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Perspectives on Engineering Competencies and Competency Development Approaches – Early-Career Engineers *versus* Managers of Engineers

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It has been claimed that a better understanding of the needs of engineering practice is necessary in order to improve students' preparedness for engineering work. The fourfold purpose of this study is to compare perspectives on engineering competencies between early-career engineers and managers of engineers in leadership positions regarding, importance, satisfaction, contribution of Project Based Learning (PBL) and contribution of traditional learning. Based on a set of sixteen engineering competencies, questionnaire based interviews are carried out resulting in usable responses from 92 managers of engineers and 67 early-career engineers. Fuzzy TOPSIS analysis is applied. Results show that engineering educators should give more importance to competencies related to professional and personal attributes. Furthermore, students should be exposed more often to a larger variety of real life problems, and PBL should be the primary learning approach for 12 of the 16 analysed competencies.

Keywords: engineering competency; competency development; early-career engineer; manager; fuzzy TOPSIS

1. Introduction

One goal of engineering education is the preparation of engineering graduates for employability. In fact, it has been postulated that engineering educators are primarily responsible for graduates being prepared adequately for engineering work [1]. In order to improve students' preparedness, it has been found that a better understanding of engineering practice is needed [2, 3]. Such an improved understanding is considered to have potential to help "bridge the gap between 'school-engineering' and 'work-engineering'" [4].

The shortcomings of engineering programmes in preparing graduates for engineering work are reflected by graduates who are pressured to adapt to unfamiliar industry needs, the need to acquire missing competencies through additional training, or decide to abandon the field of engineering because they feel insufficiently prepared [5]. Based on surveys among senior engineering students [6–8], it was concluded that senior students seem to understand the importance of skills such as communication and teamwork skills, whereas they seem not to understand how these skills are actually applied in engineering practice [9]. This lack of understanding the application of skills in practice, might also be true for other engineering skills.

It is the main aim of the present study to contribute to improving engineering education by comparing perspectives of managers *versus* early-career engineers regarding the importance of, and the satisfaction with engineering competencies, as well as the contribution of Project Based Learning and traditional learning to the development of engineering competencies.

1.1 Relative Importance of Engineering Competencies

It was shown that the satisfaction with engineering competencies and identified gaps in engineering curricula can be used to prioritize areas for improvement of a specific programme, but that these gaps cannot be used for generalizations of other programmes, since it is the relative importance of target competencies that are needed to design a programme, not the gaps [10]. Furthermore, Washington Accord or ABET (Accreditation Board for Engineering and Technology) accreditation requirements expect faculty to envision, articulate and prioritize competencies that students should gain from a programme, which requires faculty to answer questions regarding the relative importance of generic engineering competencies for professional practice in order to create specifications for designing a programme [11]. The authors mention that the Washington Accord [12] allows competencies to differ by country and that the relative emphasis of the competencies needs to be determined by each programme.

1.2 Satisfaction with Engineering Competencies

Based on an extensive literature review, persistent gaps between competencies required for engineer-

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ing work and the competencies developed in engineering education were found [1]. These gaps range from non-technical competencies, such as communication skills [13, 14], leadership and social skills [15], emotional intelligence [16], teamwork [17], application of theory and business skills [17, 18], to poor fundamental science and engineering knowledge [14]. It was concluded [1] that most frequent concerns are related to generic competencies and that one problem is the relatively low status of generic competencies in engineering education.

More recent studies reflect a similar situation. Based on a survey of 215 engineering professors, it was found that the focus on developing competencies in teaching practice did not match the assigned importance of these competencies [19]. Analysing studies of practicing engineers regarding how well their undergraduate education had prepared them for engineering work, practitioners across these studies reported that most of their current work was learned on the job and that knowing how to communicate and work with other people is paramount [5]. Science and engineering workplace expectations were found to be higher than abilities of current graduates regarding all of the analysed competencies (except digital interpersonal skills), with some of the greatest gaps related to "competencies that are core to the university curriculum (e.g., critical thinking, problem solving, conceptual thinking, creative thinking, and technical skills)" [20].

Since perception of the satisfaction with engineering competencies can be used to prioritize areas for improvement, and, perception of relative importance can be used to design and develop a curriculum, it was decided to survey both within the framework of the study here.

1.3 Managers of Engineers versus Early-career Engineers

Based on ABET's professional practice competency, it was found that graduates across engineering disciplines perceive a similar importance of a given competency over time, when surveying graduates 0, 2, 6 and 10 years after their graduation [10]. However, based on 52 studies related to the need and the importance of engineering competencies, "[n]o particular study's results generalize across . . . different experience levels (such as recent graduate, mid-career, or senior engineers)" [11]. A survey among professional engineers in New Zealand was carried out in order to identify the importance of management and leadership related topics [21]. It was found that the relative importance of various topics was perceived differently with years of experience in that most management topics were perceived significantly more important with increasing years of experience. Among these management topics were competencies such as communication; business process; change management; contracts; accounting; and ethics, law, health and safety.

The latter two studies indicate that early-career engineers may have a different perspective on the importance of competencies than more experienced engineers. At the same time, it can be assumed that early-career engineers have already a more realistic perspective on the nature and importance of various engineering competencies than student engineers. Therefore, the authors of this study decided to compare perspectives of early-career engineers with the perspective of managers of engineers with leadership function, in order to draw conclusions for engineering educators.

1.4 Strategies to Bridge the Gap

The discrepancy between competencies required for engineering work and competencies developed in engineering education has motivated many engineering institutions to introduce a range of educational strategies in order to bridge the gap [22], and it has prompted accreditation bodies [23] and engineering societies [24] to call for innovation and improvement of engineering education [4].

One strategy is a stronger focus on competencies by incorporating practical work and group learning, and it was found that this leads to students taking a deeper approach to learning [25]. Internships and "Work Integrated Learning (WIL)" have been suggested as approaches to meet industry expectations better [26].

Community engagement within the framework of Learning Through Service (LTS) [27], such as the Engineering Projects in Community Service (EPICS) [4], have been developed to prepare graduates for the workplace and were found to have a positive impact on the development of competencies. Interviewed alumni of the EPICS perceived the programme as a bridge from education to practice, a means to gain workplace experience and an opportunity to develop a variety of professional skills.

Students' participation in humanitarian engineering initiatives such as the EWB (Engineers Without Borders) Australia programmes, helped students to develop global competencies, among other learning benefits such as the understanding of operating in a holistic society and consideration of social factors that influence design [28].

Introducing interdisciplinarity to the engineering programme has been yet another strategy with positive impact on competency development. Observing students' competencies over a period of three years, interdisciplinary education has been found to improve engineering students' competencies every year [29].

These and similar educational strategies exhibit all, to some extent, features that are typical for Problem-Based Learning (PBL). Based on the constructivist-sociocultural approach to learning, PBL incorporates the following main learning approaches [30]:

1. Learning is organized around problems, carried out in projects and is based on the learner's experience (cognitive approach);
2. Learning is interdisciplinary and supports the relation between theory and practice by involving an analytical approach using theory in analysing problems and problem-solving methods (content approach); and,
3. Learning is team-based and utilizes dialogue and communication (social approach).

The positive impact of PBL on engineering competency development has been highlighted before and the following section summarizes some results.

1.5 Contribution of PBL to Develop Competencies

It has often been recognized by engineering educators that learning guided by projects develops technical and non-technical competencies [31]. This perspective has been confirmed by engineering practitioners who emphasized the importance of PBL for the quality of an engineering curriculum and the development of both technical and transversal competencies [32]. The study of engineering competencies in Saudi Arabia was concluded with the suggestion to utilize mentoring and engaging students in Problem-Based or Project-Based Learning, in order to provide opportunities for students to develop the needed soft-skills [33]. Focussing on more effective development of innovation competency in Russia, it was recommended to use practice based approaches to learning paired with active employer involvement during students' formal studies [34]. In order to improve international competitiveness and related competencies in China, the development of the International Engineering Practice Program (IEPP) based on PBL was reported [35]. Within the framework of the IEPP and guided by instructors, students cooperate in multidisciplinary research, design activities, manufacturing and presenting projects, and more than 90% of students considered the programme effective in developing their knowledge and abilities.

These findings indicate a general positive effect of PBL on the development of engineering competencies. This effect seems to be independent of the national and cultural context, and it seems to apply to both technical competencies and non-technical competencies. However, it is unclear how much competencies were developed through PBL and how much they were developed by traditional learning when both learning approaches occur during formal studies. Furthermore, it can be expected that some competencies are developed more effectively by PBL, whereas other competencies are more effectively developed by traditional learning. In addition to the importance of and satisfaction with competencies, the present study aims at identifying the potential of PBL *versus* the potential of traditional learning in developing competencies.

1.6 Fuzzy TOPSIS Method

The Fuzzy TOPSIS method is used in this work to rank the competencies. The TOPSIS method was proposed by [36] as a multi-criteria decision making method to identify a solution from a finite set of points. The chosen points are the 'shortest' points in distance from the positive ideal (sometimes called the benefit criteria) and the 'farthest' points in distance from the negative ideal (sometimes called the cost criteria) solution. A wide variety of studies on the TOPSIS method can be found in the literature [37]. The extension of TOPSIS, the Fuzzy TOPSIS method, is very suitable for solving group decision making problems in a fuzzy environment, as in real world situations, because of incomplete, subjective or non-obtainable information, making the data (attributes) not so deterministic, and therefore imprecise. Evaluating the importance of, or satisfaction with competencies, and the PBL and traditional learning contributions to competency development is fuzzy/imprecise, due to subjectivity. Fuzzy TOPSIS is used in a wide range of areas such as in medicine [38] through to civil engineering projects [39].

2. Purpose

The fourfold purpose of this study is to compare perspectives on engineering competencies between early-career engineers and managers of engineers in leadership positions regarding the perceived:

(1) importance of engineering competencies;
(2) satisfaction with the level of these competencies found in graduates;
(3) contribution of PBL in developing these competencies; and,
(4) contribution of traditional learning in developing these competencies.

One limitation of previous studies related to gaps between engineering education and engineering practice was that studies captured only one perspective, i.e., either engineers evaluated academic preparation, or students were asked to anticipate their future engineering work [9]. With consideration of both, early-career engineers and managers of engineers in a leadership position, junior and senior perspectives have been included in this study. The latter perspective is of great value since it is based on more engineering experience and the additional experience of employing graduates. The early-career engineer perspective is also of value since early-career engineers are in a better position to judge the third and fourth purpose of this study. Managers of engineers may not have experienced themselves a PBL approach, and a long period of time since they graduated may have potential to distort their perspectives. This methodological challenge will be discussed in detail in the following Methodology section.

The scope of this study is not limited to competencies of a specific engineering domain (e.g., systems engineering), a specific certification (e.g., Project Management certification), an engineering skill (e.g., research), or a purpose (e.g., success). Rather, generic competencies that are considered essential for all engineering disciplines are used for this study and its selection is reported in the Methodology section.

3. Methodology

3.1 Investigation Framework

The investigation framework of this study is reflected by the following three dimensions:

(1) a common set of sixteen engineering competencies;
(2) four common aspects, namely, importance of competencies, satisfaction with competencies, contribution of PBL and contribution of traditional learning to the development of these competencies; and,
(3) two groups of respondents, namely, managers of engineers and early-career engineers.

For the common set of engineering competencies, Engineers Australia's sixteen competency elements for Engineering Technologists haven been chosen [40]. The choice is based on the reasons that these competency elements:

(1) represent the basis of the engineering programme from which all early-career engineers of this study graduated from;
(2) are generic enough to cover only competencies that were relevant in all organizations of the interviewed managers of engineers;
(3) cover all essential skills of engineering graduates as identified by [41]; and,
(4) include the competencies of other associations such as the Accreditation Board for Engineering and Technology [42] and the graduate attributes of the Washington Accord as shown by the International Engineering Alliance [12].

The sixteen competency elements, grouped into three competency areas, are shown in Table 1.

3.2 Research Questions

The research questions related to these sixteen competency elements and based on both, the perceptions of managers of engineers and early-career engineers, are:

1. What are the biggest differences regarding the perceived importance of competencies?
2. What are the biggest differences regarding the perceived satisfaction with graduates inhibiting these competencies?
3. What are the biggest differences regarding the contribution of PBL in developing these competencies?
4. What are the biggest differences regarding the contribution of traditional learning in developing these competencies?

Table 1. Sixteen 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 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.

Table 2. Demographic data of interviewees

Variable	Interviewee			
	Managers		Early-career engineer	
Answer Category	#	%	#	%
Education				
Bachelor	73	80	66	9
Master	17	18	1	1
Ph.D.	2	2		
Total Education	92	100	67	100
Position				
Upper management	37	40	21	31
Lower management	55	60	46	69
Total Position	92	100	67	100
Industry				
Petroleum	32	35	24	36
Construction	40	44	32	48
Manufacturing	5	5	2	3
Telecommunication / Electrical	15	16	0	0
Other	0	0	9	13
Total Industry	92	100	67	100
Sector				
Private	35	38	38	57
Public	57	62	29	43
Total Sector	92	100	67	100
Size of Organization				
<10	6	6	5	7
10-100	30	33	20	30
>100	56	61	42	63
Total Size of Organization	92	100	67	100
Industrial experience [ave. years]	12.7		1.3	

3.3 Data Collection

In order to answer these questions, the following methodology has been applied. Questionnaire-based interviews have been carried out with 92 managers of engineers and 67 early-career engineers. The managers of engineers held an engineering degree, had substantial work experience, were actively involved in a leadership position that included leading engineers, and they were approached based on personal contacts. The early-career engineers were mechanical and civil engineering students, who graduated recently from an Engineering Technology programme of a private college in the Middle East. During their formal studies, they had experienced a curriculum based on the sixteen competency elements and the same PBL model (course based model with one subject per semester utilizing PBL) as well as comparable facilitation of traditional learning. The interviewees were asked to rate the sixteen competency elements of Table 1 for each of the four research questions on a 5-point Likert scale (importance: very unimportant (1) to very important (5); satisfaction: very unsatisfied (1) to very satisfied (5); PBL contribution: very little (1) to very much (5); traditional learning contribution: very little (1) to very much (5)). The demographic data of the interviewees is shown in Table 2.

Prior to answering question 3 and 4, the main differences between PBL and traditional learning were explained to the interviewees based on the graphic shown in Fig. 1. For the early-career engineers this was merely a reminder since they had experienced this difference during their formal studies. However, for the managers of engineers, this was an important clarification in order to ensure each interviewee had an understanding of the two learning approaches.

3.4 Analysis using Fuzzy TOPSIS Methodology

In addition to descriptive statistics and a Wilcoxon test ($\alpha = 0.05$) in order to test if there are significant differences between the perceived contribution of PBL *versus* traditional learning, Fuzzy TOPSIS analysis was carried out since interviewees' responses included subjectivity. Readers familiar with the Fuzzy TOPSIS methodology may want to continue reading with section 4.

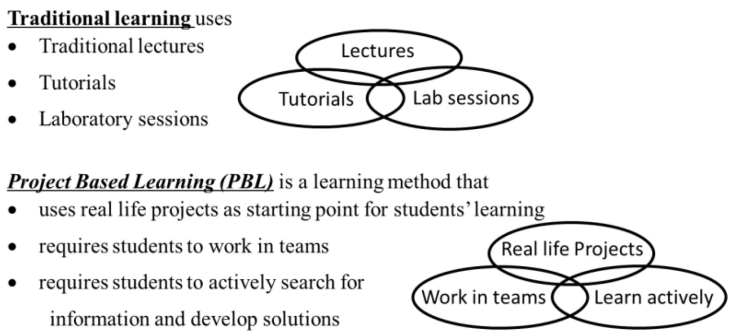

Fig. 1. Simplified comparison of traditional teaching *versus* Project-Based Learning.

3.4.1 *Fuzzy Data*

In brief, fuzzy data can be defined as follows. Let X be a classical set of objects whose generic elements are denoted by x with the membership in a crisp subset of X often viewed as the characteristic function μ_A from X to $\{0, 1\}$ such that

$$\mu_A(x) = \begin{cases} 1 & \text{if and only if } x \in A, \\ 0 & \text{otherwise,} \end{cases} \tag{1}$$

where $\{0, 1\}$ is called a valuation set. If the valuation set is allowed to be the real interval $[0, 1]$, A is called a fuzzy set and denoted by $\tilde{A}$, and $\mu_{\tilde{A}}(x)$ is the degree of membership of x in $\tilde{A}$. The fuzzy set $\tilde{A}$ is characterized by the set of ordered pairs

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\}. \tag{2}$$

A fuzzy number $\tilde{A}$ is a convex normalized fuzzy set $\tilde{A}$ of the real line $\mathbb{R}$ with continuous membership function. In this work triangular fuzzy numbers are used which can be denoted as $\tilde{A} = (a, m, n)$ where a is the central value ($\mu_{\tilde{A}}(a) = 1$), m is the left spread and n is the right spread as shown on Fig. 2.

3.4.2 *TOPSIS Method*

The TOPSIS procedure for crisp numbers can be summarized in six steps. The first is to calculate the normalized decision matrix with the normalized value n_{ij} using

$$n_{ij} = x_{ij} \Big/ \sqrt{\textstyle\sum_{i=1}^{m} x_{ij}^2}, \quad i = 1, \ldots m, \; j = 1, \ldots, n. \tag{3}$$

Next the weighted normalized decision matrix value is calculated as $v_{ij} = w_j n_{ij}$, $i = 1, \ldots, m$, $j = 1, \ldots, n$, where w_j is the weight of the ith criterion and $\sum_{j=1}^{n} w_i = 1$. The positive and negative ideal solution are then calculated as

$$A^+ = \{v_1^+, \ldots, v_n^+\} = \left\{\left(\max_j v_{ij} | i \in I\right), \left(\min_j v_{ij} | i \in J\right)\right\}, \tag{4}$$

$$A^- = \{v_1^-, \ldots, v_n^-\} = \left\{\left(\min_j v_{ij} | i \in I\right), \left(\max_j v_{ij} | i \in J\right)\right\}, \tag{5}$$

where I is associated with benefit criteria and J is associated with cost criteria. Calculation of the separation measures from the ideal solution, using the n-dimensional Euclidean distance comes next from

$$d_i^+ = \left\{\textstyle\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right\}^{\frac{1}{2}}, \; i = 1, \ldots, m, \tag{6}$$

$$d_i^- = \left\{\textstyle\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right\}^{\frac{1}{2}}, \; i = 1, \ldots, m. \tag{7}$$

The relative closeness of alternative A_i with respect to A^+ is then calculated using

$$R_i = d_i^- / (d_i^+ + d_i^-), \; i = 1, \ldots, m. \tag{8}$$

Since $d_i^- \geq 0$ and $d_i^+ \geq 0$ then $R_i \in [0, 1]$. Finally, the TOPSIS procedure involves ranking the alternatives.

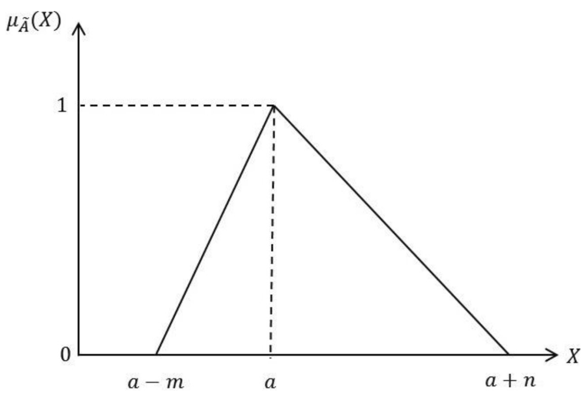

Fig. 2. A triangular fuzzy number $\tilde{A}$ with central value, left spread and right spread.

3.4.3 *TOPSIS Method for Fuzzy Data*

Suppose $A_1, A_2, \ldots A_m$ are m possible alternatives among which decision makers have to choose, $C_1, C_2, \ldots C_n$ are criteria with which alternative performance are measured, $\tilde{x}_{ij}$ is the rating of alternative A_i with respect to criterion C_j and is a fuzzy number. A decision making problem with fuzzy data can be precisely expressed in matrix form as

	C_1	C_2	$\cdots$	C_n
A_1	$\tilde{x}_{11}$	$\tilde{x}_{12}$	$\cdots$	$\tilde{x}_{1n}$
A_2	$\tilde{x}_{21}$	$\tilde{x}_{22}$	$\cdots$	$\tilde{x}_{2n}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	$\tilde{x}_{m1}$	$\tilde{x}_{m2}$	$\cdots$	$\tilde{x}_{mn}$

$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]$, where $\tilde{w}_j$ is the weight of criterion C_j and is also a normalized fuzzy number.

When using the TOPSIS method for fuzzy data the first step is the identification of the criteria to be evaluated, which in the present work was the Engineers Australia's sixteen competency elements for Engineering Technologists [40]. Step two is using data obtained in crisp number form from the two groups of decision makers and step three is to convert this crisp data into fuzzy data, after identification of the weightings. The normalized fuzzy decision matrix is then constructed as $\tilde{x}_{ij} = (x_{ij}, \alpha_{ij}, \beta_{ij})$ where $\tilde{x}_{ij}$ is a triangular fuzzy number. The method then follows a similar procedure to that described above for the TOPSIS method with crisp data.

Each group of decision makers was asked to complete a survey of the sixteen engineering criteria using the decision rating of a 5-point Likert scale. The decision ratings in linguistic values, Likert equivalents and fuzzy triangular fuzzy number equivalents are presented in Table 3 and Table 4 where here, for computing convenience, the triangular fuzzy numbers are written as $(\alpha_{ij}, x_{ij}, \beta_{ij})$. For example, with reference to Table 4, if a decision maker (DM_1) makes a rating of 'high (H)' for criteria (C3) then the membership function is defined as (0.5, 0.75, 1) so building a set of fuzzy triangular numbers. Similarly, the other DMs decide on their own ratings in a similar manner for all sixteen criteria.

Table 3. Assessment used by decision makers

Linguistic	Likert Scale	Triangular Fuzzy Number
Very High (VH)	5	(0.75,1,1)
High (H)	4	(0.5,0.75,1)
Fair (F)	3	(0.25,0.5.0.75)
Average (A)	2	(0,0.25,0.5)
Low (L)	1	(0.0,0.0,0.25)

Table 4. Example of ratings entered by decision makers

Criteria	Decision Makers			
	DM1	DM2	...	DMm
C1	H	F	...	H
C2	VH	A	...	A
C3	H	H	...	F
⋮	⋮	⋮	⋮	⋮
C16	VH	A	...	F

4. Results

Results of the descriptive statistics are shown in Table 5 for the perspective of managers of engineers (in the following "Managers") and in Table 6 for the early-career engineers (in the following "Engineers"). In both tables, column one shows the sixteen competency elements and column two, three, four and five the Mean and Standard Deviation (SD) of the importance of competency (Importance), satisfaction with the competency (Satisfaction), contribution of PBL to the development of the competency (PBL) and the contribution of traditional learning to the development of the competency (traditional).

From the perspective of Managers (Table 5), the most important competencies are Ethical conduct... and Effective team membership... (both 4.7) and the least important are Knowledge of contextual factors... and Application of systematic design... (both 3.9). They were highest satisfied with "Effective oral and written communication... and Effective team membership... (both 3.8) and least satisfied with Knowledge of contextual factors... (3.1). The Managers perceived the highest contribution of PBL to the development of Effective team membership... (4.6) and the lowest contribution of PBL to the development of Conceptual understanding of mathematics... (3.6), whereas they see the highest contribution of traditional learning to the development of Conceptual understanding of mathematics... (4) and the lowest contribution to the Knowledge of contextual factors... (2.7).

From the perspective of Engineers (Table 6), the most important competencies are Conceptual understanding of mathematics..., Understanding of accountabilities. . . and Application of problem solving... (all 4.4) and the least important is Knowledge of contextual factors... (3.6). They perceived the highest satisfaction with Effective oral and written communication... (4.4) and the lowest satisfaction with Knowledge of contextual factors... (3.3). Engineers saw the highest contribution of PBL to the development of Orderly management of self... (4.3) and the lowest to Theory based understanding... (3.6), whereas they perceived the highest contribution of traditional learning to the

Table 5. Descriptive statistics of competency elements – Managers

Competency Element	Importance		Satisfaction		PBL		Traditional	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1.1. Theory based understanding. . .	4.1	0.9	3.6	1.0	3.7	1.0	3.9	1.0
1.2. Conceptual understanding of mathematics. . .	4.2	0.8	3.6	1.0	3.6	1.0	4.0	0.9
1.3. In depth understanding. . .	4.5	0.7	3.4	1.0	4.1	0.9	3.6	0.9
1.4. Discernment of current knowledge. . .	4.3	0.7	3.5	0.9	4.3	0.8	3.2	1.0
1.5. Knowledge of contextual factors. . .	3.9	0.9	3.1	1.2	4.1	0.9	2.7	1.1
1.6. Understanding of accountabilities. . .	4.5	0.6	3.7	1.0	4.2	0.8	3.4	0.9
2.1. Application of problem solving. . .	4.4	0.7	3.4	1.1	4.4	0.8	3.2	1.0
2.2. Application of engineering techniques. . .	4.3	0.7	3.4	1.0	4.3	0.8	3.2	1.0
2.3. Application of systematic design. . .	3.9	1.0	3.4	1.0	4.1	1.0	3.6	1.0
2.4. Application of systematic management. . .	4.2	0.7	3.3	1.0	4.3	0.8	3.1	1.0
3.1. Ethical conduct. . .	4.7	0.5	3.7	1.1	4.2	0.9	3.2	1.2
3.2. Effective oral and written communication. . .	4.5	0.6	3.8	1.0	4.4	0.7	3.4	1.1
3.3. Creative, innovative and pro-active. . .	4.3	0.8	3.5	1.0	4.2	0.8	3.0	1.1
3.4. Professional use of information. . .	4.3	0.7	3.5	1.0	4.2	0.7	3.3	1.1
3.5. Orderly management of self. . .	4.2	0.7	3.6	0.9	4.3	0.7	3.3	1.0
3.6. Effective team membership. . .	4.7	0.6	3.8	1.0	4.6	0.6	3.2	1.1

Table 6. Descriptive statistics of competency elements – Engineers

Competency Element	Importance		Satisfaction		PBL		Traditional	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1.1. Theory based understanding. . .	4.2	1.0	3.8	1.0	3.2	1.4	4.1	1.0
1.2. Conceptual understanding of mathematics. . .	4.4	0.9	3.9	1.0	3.5	1.2	4.1	1.0
1.3. In depth understanding. . .	4.1	1.0	3.7	1.1	3.8	1.2	3.7	1.1
1.4. Discernment of current knowledge. . .	4.3	0.9	3.7	1.1	4.0	1.0	3.5	1.2
1.5. Knowledge of contextual factors. . .	3.6	1.2	3.3	1.1	3.7	1.2	3.1	1.3
1.6. Understanding of accountabilities. . .	4.4	0.9	4.0	0.9	4.0	1.1	3.7	1.1
2.1. Application of problem solving. . .	4.4	1.0	4.2	0.9	4.1	1.0	3.6	1.1
2.2. Application of engineering techniques. . .	4.0	1.0	4.1	0.9	4.0	1.0	3.4	1.2
2.3. Application of systematic design. . .	4.3	1.0	4.1	0.9	4.1	1.1	3.5	1.3
2.4. Application of systematic management. . .	4.2	1.0	4.0	1.0	4.1	1.1	3.4	1.2
3.1. Ethical conduct. . .	4.2	1.0	4.3	1.0	4.2	0.9	3.2	1.2
3.2. Effective oral and written communication. . .	4.1	1.2	4.4	0.9	3.9	1.2	3.4	1.2
3.3. Creative, innovative and pro-active. . .	4.1	1.1	4.2	1.0	4.2	1.0	3.5	1.2
3.4. Professional use of information. . .	4.2	1.0	4.2	0.9	4.1	0.9	3.3	1.3
3.5. Orderly management of self. . .	4.0	1.0	4.2	0.8	4.3	1.0	3.5	1.2
3.6. Effective team membership. . .	4.3	1.1	4.3	1.0	4.1	1.0	3.4	1.2

development of Conceptual understanding of mathematics. . . (4) and the lowest to Knowledge of contextual factors. . . (2.7).

Results of the Wilcoxon test are shown in Table 7 for the perspective of Managers and Table 8 for the perspective of Engineers. The columns of both tables present the competencies, median and standard deviation (SD) for PBL contribution and traditional learning contribution, Z value and the statistical significance level *p*.

The results related to the Manager perspective (Table 7) show that the contribution of PBL is for all competencies statistically significantly higher than the contribution of traditional learning except for Theory based understanding. . . and Conceptual understanding of mathematics. For Theory based understanding. . . ($Z = -1.356$, $p = 0.175$), traditional learning is perceived to have a higher contribution albeit not statistically significant higher. For Conceptual understanding of mathematics. . . ($Z = -3.142$, $p = 0.002$), the respondents perceive a statistically significant higher contribution of traditional learning.

The results of the Engineers' perspective (Table 8) show that the contribution of PBL is for all competencies statistically significant higher than the contribution of traditional learning except for the four competencies Theory based understanding. . . ($Z = -3.740$, $p = 0.000$), Conceptual understanding of mathematics. . . ($Z = -1.629$, $p = 0.103$),

Table 7. Wilcoon test – PBL *versus* traditional learning – Managers

Competency	PBL		Trad		Wilcoxon test	
	Median	SD	Median	SD	Z	*p*
1.1. Theory based understanding. . .	4.0	1.0	4.0	1.0	–1.356	0.175
1.2. Conceptual understanding of mathematics. . .	4.0	1.0	4.0	0.9	–3.142	0.002
1.3. In depth understanding. . .	4.0	0.9	3.0	0.9	3.557	< 0.0001
1.4. Discernment of current knowledge. . .	4.0	0.8	3.0	1.0	6.511	< 0.0001
1.5. Knowledge of contextual factors. . .	4.0	0.9	3.0	1.1	3.945	< 0.0001
1.6. Understanding of accountabilities. . .	4.0	0.8	3.0	0.9	4.579	< 0.0001
2.1. Application of established engineering. . .	5.0	0.8	3.0	1.0	7.607	< 0.0001
2.2. Application of engineering techniques. . .	4.5	0.8	3.0	1.0	6.489	< 0.0001
2.3. Application of systematic design. . .	4.0	1.0	4.0	1.0	3.242	0.001
2.4. Application of systematic management. . .	4.0	0.8	3.0	1.0	5.711	< 0.0001
3.1. Ethical conduct. . .	4.0	0.9	3.0	1.2	4.161	< 0.0001
3.2. Effective oral and written communication. . .	5.0	0.7	3.0	1.1	7.380	< 0.0001
3.3. Creative, innovative and pro-active. . .	4.0	0.8	3.0	1.1	4.919	< 0.0001
3.4. Professional use of information. . .	4.0	0.7	3.0	1.1	4.330	< 0.0001
3.5. Orderly management of self. . .	4.0	0.7	3.0	1.0	5.484	< 0.0001
3.6. Effective team membership. . .	5.0	0.6	3.0	1.1	10.838	< 0.0001

Table 8. Wilcoxon test – PBL *versus* traditional learning – Engineers

Competency	PBL		Traditional		Wilcoxon	
	Median	SD	Median	SD	Z	*p*
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
2.1. 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
3.1. 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

In depth understanding. . . ($Z = 0.995$, $p = 0.320$) and Knowledge of contextual factors. . . ($Z = 0.387$, $p = 0.699$).

Table 9 to Table 12 present the ranking of Managers and Engineers by importance (Table 9), satisfaction (Table 10), contribution of PBL (Table 11) and contribution of traditional learning (Table 12). These tables show the competency elements in column one; D plus, D minus, CC and Rank for Managers in column two; D plus, D minus, CC and Rank for Engineers in column three; and the difference in ranking (Rank Diff.) in column four.

The ranking by importance (Table 9) shows for Managers the highest importance of Ethical conduct. . . and the least importance of Application of systematic design, and for Engineers the highest importance of Understanding of accountabilities. . . and the least importance of Knowledge of contextual factors. . . The ranking by satisfaction (Table 10) shows for Manager the highest satisfaction with Effective team membership. . . and the lowest satisfaction with Knowledge of contextual factors. . ., and for Engineers the highest satisfaction with Effective oral and written communication. . . and the lowest satisfaction with Knowledge of contextual factors. . . The ranking by PBL contribution (Table 11) shows for Managers the highest PBL contribution to Effective team membership. . . and

Table 9. Ranking of competencies by importance – Managers *versus* Engineers

	Managers				Engineers				Rank
Competency element	**D plus**	**D minus**	**CC**	**Rank**	**D plus**	**D minus**	**CC**	**Rank**	**Diff.**
1.1. Theory based understanding. . .	25.01	34.49	0.58	14	18.63	71.63	0.79	12	2
1.2. Conceptual understanding of mathematics. . .	21.58	38.04	0.64	11	12.26	77.79	0.86	3	8
1.3. In depth understanding. . .	14.06	45.35	0.76	5	18.79	71.71	0.79	13	8
1.4. Discernment of current knowledge. . .	20.07	39.60	0.66	7	14.55	75.57	0.84	5	2
1.5. Knowledge of contextual factors. . .	30.60	28.54	0.48	15	30.87	59.79	0.66	16	1
1.6. Understanding of accountabilities. . .	13.64	45.78	0.77	4	11.33	78.58	0.87	1	3
2.1. Application of problem solving. . .	16.34	43.36	0.73	6	12.02	77.86	0.87	2	4
2.2. Application of engineering techniques. . .	20.47	39.25	0.66	10	20.79	69.63	0.77	15	5
2.3. Application of systematic design. . .	31.23	28.14	0.47	16	15.11	75.14	0.83	6	10
2.4. Application of systematic management. . .	22.43	37.31	0.62	13	16.56	73.49	0.82	9	4
3.1. Ethical conduct. . .	7.14	51.75	0.88	1	16.15	74.04	0.82	7	6
3.2. Effective oral and written communication. . .	12.91	46.58	0.78	3	18.21	71.85	0.80	11	8
3.3. Creative, innovative and pro-active. . .	20.23	39.18	0.66	9	18.07	72.11	0.80	10	1
3.4. Professional use of information. . .	20.13	39.56	0.66	8	16.30	74.26	0.82	8	0
3.5. Orderly management of self. . .	22.48	37.41	0.62	12	19.87	71.13	0.78	14	2
3.6. Effective team membership. . .	7.83	51.16	0.87	2	13.77	76.01	0.85	4	2

Table 10. Ranking of competencies by satisfaction – Managers *versus* Engineers

	Managers				Engineers				Rank
Competency element	**D plus**	**D minus**	**CC**	**Rank**	**D plus**	**D minus**	**CC**	**Rank**	**Diff.**
1.1. Theory based understanding. . .	30.86	40.03	0.56	7	21.26	23.79	0.53	13	6
1.2. Conceptual understanding of mathematics. . .	29.18	41.66	0.59	5	18.72	26.34	0.58	12	7
1.3. In depth understanding. . .	34.99	35.86	0.51	12	22.39	22.53	0.50	15	3
1.4. Discernment of current knowledge. . .	33.47	37.50	0.53	9	22.46	22.66	0.50	14	5
1.5. Knowledge of contextual factors. . .	45.15	25.57	0.36	16	31.68	13.07	0.29	16	0
1.6. Understanding of accountabilities. . .	27.57	43.57	0.61	4	15.95	29.11	0.65	10	6
2.1. Application of problem solving. . .	37.44	33.56	0.47	14	12.82	32.15	0.71	6	8
2.2. Application of engineering techniques. . .	34.67	36.23	0.51	11	14.45	30.53	0.68	9	3
2.3. Application of systematic design. . .	36.62	34.12	0.48	13	14.40	30.75	0.68	8	5
2.4. Application of systematic management. . .	40.21	30.53	0.43	15	16.95	27.87	0.62	11	4
3.1. Ethical conduct. . .	27.14	43.39	0.62	3	10.82	33.85	0.76	2	1
3.2. Effective oral and written communication. . .	25.04	45.82	0.65	2	8.85	35.93	0.80	1	1
3.3. Creative, innovative and pro-active. . .	31.48	39.55	0.56	8	12.97	32.00	0.71	7	1
3.4. Professional use of information. . .	34.14	36.68	0.52	10	11.54	33.46	0.74	4	6
3.5. Orderly management of self. . .	29.69	41.15	0.58	6	11.75	33.42	0.74	5	1
3.6. Effective team membership. . .	24.10	46.75	0.66	1	10.97	33.79	0.75	3	2

the lowest to Conceptual understanding of mathematics. . ., and for Engineers the highest PBL contribution to Effective oral and written communication. . . and the lowest for Knowledge of contextual factors. . . The ranking by the contribution of traditional learning (Table 12) shows for Managers the highest contribution to the development of Conceptual understanding of mathematics. . . and the lowest to the development of Knowledge of contextual factors. . ., and for Engineers the highest contribution to the development of Theory based understanding. . . and the lowest to the development of Knowledge of contextual factors. . .

5. Discussion

Comparing the Mean values in Table 5 and Table 6, with the ranking in Table 9 to Table 12, shows the advantage of using Fuzzy TOPSIS methodology. For example, the three competencies Discernment of current knowledge. . ., Creative, innovative, and pro-active. . . and Professional use of information. . . have exactly the same Mean value (Mean: 4.3, Table 5), even when considering 12 digits, and all three competencies would be on rank 8 if ranked by Mean value. However, using the Fuzzy TOPSIS approach and the consideration of fuzziness of evaluations, provide rank 7, 9 and 8 for the three

Table 11. Ranking of competencies by PBL contribution – Managers *versus* Engineers

	Managers				Engineers				Rank
Competency element	**D plus**	**D minus**	**CC**	**Rank**	**D plus**	**D minus**	**CC**	**Rank**	**Diff.**
1.1. Theory based understanding. . .	33.98	27.96	0.45	15	34.50	13.53	0.28	16	1
1.2. Conceptual understanding of mathematics. . .	37.32	24.45	0.40	16	27.11	21.29	0.44	15	1
1.3. In depth understanding. . .	22.16	39.83	0.64	13	20.74	27.89	0.57	13	0
1.4. Discernment of current knowledge. . .	16.04	46.17	0.74	4	17.11	31.43	0.65	11	7
1.5. Knowledge of contextual factors. . .	21.99	39.95	0.64	12	23.09	25.47	0.52	14	2
1.6. Understanding of accountabilities. . .	19.54	42.49	0.68	10	16.61	31.88	0.66	10	0
2.1. Application of problem solving. . .	14.05	47.79	0.77	3	13.53	34.89	0.72	4	1
2.2. Application of engineering techniques. . .	16.04	45.88	0.74	5	16.17	32.30	0.67	9	4
2.3. Application of systematic design. . .	23.73	37.68	0.61	14	13.65	34.66	0.72	6	8
2.4. Application of systematic management. . .	17.21	44.88	0.72	7	14.42	33.96	0.70	8	1
3.1. Ethical conduct. . .	21.27	40.95	0.66	11	18.50	29.89	0.62	12	1
3.2. Effective oral and written communication. . .	13.68	48.14	0.78	2	12.32	36.04	0.75	3	1
3.3. Creative, innovative and pro-active. . .	18.70	43.62	0.70	8	14.07	34.77	0.71	7	1
3.4. Professional use of information. . .	19.17	43.18	0.69	9	10.69	37.58	0.78	2	7
3.5. Orderly management of self. . .	16.99	45.38	0.73	6	13.55	34.92	0.72	5	1
3.6. Effective team membership. . .	7.64	53.79	0.88	1	10.08	38.24	0.79	1	0

Table 12. Ranking of competencies by traditional learning contribution – Managers *versus* Engineers

	Managers				Engineers				Rank
Competency element	**D plus**	**D minus**	**CC**	**Rank**	**D plus**	**D minus**	**CC**	**Rank**	**Diff.**
1.1. Theory based understanding. . .	19.58	55.70	0.74	2	10.93	37.20	0.77	1	1
1.2. Conceptual understanding of mathematics. . .	16.71	58.63	0.78	1	11.55	36.74	0.76	2	1
1.3. In depth understanding. . .	31.25	44.34	0.59	4	20.03	28.51	0.59	3	1
1.4. Discernment of current knowledge. . .	43.96	31.70	0.42	13	24.64	23.61	0.49	7	6
1.5. Knowledge of contextual factors. . .	57.41	17.77	0.24	16	32.97	15.32	0.32	16	0
1.6. Understanding of accountabilities. . .	37.37	38.66	0.51	6	21.22	27.35	0.56	4	2
2.1. Application of problem solving. . .	41.33	34.45	0.45	9	21.81	26.63	0.55	5	4
2.2. Application of engineering techniques. . .	43.76	31.86	0.42	12	26.78	21.62	0.45	10	2
2.3. Application of systematic design. . .	28.61	47.17	0.62	3	24.12	24.14	0.50	6	3
2.4. Application of systematic management. . .	46.21	29.45	0.39	14	28.00	20.38	0.42	13	1
3.1. Ethical conduct. . .	43.37	32.07	0.43	10	27.07	21.22	0.44	11	1
3.2. Effective oral and written communication. . .	36.84	38.79	0.51	5	25.40	22.94	0.47	8	3
3.3. Creative, innovative and pro-active. . .	49.34	25.97	0.34	15	29.93	18.32	0.38	14	1
3.4. Professional use of information. . .	40.80	34.94	0.46	8	25.43	22.84	0.47	9	1
3.5. Orderly management of self. . .	38.58	37.16	0.49	7	27.03	21.17	0.44	12	5
3.6. Effective team membership. . .	43.61	31.99	0.42	11	31.38	16.65	0.35	15	4

competencies (Table 9). The following discussion and interpretations will be based on the Fuzzy TOPSIS results as shown in Table 9 to Table 12 and will concentrate on the two biggest differences between the Managers' perspective and Engineers' perspective.

5.1 Importance

Before considering specific differences, it should be noted that all competencies belonging to the competency area "Professional and Personal Attributes" (c.f. Table 1) are lower or equally ranked by Engineers than by Managers. This might be a consequence of the earlier identified problem of the relatively low status that is assigned to generic competencies in engineering education which has shifted the focus towards theory rather than practice [1]. This difference between the two groups of interviewees should encourage engineering educators to give more importance to this competency area.

The biggest difference in the ranking of competencies by importance (Table 9) is found for Application of systematic design. . . , which is on rank 16 for the Managers and 6 for the Engineers. This reflects that the Engineers are still more under the impression (they received during their formal studies) that systematic design is quite an important competency, whereas Managers with many years' experience and leadership function perceive it to be the least important competency when comparing with the remaining competencies. It might also reflect a specific feature of engineering work in the region of the Gulf Cooperation Countries (GCC) in that design work is frequently outsourced and carried out by engineering firms outside the region. The impact of cultural and national specifics on the perception of importance of competencies confirm earlier findings [43–45].

Three further competencies show big differences, namely Conceptual understanding of mathematics. . . (Managers: 11, Engineers: 3), In depth understanding of specialist knowledge. . . (Managers: 5, Engineers: 13) and Effective oral and written communication. . . (Managers: 3, Engineers: 11). These differences can be explained in line with the previous interpretation. The Engineers are still more under the impression they received during their formal studies, which have emphasized Conceptual understanding of mathematics. . . more than most of the other competencies, and which may have insufficiently emphasized the importance of In depth understanding of specialist knowledge. . . and Effective oral and written communication. The difference between Managers and Engineers confirms earlier findings [46] who found that as importance of technical knowledge and skills that students learn in school appears to decline, the importance of professional knowledge and skills that are needed to do the job increases. The high importance of communication is in line with many studies that found communication and teamwork to be among the most important competencies for engineering [1]. Effective oral and written communication. . . should be emphasized more by engineering educators in order to reduce the gap between Managers and Engineers.

In summary, since the relative importance can be used to design and develop curricula [11], a curriculum review should consider giving less importance to the Application of systematic design. . . and Conceptual understanding of mathematics. . ., and giving more importance to the In depth understanding of specialist knowledge. . . and Effective oral and written communication.

5.2 Satisfaction

Compared with the previously discussed ranking by importance, the ranking by satisfaction (Table 10) reflects somewhat more agreement between the Managers and Engineers (i.e., the biggest difference is 8 ranks for one competency, followed by 7 ranks for another competency). This might reflect that work experience of early-career engineers allows quicker to realize competency deficiencies and satisfaction with the development of competencies during formal studies, than the relative importance of these competencies during engineering work.

The biggest differences were found for Application of problem solving. . . (Managers: 14, Engineers: 6) and Conceptual understanding of mathematics. . . (Managers: 5, Engineers: 12). Regarding the first competency, Engineers may still not have experienced enough challenges that required applying established problem solving methods, whereas Managers realized in their leadership function that graduates are not sufficiently prepared for solving problems. Engineering educators should consider exposing students more often to a larger variety of real life problems, which are fuzzier than textbook problems.

Regarding the second competency, Managers are quite satisfied with the Conceptual understanding of mathematics. . ., but Engineers seem to face work situations that make them much less satisfied with their preparation. Because of the high importance of Conceptual understanding of mathematics during formal studies, early-career engineers might feel unsatisfied with their preparation since the competency does not help them with the work they have to carry out. This may create a feeling of being ill-prepared regarding Conceptual understanding of mathematics. . .

5.3 Contribution of PBL

Although one of the sixteen competencies shows a difference of 8 ranks and two further competencies show a difference of 7 ranks, it should be noted that most competencies have a difference of only one rank (Table 11). This reflects much more agreement between Managers and Engineers, than the differences regarding the importance of and satisfaction with competencies, which were considered in the two previous sections. This agreement confirms earlier findings that found that PBL may be particularly useful for developing competencies such as communication and collaborative work [46], that "project-based service learning experiences can play an important role in the preparation of future professionals" [4] and that embedding learning content in the context of professional practice is required for developing and integrating technical and professional competencies [10]. Finally, the wide agreement between Managers and Engineers should encourage engineering educators to apply PBL to the higher ranked competencies. A summarizing comparison with the contribution of traditional learning at the end of the following section provides specific insights as to which competencies are more effectively developed by PBL *versus* traditional learning.

However, the focus of this study is on the differences between the two groups of interviewees. The biggest difference was found for Application of systematic design... (Managers 14, Engineers: 6). Managers do not perceive much contribution of the PBL approach to the development of this competency, whereas the Engineers perceive some contribution. This might be related to the fact that the Engineers studied here experienced during their formal studies the utilization of PBL in design subjects, whereas this might have been difficult to imagine for the Managers.

The second biggest difference was found for Discernment of current knowledge. . . (Managers: 4, Engineers: 11) and Professional use of information... (Managers: 9, Engineers: 2). Regarding the first competency, Managers can imagine that the PBL approach contributes to identifying current knowledge, whereas Engineers may have experienced difficulties during their PBL experience when it came to discerning the currency of knowledge they were using. This means for engineering educators using the PBL approach that their learning facilitation needs to include guidance regarding the currency of knowledge used for students' project work, which may be given delivering a lecture at the right time of the project progress. Obviously, this shows the importance of educators being up to date themselves.

Regarding the second competency, the perspectives are turned around. Managers do not perceive much contribution of PBL to the development of using professionally information, whereas Engineers *do* see a high contribution of PBL. This may reflect that Engineers used information in a similar manner as they do at the workplace. During their PBL experience they learnt about the difference between reliable and unreliable sources, using information during team meetings and individually processing information using software they use at the workplace. Therefore, the lower ranking by Managers is most likely a consequence of the simplified and general explanation of the PBL approach.

5.4 Contribution of Traditional Learning

Similar to the previous section, there is a lot of agreement between Managers and Engineers on the contribution of traditional learning to the development of the considered competencies (c.f. Table 12). The two biggest differences are related to Discernment of current knowledge... (Managers: 13, Engineers: 7) and Orderly management of self... (Managers: 7, Engineers: 12).

Regarding the first competency, the Managers' perspective is very interesting since they also did not see a high contribution of PBL to the development of Discernment of current knowledge... It seems to reflect the common practice in industry that Professional Development is used to discern current knowledge, whereas Engineers see a higher contribution of traditional learning compared with the PBL approach regarding the development of this competency. Confirming the previous interpretation, engineering educators should be aware of the need to guide students regarding the currency of knowledge they identify and use in their project work.

Regarding the second competency, Managers perceive more contribution of traditional learning to the development of Orderly management of self... than Engineers. The Engineers studied here received frequent feedback on managing themselves in subjects utilizing PBL, whereas this competency was not emphasized in traditional, lecture based learning. This finding should encourage engineering educators to provide feedback on students' development of Orderly management of self..., especially if it is not developed effectively in traditional learning approaches.

Results of the Wilcoxon tests (Table 7 and Table 8) show that Managers and Engineers agree in that all four competencies of the Engineering Application Ability competency area and all six competencies of the Professional And Personal Attributes competency area (c.f. Table 1) are developed more effectively by PBL *versus* traditional learning. Regarding the six competencies of the Knowledge and Skills competency area (c.f. Table 1) the situation is more differentiated. Managers perceive all six competencies more effectively developed by PBL except Theory based Understanding... and Conceptual understanding of mathematics... The latter competency is perceived to be statistically significant more effectively developed by traditional learning. The Engineers perceive Theory based Understanding... statistically significant more effectively developed by traditional learning. In addition, they do not perceive In depth understanding... and Knowledge of contextual factors... to be statistically significant more effectively developed by PBL. In addition to the previous interpretations based on the rankings, this presents a strong case for the application of PBL in developing most of the competencies. Engineering Educators should be encouraged to utilize PBL for the Engineering Application Ability competency area and the Professional And Personal Attributes competency area, as well as Discernment of current knowledge... and Understanding of accountabilities... from the Knowledge and Skills area.

5.5 Limitations and Future Studies

Construct validity was ensured by utilizing semi-structured questionnaire-based interviews and a comparable understanding of traditional learning and PBL. Furthermore, an undesirable maturation effect by respondents' familiarization with questions was controlled by introducing respondents to the questions only during the interviews. However, these advantages in itself may also have potential to distort responses [47].

The external validity of the findings is given for the perspectives of respondents and scope of this study. Respondents from different socio-economic contexts or a different set of generic competencies may lead to different results. Future studies are recommended to investigate further the impact of these independent variables on perspectives of competencies.

6. Conclusion

It can be concluded that engineering educators should give more importance to the competency area Professional And Personal Attributes. Furthermore, the findings showed that less importance should be given to the Application of systematic design... and the Conceptual understanding of mathematics... and instead more importance to the In depth understanding of specialist (locally relevant) knowledge... and Effective oral and written communication... Also, students should be exposed more often to a larger variety of real life problems. These implications require that engineering educators have sufficient industry experience.

Based on the wide agreement between Managers and Engineers regarding the contribution of PBL and the contribution of traditional learning, it can be concluded that PBL should be the primary learning approach for developing competencies of the Engineering Application Ability area, the Professional And Personal Attributes area, and two competencies of the Knowledge And Skills area, namely, the competencies Discernment of current knowledge... and Understanding of accountabilities... However, the results also confirmed the importance of guidance and learning facilitation during students' project work, especially related to Discernment of current knowledge... and Orderly management of self... Interviewees agreed that Theory based understanding... and Conceptual understanding of mathematics... are more effectively developed using a traditional learning approach. Therefore, engineering educators should be required to have solid knowledge of the PBL pedagogy and skills in utilizing the PBL approach.

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