental Protection (focus: awareness of environmental issues in the oil and gas industry)</td>
</tr>
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Figure 14  PBL courses in the Department of Petroleum Engineering at ACK

Discussion of a Case Study in the Petroleum Engineering Department

Our experience in the Selected Topics course at ACK, which is offered as a PBL course, creates tasks and conditions under which students’ thinking can reveal a process that involves inquiry, dialogue, and skill building as the project proceeds, and to deal with problems and to find the solution for problems is an essential quality for a professional. Therefore, the curriculum needs to educate and prepare the students to be a problem solver. With different learning styles, students are able to express their skills and talents through working on projects. By integrating design and technology tools into engineering education, the aim is to provide students with dynamic learning opportunities to actively investigate and construct innovative design solutions.

Working in ACK as a PBL course instructor has shown me that giving the students some theoretical projects could be beneficial, but, in order to take the concept to a new level, they must work on practical issues and use their understanding to analyze those projects.

For this semester, the PBL students work on well control which by itself is an important subject, and if anyone wants to join the drilling industry and especially work on rigs, they must take the well control certificate which will be given by the International Association of Drilling Contractor (IADC) and/or any other authorized local or international associations.
Therefore, the idea came to our mind that the students must know about this as much as possible in order for them to be able to find their position easier in the oil and gas industry.

But it will be good to know a bit more about well control, what is it and why it is important and what will be the reason that we need to do well control. In short, well control can be described as the core for human safety on board a platform or a rig. It includes a variety of elements that go under the name barrier elements that are in place to prevent an unwanted inflow of formation fluids. They need to be functional in order to fulfill their purpose. Elements are made, controlled and replaced by people, it is therefore vital that the people working with them know how they work in order to detect failure so they can be repaired or replaced as soon as possible. It is also important that everyone working in a drilling operation knows what well control is and the different scenarios that can develop if one should emerge. If the students want to know why this is important, they must understand the concept and they must learn about the most important parameters which will affect it. In order to understand the well control and to be able to control the well and not for the blow out to happen, a student must know about the phase behavior of gas and liquid and the sources of gathering information about the formation, known as formation evaluation e.g. petrophysical well logging tools like sonic logs, density logs, electric logs and gamma ray logs.

In conclusion, the incorporation of PBL courses provides an excellent opportunity to bridge the missing link within the curriculum with the freedom to direct the emphasis based on the project choice.

**Reference**

A FRAMEWORK TO INTRODUCE ENVIRONMENTAL PROJECTS THROUGH PROJECT-BASED LEARNING

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Abstract
Environmental projects can be categorized as municipal environmental projects such as water treatment and distribution, and specific environmental problems such as remediation of polluted sites. This study presents a systematic framework to introduce such environmental projects to undergraduate students through Project-Based Learning (PBL) methodology. The framework allows students to choose their project based on their interests, future goals, and learning outcomes. As part of the PBL methodology, students face realistic challenges such as lack of statistical data for future forecasting, or obtaining and deciphering technical data from various sources such as governmental bureaus. Students and instructors utilize substantial energy and time to complete each project in real-life conditions, and these experiences improve students’ learning levels, as well as, their professional development.

Keywords  Project-Based Learning, PBL, environmental projects, framework

Introduction
Water treatment and distribution, wastewater collection and treatment, and solid waste management are among the well-known municipal environmental projects that are completed through well-established steps (AWWA, 2011; Tchobanoglous & Kreith, 2002). For instance, a typical municipal project such as water treatment and distribution requires future population forecasting, estimation of future water demand, designing treatment units, and designing water distribution network. Likewise, a specific environmental project such as remediation of polluted groundwater usually requires characterization of contaminants, experimental data analysis, selection of removal mechanisms, e.g., chemical versus microbiological processes, computer simulations, pilot-scale studies, and on-site application of the proposed remedial approach. (Hyman & Dupont, 2001). Depending on the problem’s complexity, particular
expertise and multidisciplinary approaches usually are required to develop case-specific solutions.

Whether or not it is a municipal project or a particular pollution problem, the conventional approach to introduce environmental projects to undergraduate students has been through lecture-based learning, during which instructors explain concepts and provide examples to complete a task, e.g., forecasting future populations. Although the lecture-based approach serves well for fundamental courses such as calculus, this approach is limited to present various subjects from rapidly growing fields such as environmental engineering. Hence, engineering schools face challenges to cover in their undergraduate curriculum various environmental subjects such as solid waste management, water treatment, wastewater treatment, air pollution control and climate change, as well as, specific pollution problems such as groundwater remediation. Thus, these subjects usually are offered as advanced level units as part of graduate curriculums.

Alternatively, the undergraduate learning experience can be enhanced through Project-Based Learning (PBL) methodology that requires students to participate in the learning process (Kolmos et al., 2008). In the PBL methodology, students form teams, work on a project that covers the learning outcomes, define and distribute tasks among the team members, gather information and/or make necessary calculations, apply theoretical knowledge carefully to complete each task of their project, conduct weekly meetings, prepare progress reports, and reflect on their learning. Collectively, these steps constitute a platform for students to learn the theoretical knowledge and to apply their knowledge into hands-on projects. However, a systematic approach must be developed to introduce environmental projects to undergraduate students through the PBL methodology, and to monitor students’ learning levels and their professional development.

In this study, we present a framework to facilitate environmental projects in an environmental unit utilizing PBL. This framework has been developed for and implemented in the Water and Environmental Design course unit that is offered by Civil Engineering Department of the Australian College of Kuwait (ACK). Critical challenges that students and instructors face during various stages of the course are summarized along with several suggestions to resolve any deadlocks. The experiences at ACK show that PBL methodology demands significant effort both from students and instructors; however, it also improves the quality of learning as well as students’ professional development in comparison to other learning methods.
**Systematic Methodology**

The framework to introduce a municipal environmental project through PBL methodology can be summarized as follows:

1. Instructor briefly describes municipal environmental projects so that students can evaluate each project area (e.g. water treatment vs. wastewater treatment), review its parts (e.g., desalination, filtration), and select their project based on their interests and future goals.

In parallel, instructors can encourage students to tackle an existing environmental problem in their country/region. For example, Figure 1 shows the Sulaibikhat Bay of Kuwait where seawater is shallow and its circulation is limited. The bay is surrounded with industrial facilities, governmental buildings, and residential neighborhoods. Continuous municipal wastewater discharges into the bay area results in accumulation of pollutants in the seawater, sediments, and along the shoreline. This is one of the specific environmental problems that must be resolved urgently in Kuwait. Hence, this project serves as a good example of specific environmental projects that students can focus on.
Figure 1  Layout of Sulaibikhat Bay in Kuwait, yellow squares show the outlet points at which municipal wastewater is discharged into the bay.

2. Students form teams, and choose their projects based on their reviews, interests, future goals, and the course learning outcomes to be covered. Instructor should emphasize that success in a PBL unit heavily relies on team dynamics.

3. Students identify a town or a city where they implement the municipal project. The tasks to complete a municipal project are described below for water treatment and distribution project. Likewise, the steps for other municipal projects such as solid waste management, and wastewater treatment are provided in relevant parts.

4. Instructor lists the names of population forecasting methods (e.g., linear, geometric, logistic, and ratio method) and he/she demonstrates how to apply one of the methods to an existing town. Then, the instructor asks each team to review and to apply the other forecasting methods to their selected area/city. Instructor also requires that teams should discuss their results and reflect on their learning.
5. Teams must search for water consumption per person in their country/region, compare it with the other parts of the world, and they must discuss critical trends such as whether or not water consumption will decrease or increase in the future in their region. Then, teams must decide on per-capita water consumption values for future years, and they must estimate future water demand for their city.

For wastewater treatment projects, teams should estimate per capita wastewater generation, and then, compute total wastewater generation for future years. Similarly, for solid waste management projects, students should find out per-capita solid waste generation for their region, and then, compute the total solid waste amount for future years.

6. Instructor highlights that relevant laws, regulations, and standards must be reviewed and must be integrated into the projects. For example, water quality parameters and standards must be discussed to assess quality of potential source waters (e.g., seawater versus groundwater). Likewise, similar reviews are required for wastewater treatment, and for solid waste management projects.

7. Instructor should provide general description and basic design criteria of each treatment unit (e.g. settling tanks must provide enough time for solids to settle). Then, the instructor should supervise teams to design each unit and to produce alternatives, e.g., rectangular versus circular settling tanks. Students must design the treatment units such as intake structures, settling tanks, coagulation/flocculation units, media filters, and disinfection units.

For wastewater treatment projects, a similar approach must be taken to design treatment units such as settling tanks, and aeration basins.

For solid waste management projects, composition of solid waste must be identified to explore recycling opportunities. Then, alternative disposal methods such as an engineered landfill versus an incinerator should be designed, while advantages and disadvantages of each disposal method must be discussed in detail.

8. Instructor may describe basic design principles for elements of water distribution networks such as pumping stations, water storage facilities, and pipe networks. Students should design each element with alternatives.

Similarly, elements of wastewater collection systems such as sewer pipe networks, and lift stations must be designed with alternatives.
For solid waste management projects, gas collection systems in landfills as well as leachate collection systems should be addressed in this step.

This framework allows students to conduct basic research on each task during which they face numerous challenges such as lack of statistical data, or background knowledge about a specific process such as coagulation/flocculation. Highlights of these challenges are presented in the next section along with suggestions to resolve such obstacles.

Discussions and Conclusion

In lecture-based learning, instructors explain concepts, provide example calculations, and assign homework problems, for which they provide necessary data for solution. As an example, the first task in municipal projects is to compute future population of the city where a municipal project will be implemented. For this task, instructors explain the forecasting methods that are commonly used for municipal applications, provide examples for each method, and ask students to compute future population of a city by using historical population data that usually is provided by the instructor.

For comparison, our framework and the PBL methodology require that instructors provide basic information on concepts, while they guide students to complete each task as independently as possible. In this context, students can choose to implement a municipal project in a developing area, for which historical population data may not be available. Hence, lack of statistical data is a realistic challenge that students experience through PBL methodology. To overcome this problem, students identify the key trends that their city will experience in the near future, and compare these trends with a few existing cities that followed a similar pathway. For example, whether or not the city population will increase exponentially or linearly will rely on particular features such as an economic boom due to nearby oil fields, or the current city is an extension in a region that has been growing steadily (linear growth). Consequently, students will compute future populations by comparing their city to others that experienced similar growth in the past.

In parallel, PBL methodology requires that students must obtain information from reliable sources such as governmental offices. For example, per-capita water consumption, per-capita wastewater generation, and per-capita solid waste generation can be obtained from sources such as Ministry of Water and Electricity, Ministry of Public Works, and Municipalities.
These authorities usually may share statistical data through their websites, or they publish it in periodic reports (Ministry of Electricity and Water, 2015). Hence, students must decipher these resources to attain the key information needed for their projects, and such efforts mimic a realistic experience for students.

Another critical challenge for instructors is that students usually lack background knowledge about process fundamentals. For example, coagulation / flocculation are typical processes to remove colloidal particles from water. This process involves neutralization of electrical charges on natural organic particles, which are charged negatively. Accordingly, positively charged ions such as Fe$^{3+}$ or Al$^{3+}$ must be added into water to neutralize natural organic particles so that they can settle in the settling tanks. Instructors must provide basics of these processes so that students understand fundamentals of the subject. One way to explain these complex processes is to explain the subject through simple experiments. For example, addition of lemon juice (e.g., proton ions (H$^+$)) into milk to coagulate milk proteins is a typical example to demonstrate charge neutralization of colloidal particles in drinking water treatment. Such experiments improve students’ learning of complex topics so that they can complete designing treatment units.

In conclusion, the framework presented in this study illustrates how to utilize the PBL methodology to introduce environmental projects to undergraduate students. In this framework, instructors must aim to transfer the responsibility of learning to students as much as possible; however, they also must fill any gap when necessary. Instructors must guide students to obtain information from reliable sources, which may require considerable time and energy. Likewise, instructors must develop simple experiments to explain basic treatment processes to students. Overall, these efforts leave long-lasting and positive impact on students’ learning levels and their professional development.

References


HANDS-ON AND THEORY – DOES SEQUENCE MATTER? THE CASE OF LEARNING TO REVIEW CONCRETE DESIGN

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Abstract

The purpose of this study is to analyze learning effectiveness when students are in training to review the design of concrete structures. Two different course delivery methods for vocational engineering students are compared. The first delivery method begins with a focus on theory followed by a hands-on approach. The second delivery method utilizes the same approach, but in reversed order.

The difference in learning effectiveness of the two delivery methods is analyzed, based on 30 test questions administered to a total of 153 students before the course, in the middle of the course, and at the end of the course. A comparative analysis was applied that identified if correct responses to these questions increased or decreased.

It was found that the second delivery method (first hands-on, then theory) led to improved learning effectiveness. Students’ learning improved during the hands-on delivery and was further consolidated during the subsequent theory focused delivery.

The study is part of an ongoing research effort related to learning effectiveness of engineering students, and the findings presented here may encourage engineering educators who facilitate learning of reviewing concrete design to utilize initially a hands-on approach before continuing with a stronger focus on theory.

Keywords Learning effectiveness, review concrete design, active learning

Introduction

Active learning has consistently been found more effective than lecturing (Felder et al., 2000). The positive impact of various forms of active learning on engineering students’ learning effectiveness has been shown in detail in different contexts. For example, it has been demonstrated that, with proper planning and sequencing of topics, it is possible to integrate
and hence enhance engineering dynamics modelling courses using hands-on programming skills, leading to increased learning effectiveness (Adair and Jaeger, 2011a). Integrating Computational Fluids Dynamics (CFD) into a traditional fluid mechanics course has shown that the inclusion of hands-on CFD laboratories gave students a better appreciation of fluid mechanics in general and the students gained better knowledge of simple concepts (Adair and Jaeger, 2011b; Adair et al., 2014). Also a mechanical engineering design course has been developed, which actively engaged students and provided a hands-on project which stimulated students’ interest and provided them with sufficient time to develop important engineering skills (Adair and Jaeger, 2014). Finally, an active learning environment, such as Project-Based Learning (PBL), has been shown to have a positive effect on students’ perception of their personal responsibility for learning (Jaeger and Adair, 2014). Perceiving personal responsibility for learning is a trait which is of high importance for students’ learning in general and, considering that incorrect reviews of concrete design may lead to fatal consequences, is of particular importance for students learning to review design of concrete structures.

**Learning “Design of Concrete Structures”**

Active learning and hands-on approaches in courses related to the design of reinforced concrete structures are not new.

Estes et al. (2002) reported positive reactions of students regarding their hands-on concrete laboratory experience. Students’ feedback was collected through end-of-semester surveys. Cleary (2006) found that students’ designing, building and testing of a reinforced concrete beam led to an improved understanding of concrete fundamentals and enhanced learning. In line with the previous study (Cleary, 2006), this observation was confirmed by students’ feedback. Jackson et al. (2012) observed that students demonstrated a high level of understanding of engineering principles and design concepts, after they had built and tested a reinforced concrete beam.

A Student Experiential Learning Centre (SELC) for undergraduate laboratory testing was initiated, in order to allow students to carry out independent and unsupervised laboratory work after they received relevant instructions (Dawes et al., 2005). An increase of students’ responsibility for their learning, improved students’ skills, and students’ perception that they benefited from the learning experience were observed. Second year students of a course
related to reinforced concrete structures used the SELC approach and, based on observations and anecdotal evidence, students felt that it enabled them to learn about the behavior of reinforced concrete (Dawes et al. 2005). In a similar approach, students were responsible for conducting parts of concrete laboratory sessions with minimal supervision. Consistent with the previous studies, a high level of active learning was observed (Phelps et al., 2008).

Rumsey et al. (2010) reported that the integration of the following three methods enhanced students’ comprehension and retention of concrete design skills:

- Use of a concrete building code;
- Application of programming exercises; and,
- Full-scale design, construction and testing of a reinforced concrete beam.

However, so far it has not been identified if a comprehensive hands-on approach to building a concrete structure has a positive learning effect on reviewing designs of concrete structures. Furthermore, it is still unclear if and how different modes of learning facilitation influence each other. In the next section, the purpose of this study will be described in more detail, followed by method, results, discussions and conclusion sections.

**Purpose**

The purpose of this study is the analysis of the effectiveness of learning “reviewing concrete design”, when using two different delivery methods, and the study if part of a larger research effort aiming at improving learning effectiveness in engineering education.

The first delivery method begins with a period of traditional teaching that focusses on theory (in the following called “theory”), followed by a period of active learning based on a hands-on project (in the following called “hands-on”). The second delivery method combines the same approaches, but in reverse sequence: It begins with a period of hands-on learning, followed by a period of theory-focused learning. It can be expected that one of these two delivery methods leads to higher learning effectiveness, since each delivery method utilizes a different approach to reinforce previous learning.
Method

Methodologically, learning effectiveness can be analyzed by comparing the learning effectiveness of students learning based on the first delivery method (control group), with students learning based on the second delivery method (experimental group).

For this study, the experimental groups (i.e. first hands-on, then theory) consisted of a total of 44 students, and the control groups (i.e. first theory, then hands-on) consisted of 109 students. All students were students of civil engineering in their fourth semester at a private college in the Middle East. Experimental and control groups were comparable regarding gender mix, average age, average grade and all students were taught by the same instructors who coordinated the delivery of learning material in order to ensure learning of the same learning outcomes. Following good teaching practice, the instructors alternated theory input with time for reflection and activities in order to optimize students’ learning process (Felder and Silverman, 1988). The instructors allowed a similar amount of time for reflection during both approaches (i.e. theory and hands-on), whereas students had obviously more time for activities during the hands-on approach. Therefore, potential group bias is considered to be controlled.

The course considered here is “RIICWD533A - Prepare detailed design of civil concrete structures” as published by the National Register on Vocational Education and Training (VET) in Australia (NRVET, 2014). It is part of the curriculum “Diploma of Civil Construction Design” and is delivered over a period of 13 weeks with five contact hours per week. The course includes 19 learning outcomes that are organized into four groups:

1. Plan for the detailed design of civil concrete structures;
2. Undertake the detailed design of civil concrete structures;
3. Finalize design processes of civil concrete structures; and,
4. Support and review the application of the design of civil concrete structures.

The following learning outcomes belong to the fourth group of learning outcomes:

1. Provide clarification and advice to those applying the design;
2. Review the application of the design and recommend changes for the continuous improvements of civil concrete structures detailed designs; and,
3. Contribute to the validation of the design (NRVET, 2014).

It is the second of these learning outcomes, “Review the application of the design and recommend changes for the continuous improvements of civil concrete structures detailed
designs” (in the following called “Review Design of Concrete Structures”), that is considered in this study. Although this learning outcome is not an explicit learning outcome in all civil engineering curricula around the world, it can be considered an implicit learning outcome in all diploma and degree level courses related to reinforced concrete structures, since students need to learn to identify shortcomings in concrete design.

The hands-on project consisted of building a reinforced concrete frame consisting of two columns, each based on a column footing, and connected by a beam. The dimensions are shown on Figure 1.

![Figure 1 Dimensions of concrete frame](image)

Based on provided structural drawings, students had to:

- Erect formwork using proprietary formwork elements;
- Produce and install the reinforcement cages;
• Prepare spacers;
• Participate in casting supplied ready mixed concrete (Figure 2);
• Remove (strip) formwork; and,
• Cure concrete.

Students had seven five-hour sessions available and received assistance from the instructors and a lab technician. At appropriate points of time, the instructors explained the aspects that were covered by the pre- and post-tests in a similar manner to that used during the theory sessions.

A pre-test was administered to all students in Week One, in order to identify their competencies in reviewing design of concrete structures at the beginning of the course. A first repetition of the same test (in the following called “first post-test”) took place in Week Seven, when the experimental groups finished their hands-on project and the control groups finished their theory component. A second repetition of the same test was administered in
Week 13, when the experimental groups finished their theory component and the control groups finished their hands-on project. Students were not informed that the test with the same questions would be administered repeatedly throughout the semester. However, they were informed at the beginning of each test that the test was not part of the assessment items for this course and that it had no influence on their grades; rather, it presented an additional opportunity for them to identify their current competencies related to reviewing concrete design. All students being present on the test days used this opportunity and participated. The test consisted of 30 True/False questions, Q1 to Q30, and did not include questions that were part of course assessment items. An example question is shown on Figure 3.

![Concrete and Steel Bars](image)

**Figure 3** Example of True/False test question

In order to analyse the collected data and utilizing a binary scale, students’ answers were encoded with “1” for a correct answer and “0” for an incorrect answer. The mean values of correct answers have been calculated for all questions of all tests, and the mean values of correct answers of the pre-tests have been compared with the mean values of correct answers of the first and the second post-tests in order to identify how many answers improved and how many answers worsened. If the answers to any of the 30 questions did neither improve nor worsen, these answers will not be shown in the analysis since the intention here is to identify trends of improving or worsening results after exposure to different learning approaches (i.e. theory versus hands-on).
Results

A summary of the results is given in the following before these results will be discussed and conclusions will be drawn.

Table 1 shows the results of the control groups (first theory, then hands-on) in Fall 2014. Comparing the results of the first post-tests with the results of the pre-tests, it can be seen for Group A that more results became worse than results that became better (8 answers improved, 18 answers worsened), for Group B more results became better than results that became worse (22 answers improved, 4 answers worsened), and for Group C an equal number of results became better and worse (12 answers improved, 12 answers worsened). Comparing the results of the second post-tests with the results of the pre-tests, for Group A more results became worse than results that became better (9 answers improved, 13 answers worsened), for Group B more results became better than results that became worse (16 answers improved, 14 answers worsened), and for Group C more results became worse than results that became better (10 answers improved, 19 answers worsened).

**Table 3** Numbers of improved and worsened results - Fall 2014 control groups (first theory, then hands-on)

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th></th>
<th>Group B</th>
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<tbody>
<tr>
<td></td>
<td>improved</td>
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<tr>
<td>1\textsuperscript{st} post-test vs. pre-test</td>
<td>8</td>
<td>18</td>
<td>22</td>
<td>4</td>
<td>12</td>
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<tr>
<td>2\textsuperscript{nd} post-test vs. pre-test</td>
<td>9</td>
<td>13</td>
<td>16</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

(Numbers of improved and worsened answers may not match the total number of 30 questions because answers without improvement or worsening were excluded)

In Table 2 the results of the control groups (first theory, then hands-on) in Fall 2015 are summarized. Comparing the results of the first post-tests with the results of the pre-tests, for Group A more results became worse than results that became better (12 answers improved, 16 answers worsened), for Group B more results became better than results that became worse (22 answers improved, 8 answers worsened), and for Group C more results became worse than results that became better (12 answers improved, 18 answers worsened). Comparing the second post-tests with the pre-tests of the same groups of students, for Group
A more results became better than results that became worse (14 answers improved, 13 answers worsened), for Group B more results improved than results that became worse (18 answers improved, 12 answers worsened), and for Group C more results became worse than results that became better (12 answers improved, 18 answers worsened).

<table>
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<tr>
<th></th>
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<tr>
<td>1st post-test vs. pre-test</td>
<td>12</td>
<td>16</td>
<td>22</td>
<td>8</td>
<td>11</td>
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<tr>
<td>2nd post-test vs. pre-test</td>
<td>14</td>
<td>13</td>
<td>18</td>
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</tbody>
</table>

(Numbers of improved and worsened answers may not match the total number of 30 questions because answers without improvement or worsening were excluded)

In Table 3 the results of the experimental groups (first hands-on, then theory) in Spring 2015 are summarized. Comparing the results of the first post-test with the pre-test, for Group A more results became better than results that became worse (16 answers improved, 13 answers worsened), for Group B more results became better than results that became worse (16 answers improved, 14 answers worsened), and for Group C more results improved than results that became worse (16 answers improved, 14 answers worsened). Comparing the second post-test with the pre-test, for Group A more results became better than results that became worse (16 answers improved, 12 answers worsened), for Group B more results became better than results that became worse (17 answers improved, 13 answers worsened), and for Group C more results became better than results that became worse (16 answers improved, 14 answers worsened).
Table 3  Numbers of improved and worsened results - Spring 2015 experimental group (first hands-on, then theory)

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
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<tr>
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</tbody>
</table>

(Numbers of improved and worsened answers may not match the total number of 30 questions because answers without improvement or worsening were excluded)

These results will be discussed now in the following section.

Discussion

Regarding the six control groups (A, B and C in both semesters, Fall 2014 and Fall 2015) and the sequence of learning approaches in these groups (i.e. first theory, then hands-on) the following can be observed. After exposure to the theory focus, students’ results may have improved, results may have worsened, or results have not changed. The results of two groups improved, results of three groups worsened, and the results of one group did not reflect any change. Acknowledging that there may have been a number of influencing factors that led to this little encouraging observation, the focus of this study is on the identification of impact of the different sequence of theory and hands-on approaches and not on the underlying causes that led to the results.

Looking at the second part of the learning experience of these six groups (i.e. hands-on approach), the results reflect that the hands-on approach did not necessarily consolidate students’ learning. In fact, the hands-on delivery had even a negative effect on students’ learning in three groups. For the other three groups, the hands-on approach contributed to further learning. Since this study has been limited to the analysis of the impact of different sequences of the two different learning approaches on students’ learning, interpretation of these results can only be speculative. However, for both parts of the students’ learning process (i.e. theory and hands-on) the results seem to indicate that this sequence inhibits
potential to confuse students’ learning. The theory focussed learning as well as the hands-on focussed learning has led to worsened results for some of the groups.

Regarding the three experimental groups (A, B and C in Spring 2015) and the sequence of learning approaches in these groups (i.e. first hands-on, then theory) the following can be observed. The results of comparing the pre-test results with the first post-test results were improving for all three groups. The hands-on approach seems not to contribute to students’ confusion and may have had some consolidating impact on students’ learning. Also, the subsequent theory focus did not lead to overall worsening results in any of the three student groups. Although the results seem not to reflect a lot of additional learning, the overall results do show that students’ learning did not worsen during the theory focus. It seems that the theory focus had some consolidating effect after students had been first introduced to the learning content during the hands-on approach.

The results presented here seem to indicate that sequence does matter when looking at the effect of hands-on and theory focussed learning when learning to review concrete design. Exposing students to hands-on activities first seems to prepare a better basis for their learning than beginning with theory. In fact, the results seem to indicate that beginning with theory contains the risk of diminishing the impact of previously learnt concepts and probably some degree of common sense when students’ competence of identifying concrete design issues is evaluated. Students may be prone to the desire to apply concepts learnt during theory focussed sessions, even if these concepts are not applicable to specific concrete design issues that are to be identified.

**Validity and Future Research**

The following can be said concerning the validity of the experiment.

The *construct validity* was given by implementing various measures to counteract “memorizing without understanding”, since the test questions were designed to measure learning and not “memorizing without understanding”. First, students were not informed about the repetitions of the experimental tests. Second, when teaching aspects relevant for the experimental tests, the instructors did not inform students about the relevance for experimental tests. Third, aspects relevant for the experimental tests were not part of any regular assessment item and, therefore, were not covered in any review-session. Fourth, the instructors did not provide any feedback on the experimental tests before the 2\textsuperscript{nd} post-test was
delivered. However, the downside of this rigid construct validity may have been students who did not take these experimental tests very seriously.

The pre-test/post-test experimental design, applied to the experimental groups and the control groups, eliminated distortion of results that may have threatened the internal validity, although the internal validity was somewhat limited by the small number of experimental groups (three) compared with the number of control groups (six). Furthermore, a maturation effect was avoided by not informing students about repetition of the same experimental tests.

Regarding the external validity, it can be expected that the results are valid for the socio-economic context of the students who were studied here. Different contexts may lead to different results.

In order to confirm these results, the experiment requires additional experimental groups, and a more rigid analysis will be carried out in order to include significance testing. Also, future research should investigate learning effectiveness of a hands-on approach with integrated theory and identification of reasons for these results by surveying students’ perceptions on their learning and learning approaches.

**Conclusions**

In order to evaluate the learning effectiveness of reviewing concrete designs, learning experiments were carried out. Utilizing a pre-test/post-test experiment design with experimental groups (first hands-on, then theory) and control groups (first theory, then hands-on) of students, it was found that students who learn first on a hands-on approach and subsequently based on a theory focused approach show more consistent improvement in their learning. After learning based on a hands-on approach, the theory focused learning seems to have the potential of consolidating learning, whereas this could not be observed when students learnt first based on a theory focus, followed by a hands-on approach. The results may encourage engineering educators who facilitate learning of reviewing concrete design, to begin with a hands-on learning approach, before focusing more on the related theory.

**Acknowledgment**

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References


Abstract
The concept of Capability Maturity Models (CMM’s) is currently integrated throughout a diverse range of domains including the manufacturing, IT and construction industries. This integration is due to the success of using CMM’s in enhancing the capabilities of the organization that are needed to achieve its objectives in a systematic manner that complies with the specific business requirements and constraints. Recently, the Educational sector has been integrating CMM’s in the continuous improvement of its procedures in order to achieve student engagement, student retention and eventually reach for educational excellence. This paper will focus on the implementation of CMM’s in the Higher Education Institutions that would facilitate the systematic evaluation and optimization of the offered Project Based Learning units. Additionally, the path of creating a Project Based Learning Capability Maturity Model (PBLCMM) that will satisfy this need of improvement will also be illustrated and discussed in this paper.

Keywords   Higher Education Institutions, engineering education, Project Based Learning, Capability Maturity Model

Introduction
Improving the learning style in engineering education should be the goal of all Higher Education Institutes. This paper presents a Capability Maturity Model (CMM) that targets the incremental enhancement of courses utilizing a Project Based Learning (PBL) approach. This Capability Maturity Model shall systematically target filling the gaps in the PBL delivery process through focusing on diverse areas in the educational process.

The characteristics of PBL in engineering education have been summarized as follows:
• Ill-structured, complex problems act as stimuli for the course, curriculum or program;
• Learning is student-centered;
• Instructor takes the role of a learning facilitator;
• Learning is realized in small groups of students who analyze, study, discuss and propose solutions to (possibly) open-ended problems; and,
• Assessment of learners is enhanced by self and peer assessment (Kolmos and de Graaff, 2007).

Different variations, models, and perspectives on PBL have emerged (Graaff and Kolmos, 2003; Savin-Baden and Wilkie, 2004; Savin-Baden, 2007) and led to approaches such as “Problem-Oriented and Project-Based Learning” (Lehmann, Christensen, Du and Thrane, 2008) and “Problem-Based Project-Organized Learning” (Garcia, Bollain and Del Corral, 2011). The common focus of the different PBL variations and models is learning around problem scenarios rather than discrete subjects (Savin-Baden, 2000, p.3) and PBL in engineering education utilizes often a badly structured real life situation which is tackled as a project (Project-Based Learning). PBL has been shown to stimulate students’ critical thinking, self-learning skills, lifelong learning, self-achievement, self-regulation, self-efficacy, communication skills, interpersonal skills and motivation (Guerra and Kolmos, 2011).

It has been explained that there are no guarantees for a successful change to PBL since each change process is unique and influenced by contextual issues such as culture (Kolmos, 2013). Although there are characteristics, such as the ones shown before, that can be implemented in different contexts, there is no PBL model that can be taken as a whole and implanted in a different institution without necessary adjustments. The general socio-cultural context of students and instructors, learning background of students, as well as the specific institutional context require adjustments in order to optimize the effectiveness of a PBL model. Numerous case studies have reported implementation of and adjustments to PBL models (e.g. Davis et al., 2011; Graaff and Kolmos, 2007), and it has been shown that adjustment processes take several years and even an implemented and practiced institutional PBL model does not mean the end to continual improvement and fine-tuning (e.g. Kolmos and Flemming, 2004; Hoffman et al., 2006). In addition to the time required for the development and initial adjustments of any institutional PBL model, it should also be noted that students require time to adjust to a PBL pedagogy (Al-Dous, 2014; Jaeger and Adair, 2013).
In general, continual improvement requires a concept that facilitates an effective improvement processes. This is also true for improving institutional PBL models in engineering education, and different concepts and approaches have been suggested.

Many institutions of higher education use some sort of Student Evaluation of Teaching (SET) surveys, such as the Good Teaching Scale (GTS) at RMIT (Jayasuriya, 2008), in order to collect students’ perceptions on their courses and instructors. The results of these surveys may also be used to identify potential for improvement and to measure improvement of PBL models. However, it needs to be considered that the input for such evaluations is provided by students, and students are representing merely one stakeholder in education. Students may not be in a position to consider sufficiently industry expectations and the effect of their previous learning approaches and learning environments on their perception on learning.

Other institutions utilize a set of success factors in order to identify problems and to facilitate systematic, continual improvement of their PBL model (e.g. Lantada et al., 2013; Masek, 2010). Yet another approach to ensure systematic, continual improvement of PBL models is the combination of various tools. Such evaluation programs provide essential feedback, measure the success of the implemented model and they may include cognitive development, technical knowledge acquisition, professional competency acquisition and student interest and motivation (e.g. Ulseth et al., 2011). Although these evaluation approaches and concepts allow identifying the current performance of PBL models and monitoring performance changes over time, they usually do not include clear descriptions of performance levels that are to be attained after a certain time.

**Capability Maturity Models**

There is a need for implementing a methodology that emphasizes the optimization of the organizations’ capability in accomplishing requirements and strategic objectives. This methodology could be based on a Capability Maturity Model (CMM) as they were developed in the Software Industry. The approach of improving the process capacity through employing a Capability Maturity Model was initially initiated by the Software Engineering Institute at the Carnegie Mellon University according to Paulk et al. (1991). Various other CMM’s were developed and gained industry wide appreciation including Capability Maturity Model Integration (CMMI), Organizational Project Management Maturity Model (OPM3) and Standardized Process Improvement for Construction Enterprises (SPICE). These and other
models were adopted in other domains including construction, manufacturing, service development and e-learning.

**CMM in Education**

Similar to the Software Industry, CMM’s have been developed in the field of education focusing on the capability of institutions to deliver successful programs and generally the ability of student learning within the modules offered. Table 1 lists some Capability Maturity Models developed for the educational sector identified in the literature.

<table>
<thead>
<tr>
<th>Source</th>
<th>Name</th>
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<tbody>
<tr>
<td>Nelson et al. (2015)</td>
<td>Student Engagement, Success and Retention (SESR-MM)</td>
</tr>
<tr>
<td>Thong et al. (2012)</td>
<td>Curriculum Design Maturity Model (CDMM)</td>
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</table>

Nelson et al. (2015) developed a Student Engagement, Success and Retention Maturity Model (SESR-MM) that focuses on the institutional capability by appraising the students’ first-year experience (FYE) and engagement. SESR-MM consists of five maturity levels and five key process areas (KPA’s) consisting 63 practices. On the other hand, Thong et al. (2012) developed the Curriculum Design Maturity Model (CDMM) that shifts focus to designing institutional curriculums consisting five levels of process capability and observing the adaptation of benchmark documents such as the Code of Practice for Programme Accreditation, Programme Standard for Computing and ISO9000 series in Malaysian institutions of higher learning. An assessment template was also developed by Thong et al. (2012) including practices that target the capability of each module developed in the curriculum. These practices include but are not exclusive to utilizing Bloom’s taxonomy in the preparation of the learning domain, peer review process enhancement and observing the scope of the modules and to constantly verify its validity.

Chen et al. (2012) developed a Teaching Capability Maturity Model (T-CMM) that focuses on enhancing the quality of the teaching process thus working as an improvement tool for the
teacher’s educational skills and knowledge rather than focusing on the organization as a whole. However, so far a CMM has not been developed and applied with the aim to improve a PBL model. This paper is aiming at filling this gap. The following sections cover the development of a Project Based Learning Capability Model, its application to three cases and a conclusion.

The Development of a PBLCMM

Courses utilizing PBL should be oriented towards the engagement of students and concentrate on improving their knowledge, skills and capabilities by conducting research, increasing their exposure to the industry and working in a collaborative manner with their team mates. As previously mentioned, courses utilizing PBL are currently set at the core of successful educational institutions with the purpose of enhancing learning of the students in a specific educational domain. On this basis, this section will highlight the route to developing and tailoring a Project Based Learning Capability Maturity Model (PBLCMM) as a step of improving the current practices conducted in courses utilizing PBL and eventually optimizing the learning process simultaneously.

The ultimate purpose of developing the model is to evaluate the ability of achieving the optimum educational value for the students and Higher Education Institutions through appraising both the output and the practices conducted. Andersen & Jessen (2003) point out that achieving high maturity in an organization reflects its high ability in obtaining its objectives. PBLCMM shall support the achievement of this scheme by benchmarking the progress of courses utilizing PBL and regularly evaluating that progress thus assuring that the unit is heading towards improvement. Eventually and when applied to various courses, PBLCMM could be used to compare between the capabilities of different courses utilizing PBL.

PBLCMM shall be developed based on the fundamental pillars of the Capability Maturity Model integration (CMMI) developed by Paulk et al. (1993). CMMI defines 22 generic process areas and five process maturity levels namely

- Initial;
- Repeatable;
- Defined;
- Managed; and,
CMMI comprises the use of two improvement representations named the *staged* and *continuous* representations. These representations shall be considered based on the fact that CMMI is the only standardized and widely approved CMM across diverse industries (Wendler, 2012) thus represents the ideal basis for the development of new capability models.

The first representation in the CMMI is the staged approach which necessitates the availability of 22 predetermined process areas. Achieving a certain level of organizational maturity is dependent on the availability of these process areas. This maturity level represents an overall score of the organization’s maturity through the establishment of 16 process areas. Naturally, gaining improved maturity secures the stability of the established processes and improved predictability for the organization.

The second representation is the continuous approach which groups the process areas together to form modules which are previewed in CMMI as the process management, project management, engineering and support group. The course is observed closely and each process area is evaluated and assigned an individual score or maturity to represent the team’s ability in conducting that specific process. This representation would provide the organization with a more detailed look into its capability within a specific process which is the first step into improving certain process areas without being overwhelmed with improving the entire project. In other words, the continuous approach targets incremental and more manageable improvements. Table 2 illustrates the difference in evaluation between both approaches as shown in the CMMI. It is clearly indicated that the continuous representation considers having a level 0 to point out that a certain capability under study does not exist within an organization.
<table>
<thead>
<tr>
<th>Level</th>
<th>Continuous Representation</th>
<th>Staged Representation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Capability Levels</td>
<td>Maturity Levels</td>
</tr>
<tr>
<td>Level 0</td>
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</tr>
<tr>
<td>Level 1</td>
<td>Performed</td>
<td>Initial</td>
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<tr>
<td>Level 2</td>
<td>Managed</td>
<td>Managed</td>
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<tr>
<td>Level 3</td>
<td>Defined</td>
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<td>Level 4</td>
<td>-</td>
<td>Quantitatively Managed</td>
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<tr>
<td>Level 5</td>
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<td>Optimizing</td>
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</table>

Based on the previous section, the continuous representation approach shall be adapted in PBLCMM in order to focus on the Higher Education Institution’s capability of delivering successfully courses utilizing PBL rather than highlighting the overall maturity of the institution.

**PBLCMM Capability Levels**

In order to properly and smoothly integrate the PBLCMM into the HEI, it is necessary to provide clearly distinct capability levels that define the prerequisite process indicators to gain a precise capability level. The four capability levels include CL0, CL1, CL2 and CL3. The capability levels are achieved through completing specific goals and practices in addition to generic goals and practices as shown in the CMMI. CL0 indicates that the specific practices were not achieved in the organization, CL1 necessitates that all the specific practices needed in the key process area is satisfied, CL2 requires that some generic goals need to be achieved in order to institutionalize the process and finally CL3 requires that the organization establishes measures that would customize the processes undertaken to the parameters and constraints of the organization. Achieving CL3 entails that the organization is on the path of continuous improvement of the key process areas under development (Paulk *et al*., 1993). The following section will look into the development of the key process areas that will be appraised using the PBLCMM.
Key Process Areas

The key process areas (KPA’s) represent the collection of processes that could be organized under one category. The capability of each of these KPA’s shall be the concern of any HEI targeting continuous improvement of its courses utilizing PBL. The KPA’s extracted from the literature and interviews with PBL facilitators are namely; quality of problem/project, quality of learning facilitation and quality of learning assessment.

KPA1: Quality of problem/project: This key process area is concerned with the suitability of the problem/project presented in the course to achieve different targets including the support of the students’ learning process and establishing learning outcomes requirements.

KPA2: Quality of learning facilitation: This area includes the preparation of students to conduct activities and tasks required in addition to activities related to the facilitator guiding the learning process of the students.

KPA3: Quality of learning assessment: This area fixates on securing a valid assessment process for the students based on objective criteria. Achieving a high capability level in this area would contribute to the overall moderation of grades amongst different PBL facilitators.

As previously mentioned, the KPA’s are appraised against achieving generic goals and practices in addition to the specific goals and practices. CMMI provides these goals and practices that are specifically oriented towards the software industry. On this basis, relevant practices are required to be utilized for the appraisal of PBL units. The next section shall focus on the extraction of the practices that are relevant to the development of the PBLCMM’s specific practices and goals.

The specific practices of PBLCMM shall be extracted from a deep literature review that examines the relevant PBL practices which illustrate good results. The next step would be conducting interviews with PBL facilitators in order to observe the validity of the practices extracted from the literature. That would be in addition to allowing experienced facilitators to add more practices that ensure a successful application of PBL. Finally, a focus group shall be formed to validate the list of specific practices and group these practices under specific goals. The collection of specific goals shall form the KPA’s of PBLCMM.

On the other hand, the generic practices and goals shall be used as presented in the CMMI. These goals secure three ultimate goals starting with achieving the specific practices and goals, institutionalize the process in the organization and tailor fit the process based on the organizational needs and constraints (Paulk et al., 1993).
PBLCMM Appraisal Approach

In order to properly conduct the process of evaluating courses utilizing PBL, the PBLCMM shall follow a specific path of appraisal according to the currently well-established standardized assessment methods used in the CMMI. Paulk et al. (1993) developed three assessment methods to conduct the comprehensive appraisal for an organizational entity known as Scampi A, B & C. Scampi A is considered the most detailed and comprehensive method of evaluation utilized in CMMI including the

- planning and preparation;
- data collection;
- data consolidation and validation;
- rating; and,
- review and feedback.

Paulk et al. (1993) insists that it is essential to use the assistance of an evaluation team comprising key stakeholders and an external facilitator to assure ideal results. On the other hand, Scampi B appraisal is less demanding by requiring a smaller assessment team but still using a detailed process of data collection and validation. Finally, Scampi C which is the simplest approach to appraisal is concerned with extracting the perspective of specific key personnel in defining the level of capability of the KPA in hand.

Given that objective evidence is the main target of this evaluation, the Scampi A approach shall be used. This perspective is agreed upon by Sun et al. (2009) when pointing out that Scampi A is the most suitable approach of a comprehensive assessment with a high objectivity. Nonetheless, the conduct of the appraisal process should be undertaken by an entity external to the course, not the course facilitators themselves to allow persistent evaluation under the control of the organization. Additionally, allowing the evaluation process to be conducted within the HEI allows for mitigation of additional costs of hiring an external entity for the evaluation process. The upcoming section shall look into the PBLCMM appraisal cycle that clarifies and is set as guidance for the conduct of the appraisal process.

This section is concerned with the application of PBLCMM appraisal utilizing both Scampi A in addition to integrating best practices utilized in the ISO9001:2008. In other words, the PBLCMM Appraisal Cycle shall extend beyond the appraisal approaches defined by Paulk et al. (1993) to cover the most common and widely accepted appraisal methods of the ISO.
One of the most important features of PBLCMM is that it is targeting the implementation of specific organizational process requirements in addition to the featured best practices. This would allow for employing a general framework of evaluation in a tailored approach to fit the necessities of the HEI. The PBLCMM Appraisal Cycle consists of three distinct yet interlinked phases namely; Planning Phase, Appraisal Phase and the Analysis & Results Phase. The proper conduct of this appraisal cycle shall secure performance reflecting outcomes of the course utilizing PBL with the main concern of preserving the objectivity of the processes.

To prevent additional work for the PBL facilitators resulting from required paper work that serves as evidence, PBLCMM shall utilize two routes in extracting evidence and conducting the appraisal. The first will be through collecting evidence through the available documentation without necessarily introducing new requirements. The second approach is through observing learning facilitation and attempting to appraise the performance against the PBLCMM best practices.

**Future Work**

In addition to extracting specific practices of PBLCMM from literature, the validity and utility of PBLCMM will be verified by carrying out three case studies. These case studies shall be conducted for three PBL units offered by the Civil Engineering Department in the Australian College of Kuwait. These case studies will verify how effective PBLCMM is in appraising the performance of the units and evaluate its applicability in order to facilitate any fine tuning to the model itself prior to utilizing it college-wide.

**Conclusion**

This paper presents the guidelines of developing a Capability Maturity Model for continual improvement of a Project Based Learning (PBLCMM) approach. These guidelines include the tailoring of the frameworks provided by the literature and in specific the CMMI which was developed for the software industry. The next steps in developing the PLCMM shall be consultation with the PBL facilitators in addition to the conduct of a deep literature review. Moreover, the model shall be validated through conducting three case studies to verify its ability to detect the PBL practices gaps. The development of such a model should achieve systematic improvements in the Higher Education Institutes that utilize PBL.
References


TEAM FORMATION CHALLENGES IN PROJECT BASED LEARNING (PBL) MULTIDISCIPLINARY TEAMWORK

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Abstract
The aim of this work is to summarize the main challenges facing a Project Based Learning (PBL) facilitator in dividing multidisciplinary classes with mechanical engineering and civil engineering students into teams to design and implement a project. The teaching staff and students at the School of Engineering, Australian College of Kuwait (ACK), were interviewed to identify the main concerns of both students and staff in creating the teams to work on a real life engineering task. The results were collected and presented in this work. It was found that the ideal number of students in each team is four students with two students from each major. Moreover, students believe they will perform better if they select their team members rather than having the facilitator randomly form the groups. Students prefer to select their team members based on whom they personally know as a friend, and who are hardworking, easy going, or helpful. Results show that the social/cultural issues are the main challenge in generating the teams.

Keywords Project Based Learning, PBL, team work, team formation

Introduction
To prepare the students for the market and real life environment, it is recommended to let them work in similar work conditions in terms of project nature where multi engineering majors are required to finish an engineering task completely, dealing with people of different and various experiences, education, and skills. Learning designs need to incorporate student-centered team based learning pedagogy such as project-based, case-based, inquiry-based and problem-based scenarios (Oliver, 2001). One of these approaches is Project Based Learning (PBL), where courses include students from two or more engineering disciplines working
together on the same real life engineering problem to find a solution that requires multi engineering disciplines.

The School of Engineering at the Australian College of Kuwait (ACK) offers a variety of courses based on a PBL approach. Some courses are offered exclusively for students of one discipline where the students work only on discipline related problems. It mainly requires learning related to one engineering discipline. On the other hand, other courses require multidisciplinary work and learning and students work together, where the work cannot be achieved without the cooperation of students from two disciplines within the School of Engineering. Team work also helps when one student’s ideas, information, conclusions, theories, and opinions are incompatible with those of another, and the two seek to reach an agreement (Johnson & Johnson, 1979, 1995). In the literature many definitions of teamwork are available and according to Scarnati (2001, p. 5) team work is defined as a cooperative process that allows ordinary people to achieve extraordinary results. Harris & Harris (1996) also explain that a team has a common goal or purpose where team members can develop effective, mutual relationships to achieve team goals. Literature focuses on one of the essential elements of a team which is its focus towards a common goal and a clear purpose (Fisher, Hunter, & Macrosson, 1997; 1999; Parker, 1990; Harris & Harris, 1996).

In this work the challenges for the single and multidisciplinary courses utilizing a PBL approach will be discussed. The results are demonstrated for both teaching staff and students.

**Case Study**

Before introducing the data collected from the interviews, there are some highlights about team generation in multidisciplinary PBL courses in the School of Engineering at ACK. One of the multidisciplinary courses is ENEG12006 - Engineering Design and Management Implementation where mechanical and civil engineering students are working together on a real industrial problem. The first step in this course is to form a team with equal number of mechanical and civil engineering students. However, this step can be performed either by random selection of the students in each team or allow the students to select their teammates. It should be mentioned here that the number and size of each team depends on the entire number of students in the class.

In PBL, and to resemble a real life work environment, a random selection procedure is recommended, but this procedure may face the following difficulties:
Culture: Mainly if there are male/female students in the same group, as some students (from different gender) may refuse working with the opposite gender. So, allowing students to select their teammates will solve the issue.

Personal: Some of the students may feel very shy if they work with others if they do not know or have previous friendship.

Scientific/Knowledge: Random selection of the group members by the facilitator may result in uneven experiences in one team, while allowing students to select their teammates based on their needs to finalize the project can result in a better performance. For example, using computer and up to date technologies in solving the problem like 3-D printing and engineering software like ANSYS is mandatory in getting high evaluation of the learning outcomes of the course. Due to the difficulty involved in the design and development of complex software systems, wide ranges of software engineering paradigms have been developed, such as object-oriented programming, structured programming, procedural programming and declarative programming (Genza & Mighele, 2013). If the students selected their teammates based on their previous knowledge and skills can result in better performance than forcing the team to work with the same skills and experiences.

Nature of the project: Some projects need professional skills in workshop activities, in which mechanical engineering students may perform better than civil engineering students and even within the same discipline some students are more skilled and handy in doing practical jobs than other students.

Based on the above mentioned reasons, it is better to allow the students to select their mates but in only one phase, which is the design phase for example, whereas in the implementation phase the facilitator can randomly assign a team to implement the design of another team to give the students a flavor of real life environment. Even if the students are allowed to generate their teams by themselves many problems arise such as the inability to reach agreements, lack of innovative ideas, conflicts, or complacency of team members.

To help the facilitator in delivering the course in its best way, the registrar’s office should facilitate enrolling a balanced number of students from each discipline.

Communication skills: Some of the students are professional and active in communicating with other people inside and outside the college. Communication in their team, with other teams and with the instructor are very important and different communication means should be used, such as verbal and written communication, since they contribute to reaching learning
outcomes such as learning outcome number 10 in ENEG 12006, which is “Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams”.

**Methodology, Results and Discussion**

To determine the best way to form teams in PBL units, teaching staff and students were interviewed where the questions were answered and analyzed based on ten teaching staff and 60 students.

Table 1 Survey results

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
</table>
| 1) What are the three most difficult challenges in building student teams? (most difficult first, least difficult last) | Students: Most Difficult:  
  - Nationality.  
  - Age.  
  - New members (not acquainted with)-Friends-Knowing our teammates-Friends that we have to choose.  
  - Not enough students from the other department.  
  - Choosing the team knowledge.  
  - Finding chemistry between members.  
  - Different cultures and different way of thinking.  
  - Team dynamics.  
  - Being in class without my friends.  
  
  In between:  
  - Gender *(mentioned 4 times)*  
  - Not being acquainted enough with other students.  
  - Teams members that work.  
  - Assigning tasks.  
  - Time schedule.  
  - Team dynamics.  
  - Time management.  
  - Communication  
  - Those who don’t work or do every effort.  

Staff: Most Difficult:  
  - Unequal number of civil & mechanical students.  
  - Some students are not welcome in groups due to either unprofessional behaviour/bad experience.  
  - Ensuring effective teamwork.  
  - Social interest.  
  - Culture sensitivity.  

  In between:  
  - Academic levels.  
  - Balance in disciplines.  
  - Gender.  
  - All good students want to team up together.  
  - There are weak students who want stronger team.
<table>
<thead>
<tr>
<th><strong>Least Difficult:</strong></th>
<th><strong>Least Difficult:</strong></th>
</tr>
</thead>
</table>
| - Age (*mentioned 2 times*).  
- Different approach in doing things.  
- Friends.  
- Getting the full workload.  
- Mix group.  
- Knowledge.  
- Time management.  
- Chemistry. | - There are undecided students unsure.  
- According to their needs  
- Having the team agree on topic  
- Being responsible.  
- Assigning students to teams. |

<table>
<thead>
<tr>
<th>2) What is the most suitable number of students in each team? Why?</th>
<th><strong>Ranked from top to down according to most favored answer.</strong></th>
</tr>
</thead>
</table>
| *4 members in one team:*  
- Easy to communicate.  
- Ease to distribute tasks fairly and equally. | *4 members in one team:*  
- Two department for multidisciplinary.  
- Every group will have 2X2.  
- Enough work for each students  
- Equal number of both majors. |
| *5 members in one team:*  
- Distribution of work and saving time. | *4-5 members in one team:*  
- Less makes it difficult and more means less people work.  
- Everyone needs to contribute. |
| *6 members in one team:*  
- More idea generation. | *3 members in one team:*  
- Students interact more efficiently. |
| *3 members in one team:*  
- To be able to focus on tasks with all members working. | *5 members in one team:*  
- Diversity |
| *2 members in one team:*  
- Less stress of coordination. | *6 members in one team:*  
- Equal numbers |
| *1 member in one team:*  
To get the entire knowledge of PBL | |

| 3) The performance of teams is better if they select themselves than if I assign them to teams. | Most answered with Yes  
1 answered with No | 7 answered with Yes  
3 answered with No |

| 4) If you assign students to teams, how do you assign them? | **Based on reputation of hard work.**  
**Strong knowledge with good manners.**  
**If I know them or not.**  
**Based on their thrust for knowledge**  
**Helpful** | **2 civil + 2 mechanical**  
**Diverse**  
**According to their major-**  
**Combination of different department**  
**I should know them in advance to team up fairly based on their** |
5) Teams perform better if all team members are equally strong. Why?

<table>
<thead>
<tr>
<th>Yes:</th>
<th>No:</th>
<th>Sometimes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mutual help</td>
<td>Lack of experience.</td>
<td>If the weak students are willing to learn.</td>
</tr>
<tr>
<td>They know what to do.</td>
<td>Strong ones land doing the job alone.</td>
<td></td>
</tr>
<tr>
<td>Keep same pace to all members.</td>
<td>Miscommunication.</td>
<td></td>
</tr>
<tr>
<td>Competition.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better outcomes for the project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Save time. Respect their work and others.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 answered with Yes:
- The team strength is driven by its members.
- They should have enough strength in different fields.

7 answered with No:
- More conflict.

6) Teams perform better if a team consists of a mix of strong and weak students. Why?

<table>
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<th>Sometimes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Help each other and work together.</td>
<td>Lack of experience.</td>
<td>If the weak students are willing to learn.</td>
</tr>
<tr>
<td>They can accomplish more</td>
<td>Strong ones land doing the job alone.</td>
<td></td>
</tr>
<tr>
<td>Learn from each other.</td>
<td>Miscommunication.</td>
<td></td>
</tr>
</tbody>
</table>

Students answered with Yes:
- Help each other and work together.
- They can accomplish more
- Learn from each other.

Students with No:
- Lack of experience.
- Strong ones land doing the job alone.
- Miscommunication.

Students answered with sometimes:
- If the weak students are willing to learn.

7 answered with Yes:
- In some cases, weak students work harder to reach the level of strong students.
- Yes diversity
- Yes, because weak students may perform better
- Yes, weak students will work hard to catch-up

3 answered with No:
- Weak students affect the performance.
- If good team culture exists.

7) When you have interdisciplinary PBL courses, do you prefer to have equal number of students from the two majors in each team? Why?

<table>
<thead>
<tr>
<th>Yes:</th>
<th>No:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skills exchange</td>
<td>Mechanical students can do the job alone.</td>
</tr>
<tr>
<td>Faster performance of work.</td>
<td></td>
</tr>
<tr>
<td>More idea generation.</td>
<td></td>
</tr>
<tr>
<td>Divide tasks equally.</td>
<td></td>
</tr>
<tr>
<td>Learn more</td>
<td></td>
</tr>
<tr>
<td>Each focus on their expertise.</td>
<td></td>
</tr>
</tbody>
</table>

2 answered with No:
- Mechanical students can do the job alone.

7 answered with Yes:
- Knowledge exchange.
- Avoid bias.
- Equal resources for all teams.
- Easier to build groups/tasks distributed fairly.
- Allows sub-teams for discipline work.

1 answered with No:
- Diversity

2 answered with Not sure:
- Depends on the students and work required from them

The results are summarized in Table 1. It can be clearly seen that the social/cultural issues are the main challenges in forming the teams, as some of the students refuse to work with others...
for reasons such as social issues like gender, previous experience, and friendship. It has also been highlighted by the teaching staff that most difficult challenges in building a team is having unequal number of civil and mechanical students while the least difficult challenge is assigning students to teams.

According to the teaching staff and students, the best size for a group is four students equally divided among participating disciplines. In addition, the teaching staff found from their experience that if the students selected themselves teammates, they will perform better. However, if the staff assigns the students to teams, the majority of the teaching staff prefers that the distribution depends on the majors to keep equal numbers of different majors in each team for fairness and equal distribution of tasks; others prefer to distribute them according to the students’ experience and skills.

Regarding the performance of the team, students strongly agree that the team performs better if all team members are equally strong whereas most teaching staff disagree with the students because students tend to have conflicts.

Different responses were noticed when students with mixed levels are in one team as the majority of the staff noticed better performance because that allows the students to share ideas and this gives the opportunity for the weak students to catch up. The students get suitable support from their colleagues which is part of the learning outcome “lifelong learning”. Others observed negative effects among the weak students as they will not keep promises of doing their work and cause a delay in team work in addition to being very dependent.

Conclusions and Recommendations

This paper has explored the PBL in ACK’s School of Engineering by interviewing the PBL facilitators and the students. It has addressed the challenges that the students and staff face in team formation such as social/ cultural aspects, members’ distribution according to their background, and students’ preference in working with people they are acquainted with. The most preferred size for each group was suggested by most of the interviewees as four students. Due to the lack of experience in team formation among students, this paper recommends that the students must be educated about team formation prior to starting their project to enable them to select team members to maximize the advantage for the project work and individual.
References


