The Perspective of Alumni in the GCC region on the Development of Engineering Competencies through Project Based Learning

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Abstract

Although the effectiveness of Project Based Learning (PjBL) has been investigated for numerous contexts and from different perspectives, it is still limited to anecdotal evidence within the countries of the Gulf Cooperation Council (GCC).

The threefold purpose of this study is to identify from an alumni perspective, first, the importance of 16 engineering competencies, secondly, the contributions of PjBL in developing these competency elements, and, thirdly, the contribution of traditional teaching in developing these competency elements.

Utilizing a questionnaire based survey among alumni who experienced the same PjBL model during their engineering studies, analysed by descriptive statistics and the Wilcoxon test, it was found that 'understanding of accountabilities…', 'conceptual understanding of mathematics…' and 'application of established engineering methods…' were perceived the most important competencies, whereas 'knowledge of contextual factors…' was perceived to be the least important competency element. Furthermore, alumni perceive 12 out of 13 significantly differently developed competencies to be more effectively developed by PjBL than by traditional teaching. These include all competency elements of the competency areas 'engineering application ability' and 'professional and personal attributes'. Only the competency element 'theory based understanding of the underpinning sciences…' was perceived to be developed significantly more effectively by traditional teaching.

The results presented here should encourage engineering educators and educational institutions in the GCC region to utilize PjBL in developing engineering competencies. This study is part of an ongoing research effort related to PjBL in the GCC region.

Keywords: Project Based Learning, Problem Based Learning, engineering competencies, alumni, Gulf Cooperation Council.

Type of contribution: research paper.

1 Introduction

Problem Based Learning (PBL) in engineering education, as well as a variety of related learning approaches, have been investigated intensively over the past decades (e.g. De Graaff & Kolmos 2007). Considering the distinctive features of these models and approaches (e.g. Savin-Baden, 2007) and as observed earlier (Jaeger and Adair 2018), "Problem-Based Project-Organized Learning" (Garcia, Bollain and Del Corral 2011) seems to be the predominant approach within engineering education in the countries of the Gulf Cooperation Council (GCC), although educational institutions, engineering educators and the general public seem to prefer the term "Project Based Learning" (PjBL). Since the recent history of PjBL in the GCC region is not as long as in other geographic regions and since the region reflects some distinct particularities, investigations of the effectiveness of PjBL in developing engineering competencies are warranted.

As has been stated (Jaeger and Adair 2018), the following aspects can be considered similar in all countries of the GCC region because of the similar socio-economic context. First, many engineering students face language challenges since most engineering programs use English as the language of instruction, whereas Arabic is used as the predominant language of instruction in most high schools in the region (Findlow 2001). Second, most engineering students are confronted with a shift from a learning environment that focusses on rote learning and memorization during their pre-university studies to an environment which emphasizes the importance of critical thinking and analysis (Webb 2008). Third, students expect a 'spoon-feeding' approach in that their learning is largely instructor-centred (Randeree 2006). Fourth, local families play a decisive role when their children choose a discipline of study, and the perceived prestige of certain disciplines is often more important than the child's giftedness and interest. Finally, policy makers began paying increased attention to engineering education in recent years because of the aim for economic diversification and reducing the dependency on expatriate labour (Webb 2008).

The aim of any engineering program is the development of complementary and interrelated engineering competencies of its students. This is in line with student expectations who aim at an engineering degree and with employer expectations who are in need of graduates with well-developed engineering competencies. It has been found earlier that many studies related to PBL neglect this overarching goal of students' learning (Patria 2012). However, some studies utilized engineering competencies (sometimes called graduate attributes or student outcomes) in order to evaluate the effectiveness of PBL. For example, Ulseth and Johnson (2015) used student outcomes to compare students who studied within a PBL environment with students who didn't study within such a learning environment. Other studies reported results of student exit surveys based on student outcomes or employer satisfaction surveys based on engineering competencies (e.g. Christoforou *et al.* 2003; Ramadi *et al.* 2016). In order to incorporate the goal of developing engineering competencies, when looking into the effectiveness of PjBL from an alumni perspective, a complete set of engineering competencies has been used as a framework for this study.

In line with an earlier study that investigated the perspective of managers of engineers regarding engineering competencies (Jaeger and Adair 2018), Engineers Australia's sixteen competency elements for Engineering Technologists (EA 2017) have been used as a framework. These competency elements represent the graduate attributes for engineering technology programs accredited by Engineers Australia, and they are similar to student outcomes used by other accreditation bodies such as ABET (Abet.org 2014). It should be noted that these competency elements cover all essential skills and attributes of an engineering graduate as identified in an earlier study (Nguyen 1998). Table 1 displays these elements organized into three competency areas, namely, knowledge and skills, engineering application ability, and professional and personal attributes.

Table 1 Competency areas and competency elements

COMPETENCY AREA / Competency Element
1. KNOWLEDGE AND SKILLS
1.1. Theory based understanding of the underpinning natural sciences
1.2. Conceptual understanding of mathematics, numerical analysis, statistics, etc.
1.3. In depth understanding of specialist knowledge areas
1.4. Discernment of current knowledge development, such as new methods and materials
1.5. Knowledge of contextual factors such as business, culture, laws, etc.
1.6. Understanding of the scope, principles, accountabilities of contemporary engineering
2. ENGINEERING APPLICATION ABILITY
2.1. Application of established engineering methods to problem solving
2.2. Application of engineering techniques, tools and resources
2.3. Application of systematic synthesis and design processes
2.4. Application of systematic approaches to the management of projects
3. PROFESSIONAL AND PERSONAL ATTRIBUTES
3.1. Ethical conduct and professional accountability
3.2. Effective oral and written communication
3.3. Creative, innovative and pro-active demeanour
3.4. Professional use and management of information
3.5. Orderly management of self and professional conduct
3.6. Effective team membership and team leadership

2 Purpose

The threefold purpose of this study is to identify the engineering alumni perspective in the GCC region regarding

1. the importance of these competency elements;
2. the contributions of PjBL in developing these competency elements; and,
3. the contribution of traditional teaching in developing these competency elements.

The importance of engineering competency elements depends largely on the specific socio-economic context of an engineering program, and it has been suggested earlier (Ramadi *et al.* 2016) that more country specific research into engineering competencies is necessary. This study is aimed at filling this gap for the GCC region based on the perspective of engineering alumni.

It has been shown that career success can be measured by using two criteria, namely, the objective/extrinsic dimension and the subjective/intrinsic dimension (e.g. Rumberger & Thomas 1993; Vermeulen 2006). This applies also to the threefold purpose of this study as outlined above, and this study is aimed at providing the subjective/intrinsic dimension for the GCC region from an alumni perspective.

3 Methodology

The research questions for this study are:

1) What is the perceived importance of the sixteen competency elements in relation to requirements at engineering workplaces from an alumni perspective?

2) Is there a statistically significant difference between the perceived contributions of PjBL *versus* traditional teaching in developing the sixteen competency elements as seen from an alumni perspective?

3) Which competency elements are developed predominantly by PjBL and which competency elements are developed predominantly by traditional teaching from an alumni perspective?

In order to answer these questions, the following methodology has been applied. Questionnaire based interviews have been carried out with engineering alumni in Kuwait, a country typical of those found in the GCC region. Only engineering alumni who experienced the same PjBL model at a private college were approached, which led to 67 usable responses. The standardized questionnaire, the provided summary regarding the difference between PjBL *versus* traditional teaching, as well as the requirement of providing contact data of the interviewees for possible follow-up on answers, contributed to comparable survey conditions while ensuring reduced bias in selecting interviewees. The questionnaire covered the sixteen elements of competency shown on Table 1, and the alumni were asked to rate them on a 5-point Likert scale regarding, first, their importance, second, regarding their perception of the contribution of PjBL in developing these competencies, and third, regarding their perception of the contribution of traditional teaching in developing these competencies. In addition, demographic data has been collected and is shown in Table 2.

Table 2 Demographic data of respondents

Criteria		**#**	**%**
Education:	Bachelor	66	99
	Master	1	1
	Ph.D.	0	0
Position:	Upper management	21	31
	Lower management	46	69
Industry:	Petroleum	24	36
	Construction	32	48
	Manufacturing	2	3
	Telecommunication /	0	0
	Other	9	13
Sector:	Private	38	57
	Public	29	43
	Size of Organization:	5	7
	10-100	20	30
	>100	42	63
Major of studies:	Mechanical	25	37
	Civil	21	31
	Electrical	6	9
	Petroleum	15	22

The analysis of data includes descriptive statistics to answer research question one and three, as well as inferential statistics to answer the second question. For the inferential statistics, the Wilcoxon test was chosen (Cohen *et al.* 2011) since the same group of respondents was evaluating two different aspects, i.e. the contribution of PjBL *versus* traditional teaching in developing the sixteen competency elements. The test converts the scores to ranks for both aspects, before it evaluates if the number of times the score of one aspect (e.g. PjBL) is significantly different from the score of the other aspect (e.g. traditional teaching). Since the scores are converted to ranks, it does not require a normal distribution of scores (unlike *t*-tests). The level of significance alpha was set to 0.05.

4 Results

The results related to the first research question, i.e. the importance of elements of competency, are reflected by the Mean and Standard Deviation (SD) and are shown in Table 3 as are the Mean and SD related to the contribution of PjBL and traditional teaching. As each has a Mean of 4.4, the following three competency elements were perceived to be the most important elements: Understanding of accountabilities… (1.6), conceptual understanding of mathematics… (1.2) and application of established engineering… (2.1). With a Mean of 3.6, the knowledge of contextual factors… (1.5) was considered to be the least important competency element. These results, as well as the results regarding the contribution of PjBL and traditional teaching in developing these competency elements, will be discussed in the discussion section below.

Table 3 Descriptive statistics (Mean, SD) of competency importance, PjBL and traditional contribution

COMPETENCY AREA Competency Element	**Importance**		**PjBL Contribution**		**Traditional Contribution**	
	Mean	SD	Mean	SD	Mean	SD
1. KNOWLEDGE AND SKILLS						
1.1. Theory based understanding…	4.2	1.0	3.2	1.4	4.1	1.0
1.2. Conceptual understanding of	4.4	0.9	3.5	1.2	4.1	1.0
1.3. In depth understanding…	4.1	1.0	3.8	1.2	3.7	1.1
1.4. Discernment of current knowledge…	4.3	0.9	4.0	1.0	3.5	1.2
1.5. Knowledge of contextual factors…	3.6	1.2	3.7	1.2	3.1	1.3
1.6. Understanding of accountabilities…	4.4	0.9	4.0	1.1	3.7	1.1
2. ENGINEERING APPLICATION						
2.1. Application of established engineering…	4.4	1.0	4.1	1.0	3.6	1.1
2.2. Application of engineering techniques…	4.0	1.0	4.0	1.0	3.4	1.2
2.3. Application of systematic design…	4.3	1.0	4.1	1.1	3.5	1.3
2.4. Application of systematic management…	4.2	1.0	4.1	1.1	3.4	1.2
3. PROFESSIONAL AND PERSONAL ATTRIBUTES						
3.1. Ethical conduct…	4.2	1.0	3.9	1.2	3.4	1.2
3.2. Effective oral and written communication…	4.1	1.2	4.2	1.0	3.5	1.2
3.3. Creative, innovative and pro-active…	4.1	1.1	4.1	0.9	3.3	1.3
3.4. Professional use of information…	4.2	1.0	4.3	1.0	3.5	1.2
3.5. Orderly management of self…	4.0	1.0	4.1	1.0	3.4	1.2
3.6. Effective team membership…	4.3	1.1	4.3	0.9	3.2	1.4

The difference between the contribution to developing competency elements by PjBL and the contribution to developing competency elements by traditional teaching is shown by the results of the Wilcoxon test as shown on Table 4. Statistically significant differences between PjBL and traditional teaching were found for all competency elements, except competency elements '1.2 Conceptual understanding of mathematics' (Z=-1.629, p=0.103), '1.3. In depth understanding…' (Z=0.995, p=0.320) and '1.5. Knowledge of contextual factors…' (Z=0.387, p=0.699). Therefore, these three competency elements will not be further considered when interpreting the results in the discussion section below.

Table 4 Difference between PjBL and traditional teaching

COMPETENCY AREA Competency Element	**PjBL**		**Traditional**		**Wilcoxon**	
	Median	SD	Median	SD	Z	*p*
1. KNOWLEDGE AND SKILLS						
1.1. Theory based understanding…	3.0	1.4	4.0	1.0	-3.740	0.000
1.2. Conceptual understanding of mathematics…	4.0	1.2	4.0	1.0	-1.629	0.103
1.3. In depth understanding…	4.0	1.2	4.0	1.1	0.995	0.320
1.4. Discernment of current knowledge…	4.0	1.0	4.0	1.2	2.267	0.023
1.5. Knowledge of contextual factors…	4.0	1.2	3.0	1.3	0.387	0.699
1.6. Understanding of accountabilities…	4.0	1.1	4.0	1.1	2.701	0.007
2. ENGINEERING APPLICATION ABILITY						
2.1. Application of established engineering…	4.0	1.0	4.0	1.1	4.134	0.000
2.2. Application of engineering techniques…	4.0	1.0	4.0	1.2	2.734	0.006
2.3. Application of systematic design…	4.0	1.1	4.0	1.3	4.292	0.000
2.4. Application of systematic management…	4.0	1.1	4.0	1.2	4.036	0.000
3. PROFESSIONAL AND PERSONAL ATTRIBUTES						
3.1. Ethical conduct…	4.0	1.2	3.0	1.2	2.034	0.042
3.2. Effective oral and written communication…	4.0	1.0	3.0	1.2	4.659	0.000
3.3. Creative, innovative and pro-active…	4.0	0.9	3.0	1.3	3.342	0.001
3.4. Professional use of information…	5.0	1.0	3.0	1.2	5.382	0.000
3.5. Orderly management of self…	4.0	1.0	3.0	1.2	3.865	0.000
3.6. Effective team membership…	5.0	0.9	3.0	1.4	5.507	0.000

Note: shaded rows indicate differences without statistical significance

The competencies were ranked by importance (most important to least important) and the ranking is shown on Table 5. The results will be discussed further in the following discussion section.

Table 5 Ranking of Competencies by Importance (most important to least important)

Rank #	Competency Element	Importance Mean	Importance SD	PjBL Mean	PjBL SD	Traditional Mean	Traditional SD
1	1.6. Understanding of accountabilities…	4.4	0.9	4.0	1.1	3.7	1.1
2	1.2. Conceptual understanding of mathematics…	4.4	0.9	3.5	1.2	4.1	1.0
3	2.1. Application of established engineering…	4.4	1.0	4.1	1.0	3.6	1.1
4	3.6. Effective team membership…	4.3	1.1	4.3	0.9	3.2	1.4
5	1.4. Discernment of current knowledge…	4.3	0.9	4.0	1.0	3.5	1.2
6	2.3. Application of systematic design…	4.3	1.0	4.1	1.1	3.5	1.3
7	3.1. Ethical conduct…	4.2	1.0	3.9	1.2	3.4	1.2
8	2.4. Application of systematic management…	4.2	1.0	4.1	1.1	3.4	1.2
9	3.4. Professional use of information…	4.2	1.0	4.3	1.0	3.5	1.2
10	1.1. Theory based understanding…	4.2	1.0	3.2	1.4	4.1	1.0
11	3.2. Effective oral and written communication…	4.1	1.2	4.2	1.0	3.5	1.2
12	3.3. Creative, innovative and pro-active…	4.1	1.1	4.1	0.9	3.3	1.3
13	1.3. In depth understanding…	4.1	1.0	3.8	1.2	3.7	1.1
14	3.5. Orderly management of self…	4.0	1.0	4.1	1.0	3.4	1.2
15	2.2. Application of engineering techniques…	4.0	1.0	4.0	1.0	3.4	1.2
16	1.5. Knowledge of contextual factors…	3.6	1.2	3.7	1.2	3.1	1.3

Note: shaded rows indicate differences without statistical significance between PjBL and traditional learning

5 Discussion

The first research question is related to the importance of these competency elements. When comparing the importance as perceived by alumni with the importance of the same competency elements within the same cultural context as perceived by managers of engineers (Jaeger and Adair 2018), as shown on Table 6, the following can be said.

Some of the competency elements are ranked similar, for example, effective team membership (managers: 1, alumni: 4), understanding of accountabilities (managers: 4, alumni: 1) and application of established engineering techniques (managers: 6, alumni: 3). This might be related to the fact that most alumni are part of a team of engineers and realize the importance of effective team work. Similar, most alumni realize the importance of accountabilities since they are accountable for specific activities and the importance of applying established techniques since this is what they are involved in.

However, the ranking shows also some differences. Some competencies are ranked quite high by alumni, but quite low by managers, for example, conceptual understanding of mathematics (managers: 13, alumni: 2) and application of systematic design (managers: 15, alumni: 6). This difference might be related to the fact that conceptual understanding of mathematics as well as application of systematic design was emphasized during engineering studies and the duration of employment was still not long enough to realize that these competencies are not as important as engineering students think.

Other competencies are ranked quite high by managers, but quite low by alumni, for example, effective communication (managers: 3, alumni: 11) and in-depth understanding of specialist knowledge areas (managers: 5, alumni: 13). Similar to the previous interpretation, alumni may still not have realized the negative consequences if work output is not communicated effectively. Also, alumni may not have been involved in highly specialised activities that would require an in-depth understanding of these activities.

Table 6 Comparison of ranking: Manager perspective *versus* alumni perspective

Ran	**Manager perspective**	**Alumni perspective**
1	3.6. Effective team membership…	1.6. Understanding of accountabilities…
2	3.1. Ethical conduct…	1.2. Conceptual understanding of mathematics…
3	3.2. Effective communication	2.1. Application of established engineering…
4	1.6. Understanding of accountabilities	3.6. Effective team membership…
5	1.3. In depth understanding…	1.4. Discernment of current knowledge…
6	2.1. Application of established engineering…	2.3. Application of systematic design…
7	3.4. Professional use of information…	3.1. Ethical conduct…
8	3.3. Creative, innovative and pro-active…	2.4. Application of systematic management…
9	2.2. Application of engineering techniques…	3.4. Professional use of information…
10	1.4. Discernment of current knowledge…	1.1. Theory based understanding…
11	3.5. Orderly management of self…	3.2. Effective oral and written communication…
12	2.4. Application of systematic management…	3.3. Creative, innovative and pro-active…
13	1.2. Conceptual understanding of	1.3. In depth understanding…
14	1.1. Theory based understanding…	3.5. Orderly management of self…
15	2.3. Application of systematic design…	2.2. Application of engineering techniques…
16	1.5. Knowledge of contextual factors…	1.5. Knowledge of contextual factors…

Regarding the second research question, namely, if there is a significant difference between the contributions of PjBL *versus* traditional teaching? On just considering the competencies with significant differences, all competencies are developed more effectively by PjBL except '1.1 theory based understanding of the underpinning sciences', which was perceived to be developed more effectively by traditional teaching. Therefore, the finding here confirms for 12 out of 13 significantly different competencies the results of previous studies (e.g. Cohen-Schotanus *et al.* 2008; Schmidt, Vermeulen, and van der Molen 2006) which found that PjBL led to higher graduate competencies. The exception regarding the theory based understanding of underpinning sciences might be related to the fact that they were able to work on projects during their studies without a need to look into underlying theories.

Regarding the third research question, namely, the identification of competencies that are predominantly developed by PjBL and competencies that are better developed by traditional teaching, the following can be said based on the results as shown on Table 3 in conjunction with Table 4. The competency elements of the competency areas 2 (engineering application ability) and 3 (professional and personal attributes) are developed more effectively by PjBL, whereas only one competency element of the competency area 1 (knowledge and skills), namely 1.1 (theory based understanding of the underpinning sciences…), is significantly more effectively developed by traditional teaching.

6 Conclusion

From analysis of the questionnaire responses it was found that ‘understanding of accountabilities…’, ‘conceptual understanding of mathematics…’ and ‘application of established engineering methods…’ were perceived the most important competencies, whereas ‘knowledge of contextual factors…’ was perceived to be the least important competency. Furthermore, alumni perceive 12 out of 13 significantly different competencies to be more effectively developed by PjBL than traditional teaching. These include all competencies related to engineering application ability and professional and personal attributes. Only ‘theory based understanding of the underpinning sciences…’ was perceived to be developed significantly more effectively by traditional teaching.

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