What are the engineering professional competences?

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Conference Key Areas: Graduate employability, Transversal skills, Reflective practice

Keywords: Graduates, Engineers, Employability, Competence

INTRODUCTION

The EU Skills Panorama [1] an European commission lead study into the labour markets of Europe found that a large number of member states experience recruitment difficulties in relation to STEM skilled labour. As part of this study, in 2016 a number of shortage occupations in Ireland were identified, with engineering professionals and technicians being listed as a mismatch priority occupation [2]. It is clear that there is an ongoing shift in the manufacturing industry as it moves away from traditional manufacturing sectors and take a larger stake in the service sector [3]. This shift has resulted in firms seeking graduates who possess not only the technical skills they have come to expect from an engineering graduate but also the professional or transversal skills required to work in the industry. This lead to an investigation of the literature surrounding competences deemed important in the existing literature followed by a report on an expert panel carried out with ESB International (ESBI) one of Irelands' leading engineering consultancies as part of the Professional Roles and Employability of Future Engineers (PREFER) project.

RESEARCH QUESTION & METHOD

The aim of the research was to capture papers which reported on the competences which were viewed as important for success in the labour market in pursuit of the question: what are the *most* important of these professional competences and is there agreement among experts on what they are? This was achieved by examining the studies carried out on:

1) Professionals working as practicing engineers and engineers working in management and supervisory roles.

2) Professionals working in HR and in executive positions in the industry

A systematic literature review was carried out utilising online data bases provided by:

1) Taylor and Francis

2) Wiley online Library

3) Springer international publishing

4) ASEE Peer

The search terms used were “engineering competences”, “generic competences”, “graduate competences” and “graduate engineer”, searching in all fields of the paper. The selection criteria were then applied, limiting the paper to those published from 2010 onward and removing overlapping papers. This lead to the identification of 40 papers. Papers were drawn from published sources from 2010 onward to frame the research in the current decade. In doing so it was hoped to identify areas of skill mismatch between what the institution can provide and what is expected from industry. Of the initial 40 papers identified, 31 papers were removed as they did not contain any Likert data on competences or they contained this data but the data pertained to undergraduate student responses. This left 9 papers which pertained specifically to industry expectations of transversal skills. Data were collected from Likert scales generated from survey [4–9] and two papers which utilised a mixture of survey and interview to gather data [10,11].

FINDINGS

Table 1 shows a breakdown of the papers utilised in the review process. The papers were profiled based on the country in which the study took place, the type of engineer or professional taking part in the survey, the framework used to compile the lists of competences in the survey and the publisher of the paper.

Comparison of the papers published in this area reveal that most authors opted to generate lists of competences inspired by either literature review or utilising various frameworks such as the ABET and Washington Accords. There is no standardised list of competences used in this type of investigation which presents a number of issues when comparing the perceptions of engineers an interdisciplinary and international level. For a meaningful comparison of engineering competences to take place,

international and interdisciplinary differences must be examined not by examining the spectra of competences that exist internationally and across disciplines, but rather by the importance a particular group places on a shared set of competences. In this way results collected from various nations and disciplines become comparable. Data collection for these studies relied on the assumption that the engineers and other professionals taking part in the surveys possessed expertise on the important competences in their professional area. Only one of the nine studies considered in this review utilised a panel of experts in the survey, the remainder were surveys sent to hundreds and in some cases thousands of engineers, creating a selection bias and poor response rates. It also assumes that Likert scale data about the relative importance of one competence over another is in some way meaningful. This raises questions over how a researcher could decide *how much more important* one particular competence was over another, when the papers' authors are quoting 2 decimal places of accuracy on a scale of 1-5. To summarise. International comparison of competences important for success in engineering could only occur with a list of shared and well defined competences. The studies considered in this paper rely on the self-report of a group of individuals we must presume are experts on what competences are most important for success and that there is something meaningful about the rating of these competences on a Likert scale. Due to the wide variation in the lists of competences utilised in these studies, little agreement was found on what competences were most important for success in the labour market.

Taking a new approach to this will be essential if we are to extract meaningful insights into the competences that will be required of future engineers on an international scale. To this end, the European commission have funded a project to investigate engineering professional practice and future employability of engineers. As part of the PREFER project the Dublin Institute of Technology, KU Leuven & TU Delft in collaboration with its' partner BDO have carried out 12 expert panels across Belgium, Ireland and The Netherlands in order to evaluate what competences will be most important for a young engineer to succeed in the labour market. As outlined in this paper a considerable amount of research has explored the transversal skills important for an engineer to succeed in the labour market but there is a scarcity of research regarding the types of roles that an engineer can fulfil after graduation [12]. To this end, a model of professional roles was developed to frame the types of jobs which are available to engineers after graduation. The model selected as the prototype was the Treacy Wiersema model [13] this decision was made in prior research, utilising structured interviews with industry officials to decide between two proposed models. The model was initially validated using a cohort of 121 industry officials, 91% of which could identify the role model in their own company [14]. The model is broken into three distinct roles and it was posited that a unique set of competences may be attached to each. All 12 panels were carried out utilising 3 engineers who fit into one of the professional roles, 2 members of HR, 1 HR manager and 1 senior manager. Participants were presented with the list of competences and asked to pick the competences they felt were of particular important to each of the professional roles. This was followed by a round table discussion about the competences and their definitions in order to distil a final list of competences for each of the three professional roles. Table 2 presents the results of the expert panel carried out with the ESBI in Ireland

Operational Excellence	Product Leadership	Customer Intimacy
Stakeholder engagement	Conceptualisation	Client focus
Focus on results	Creativity	Stakeholder engagement
Clear communication	Innovation	Solution orientated
Solution oriented	Solution-Orientated	Integrity
Work organisation	Client focus	Focus on results
Responsibility	Initiative	Persuasiveness
Client focus	Clear communication	Conflict management
Networking		Initiative
Performance motivation		Clear communication
		Stress resistance

Table 2. Results of expert panel with ESBI

DISCUSSION

The major difference between this research and previously conducted research in this area is a move away from quantitative data gathered through survey and towards a more meaningful description of the functions of an engineer and the types of competences required to fulfil those functions. Utilising the data drawn from these 12 expert panels and collated by one final review panel of experts, the PREFER project will be working closely with BDO to develop and validate a psychometric test aimed at aligning an engineering student or graduate to one or more of these engineering role(s).

It should of course be considered that the results from the ESBI expert panel are representative of the competences deemed important for success *within* the ESBI, who deal predominantly with electrical engineers. The results had to be compared with the results from other expert panels; from companies involved in a variety of economic activities, including both small, medium and large firms, across a variety of geographical locations. Pivotal to this process was the list of competences and their definitions, which came directly from BDO and were the competences utilised in all three countries to carry out the expert panels, allowing for more meaningful international comparisons.

ACKNOWLEDGMENTS

This work was supported by Erasmus+ programme of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project. The authors would like to thank the ESBI for their cooperation in the process.

Papers at a glance

#	Author	Year	Country	Cohort	Methods	Competence list	Data type	Publisher
1	Baytiyeh [4]	2010	Lebanon	Civil engineers Mechanical Engineers Electrical Computer Engineering management	Survey	ABET	Likert	ASEE/IEEE
2	Han Ahn et al [7]	2012	USA	Project manager Project engineer HR manager Director Vice President Other	Survey	Generated	Likert	Journal of professional issues in engineering and practice
3	Hinchcliff and Jolly [11]	2011	UK	HR & other management HR & other management	Survey Interview		Likert Qualitative	British Educational Research Journal
4	Husain et al [5]	2010	Malaysia	Managers (Engineers) Supervisor (Engineers) Others	Survey	SCANS Model	Likert	Procedia Social and Behavioral Sciences
5	Robles [15]	2012	USA	CEO's, presidents	Expert panel	Generated	Likert	Business Communication Quarterly
6	Warnick [6]	2011	USA	Mechanical Engineers	Survey	Generated	Likert	American Society for Engineering Education
7	Ortiz-Marcos [10]	2013	Spain	Engineers	Mixture	PMI Framework	Likert	Project management journal
8	Peiro et al [9]	2016	Jordan	Telecom engineers	Survey	Generated	Likert	European journal of engineering education
9	Pons [8]	2015	New Zealand	Engineers	Survey	Washington Accord	Likert	European journal of engineering education

Table 1: The sample of papers collected from the literat

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