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Professional Roles and Employability of Future Engineers

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ABSTRACT

Although there is high degree of agreement on the importance of transversal skills for engineers, employers observe a significant gap between expectations and reality. This paper discusses the need for the development of a framework of professional roles for future engineers and the implementation of dedicated skills education in engineering curricula to train students for this role. Based on an extensive literature study, an overview is given of previous research on this topic. The paper also outlines the next steps that will be taken by the authors as part of a European project PREFER to develop and implement these roles in engineering education.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning; Skills and Engineering Education; Curriculum Development

Keywords: Labour market entry; Transversal skills; Professional roles; Skills mismatch

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INTRODUCTION

A large survey among 467 Flemish engineers who graduated between 2014-2016, indicated that 22% of the respondents were no longer working with their first employer. Almost half of these graduates left because the job did not meet their expectations [1]. The European project PREFER (Professional Roles and Employability of Future Engineers) aims to reduce the skills mismatch in the field of engineering. Managers of human resources departments report that fresh engineering graduates frequently display (1) a lack of transversal skills required by the labour market and (2) a lack of self-awareness of their own strengths and weaknesses and of who they are as an engineer.

The objectives of the PREFER project are threefold. First, we aim to construct a Professional Roles Framework. This framework will describe the different roles engineers can take on at the beginning of their career, independently of the engineering discipline (e.g. electrical, mechanical, chemical). Each role will be characterized by an associated set of transversal skills. Thereafter, a Test System will be developed in order to (1) increase engineering students' awareness of the multitude of professional roles in engineering and (2) to make them reflect on their own engineering identity and their interests, strengths, and weaknesses. Thirdly, we will explore how to implement these innovative tools in the engineering curriculum by running a number of pilots in the participating universities.

In order to realize the PREFER objectives, a well-balanced consortium was built with both universities (University of Leuven [Belgium], Delft University of Technology [The Netherlands] and Dublin Institute of Technology [Ireland]) and companies (Engie, Siemens and ESB) involved. In order to develop reliable and valid test material, an experienced test development partner (BDO) is a member of the project team. To establish a stable connection with the engineering labour market, the three national engineering federations in Belgium, The Netherlands and Ireland were brought on board (IE-net, KIvI, Engineers Ireland). These federations play an essential role in connecting higher education institutions (HEIs) with a large number of employers that hire engineers. Validation in a wider European network of universities and companies will be tackled by respectively SEFI and FEANI.

1 PROFESSIONAL ROLES IN THE FIELD OF ENGINEERING

1.1 Problem statement

The McKinsey '*Education to Employment*' survey [2], organised with more than 5,300 young people, 2,600 employers, and 700 education providers, shows that only 35% of

the employers agree that new graduates are adequately prepared. Interestingly, for education providers, these percentages increase to 74%. Apparently, on the supply side, education institutions believe that they are equipping their students with the necessary skills and competences whereas employers, on the demand side, feel otherwise. This skills mismatch has become an important topic on the agenda of many policy makers. A focus on transversal skills (e.g. self-management, interpersonal skills, adaptability, communication skills, interpersonal skills) is often put forward as an important way to overcome this skills mismatch.
In the field of engineering education, interpersonal skills, teamwork, communication, and problem solving skills are most frequently identified as highly important by engineers [3-4]. As stipulated by Chan et al. [3], although there is high degree of agreement on the importance of these skills, employers observe a significant gap between expectations and reality.

Apart from the skills mismatch, a number of employers indicated that fresh engineering graduates are unable to identify their strengths and weaknesses during a job interview. It appears that fresh engineering graduates lack the introspective qualities to look at themselves and reflect about the question "*Who am I as a, for example, electrical engineer?*". Answering this question does not only entail a critical self-reflection on one's own thoughts and prior achievements, but also an articulation of one's future aspirations in the engineering profession. The latter aspect presumes a more detailed knowledge of the different professional roles that engineers fulfill in the labour market and which sets of competences are required. For example, in the field of chemical engineering, an R&D engineer may require a completely different set of transversal skills compared to an engineer in a more commercial role.

1.2 Employability: Increasing self-awareness

Employability is often used as a container term without exact definition. In line with Yorke and Knight [5], we endorse three components of employability: (1) increased understanding of academic knowledge, (2) a set of generic skills appropriate to the workplace, and (3) personal attributes (e.g. enthusiasm, flexibility, self-reliance, aspiration, seizing opportunities). As pointed out by Creasy [6] improving employability skills "*requires students to record their achievements and to reflect on these*" (p. 18). The author showed that students find it difficult to articulate their employability skills and that they have problems with writing reflective reviews about themselves and their own assessment of their competencies.

Increasing self-awareness among engineering students requires a high level of metacognitive thinking and the ability to reflect at a higher order level about oneself as a future engineer. Improving metacognition includes helping learners to (1) be more aware of their own implicit beliefs and (2) build a broader sense of purpose behind their learning [7].

1.3 Labour market entry for recently graduated engineers

As stated by Hofland et al. [8], there is a wide variety in career paths for graduated engineers. Going beyond the typical specialist versus management-dichotomy, this diversity is reflected both in terms of disciplinary wealth (e.g. electrical engineering, chemical engineering, civil engineering) and the professional roles that engineers fulfil in a particular organisation (e.g. service engineer, technical sales engineer, production engineer, process engineer…).

An important challenge of the PREFER project is to come up with an integrative framework wherein this multitude of engineering positions is summarized in a manageable and sensible way. Rather than mutually exclusive categories, we argue in favour of a framework wherein engineering positions can be described in overlapping sections if they fit several professional roles.

A similar framework has already been designed for the field of medicine. The CanMEDS framework that identifies and describes the abilities physicians require to effectively meet the health care needs of the people they serve. These abilities are grouped thematically under seven roles [9].

2 PROFESSIONAL ROLES FRAMEWORK

In contrast to the plethora of studies focusing on the essential transversal skills in the field of engineering, research on the classification of the multitude of professional roles that fresh engineering graduates can take on in the labour market is scarce. It is often presumed that all engineering careers are homogenous and require the same balance of technical and transversal skills [10]. Other engineering careers than the stereotypical 'engineering practitioner', for example, researcher, consultant, technical-commercial representative, often receive less attention. In their study, Brunhaver and colleagues [10] discriminate between three engineering roles of a large sample of recently graduated engineers (N=543): manager (15%), engineering consultant (21%) and engineering practitioner (64%). Problem solving and analytical skills were deemed equally important in all three engineering roles. Communication was rated as less important by engineering practitioners than by managers or consultants. Managing uncertainty, business knowledge and leadership were rated significantly higher in importance by engineering managers.

2.1 Business strategy model of Treacy and Wiersema

The business strategy model of Treacy and Wiersema [11] describes three strategic positions that companies can take in the value chain: (1) Operational Excellence (i.e. focus on maximizing efficiency by reducing costs while optimizing quality); (2) Product Leadership (i.e. focus on cutting-edge research & innovation), and (3) Customer Intimacy (i.e. focus on service of client systems and customer satisfaction).

Interestingly, the business strategy model of Treacy and Wiersema can easily be translated into the engineering field. A large-scale analysis of more than 7,500 job vacancies in the field of engineering in the year 2014 [12], showed that each job vacancy could be classified in one of the three categories outlined above: Operational Excellence (46%), Customer Intimacy (30%), and Product Leadership (24%).

2.2 First-year student survey

In the Rolling project [8], the Treacy and Wiersema model was operationalized by means of three fictional engineering job vacancies. A sample of 172 first-year engineering students was asked to indicate which job vacancy they would apply for. In contrast with the outcomes of the large-scale job vacancy analysis, 58% of the first-year students expressed a preference for the Product Leadership role. Thus, there is a very clear discrepancy between the preferred type of jobs of first-year engineering students and the jobs that are available in this category (24%).

In a second stage of the survey, the first-year students were asked to rate their self-perceived mastery levels of the 13 faculty learning outcomes (e.g. problem solving, communication, critical reflection, entrepreneurship, for a comprehensive overview, see [8]). Interestingly, students with a preference for the Operational Excellence vacancy, expressed significantly higher levels of problem solving/analysis and operationalisation compared to the other students. Analogously, students with preference for the Customer Intimacy vacancy rated themselves significantly higher in communication and entrepreneurship. In sum, there seems to be evidence that students tend to be more interested in job vacancies for which they deem themselves to have the required competencies and consider themselves to be good at.

2.3 Company survey

The Treacy and Wiersema model was also presented to a large sample of companies employing engineers (N=121). 91% of the respondents indicated that they recognised the model in their own company. A small proportion (6%) indicated that they needed some adjustments to the model (for example, management was considered missing). In a next stage, respondents were asked to indicate to relative importance of each of the aforementioned learning outcomes for each role. For example, for the Product Leadership role, design and development and specialized technical knowledge were considered to be the most important (for a more detailed overview, see [8]). In general, the company response pattern closely reflects the outcomes of the students' survey.

2.4 Conclusion

The Treacy and Wiersema model seems to be a promising framework to look at the variety of engineering positions. An important objective of the PREFER project is to fine-tune the model and to further tailor it to the engineering domain. Special focus will need to be spent on the specialist versus management dichotomy, a prevailing theme among many young engineers.

3 INTEGRATION INTO THE ENGINEERING CURRICULUM

In the following paragraphs of the paper, we will address how students' employability can be addressed in the engineering curriculum. An extensive search in engineering education literature as well as in literature on the initial path of recent engineering graduates was carried out. Despite higher education institutions' claim to prepare their students for their future career as an engineer, little evidence was found of institutions making a distinction between the different roles a graduate will function in when working as an engineer, and the skills pertinent to such a role. Many of these preparations include the earlier defined transversal skills, next to internships and other activities such as company visits, guest lectures, etc.

In order to limit the scope of this project, it was therefore decided to focus on a number of transversal skills: Entrepreneurial Skills, Innovation Skills, Communication and Networking Skills, Teamwork and Ways of Thinking, and Lifelong Learning. The selection was made based on the 4TU Centre of engineering education's vision on the future of engineering education [13].

3.1 Entrepreneurial Skills

Entrepreneurial skills are defined by Adeyemo as the ability to manage and create an enterprise by having vision and taking initiative and risk [14].

The idea of learning technical and entrepreneurial concepts while solving problems was the goal of a case study and lab experiences introduced in a core mechanical course of a Western private university. The case study comprised a realistic case scenario where engineering and entrepreneurial concepts were taught. Pre and post tests were carried out of students in order to understand if entrepreneurial skills could be implemented in core engineering courses without interfering with the technical skills and if a student's entrepreneurial self-efficacy (based on business confidence) changes with one case study. Results showed that students are able to increase their entrepreneurial skills without decreasing the learning of core engineering competencies and students reported self-efficacy improvement pre-to-post in just one case study [15].

Moreover, business and engineering are bridged by sales education in engineering programs. A department of industrial engineering supported by the university business school and industry partners provided a technical sales course introducing investment economic methods and theory. A pre-post survey of students assessed their interest and learning ability of sales skills. Results as published by Bumbluskaus et al. showed that the course enhanced students' sales skills and increased their desire to pursue a sales career [16].

3.2 Innovation Skills

Benjamin et al. defined innovation as the creation of new and technically feasible ideas or the adaptation of others' ideas [17]. Innovation requires thinking out of the box and an open mind, using creativity and imagination but also the use of logic, analytics and planning. According to Kamp [13] students should be stimulated in innovation by going to new environments with new challenges, and new ways of thinking (e.g. going abroad for studies).

The Engineering School of Los Andes University integrated a 2 semester prototyping course in the third year of the curriculum of System and Computing Engineering in order to improve teamwork and innovation skills. The students present it in periodic written reports and oral presentation, and in a final presentation carried out in an engineering projects fair. Hernandez and Ramírez [18] indicated that students' perception of this course showed that they are aware of the importance of teamwork and innovation for their projects.

The Department of Computer Science and Information Engineering in the National Chung Cheng University of Taiwan created a capstone course which integrates training creativity. This training involves workshops of management techniques provided by managers, of work experiences delivered by alumni and of sustainability and globalisation shared by industry experts. According to Hsiung et al., the results of a project-based learning in combination with creativity training showed enhancement in students' creativity skills [19].

3.3 Communication and Networking Skills

Communication for engineering universities is commonly conceived as oral and written technical skills. However, communication is no longer restricted to oral presentation and written technical reports, but involves interpersonal communication such as listening, compromising, understanding others point-of-view and discussion with others [20]. A study in the field of pharmacy in Finland showed improvement in communication competences by using practical training in real work situations, and feedback and communication between mentors and students [21].

As Kokkonen and Almonkari, we view networking as an interpersonal communication skill because networking is the ability to interconnect with individuals through initiated and maintained communication [20]. As shown by a study of Aerospace Engineering alumni at Delft University of Technology, it is essential to make students aware of the importance of networking and to enhance their networking competences which may open them to future professional opportunities [22].

Donell et al. [23] showed that there appears to be a disparity between the communication situations in the classroom and in the industry. Students are simply not able to switch when they enter a professional environment. In addition, the content of the communication courses may be too limited. Generally, communication courses in engineering curricula consist of a writing and a presenting course but typically do not involve listening exercises, intercultural communication, or observing, interviewing and meeting skills. This does not mean students are not exposed to these skills in project-based education but they are not formally taught. Whether feedback is offered, depends on the individual tutor, rather than this happening in a structured fashion.

3.4 Teamwork and Ways of Thinking

Working in teams is a vital skill in engineering. This was the primary reason it was added to the ABET criteria in 2001 [24]. We define teamwork as being based on collaboratively working in groups to achieve a goal. In teams, engineers are asked not just to think critically (i.e. to ask the right questions to formulate new directions to operate) but also to think interdisciplinarily (i.e. to collaborate and involve other engineering disciplines, humanities and social sciences) [13].

Master students of Aerospace Engineering at TU Delft have the option to attend a Forensic Engineering course which uses real-life based learning. This course consists of lectures and practical exercises, ending with a practical exam where students conduct an investigation and apply the forensic concepts learned during the course to find the cause of the accident. The results of this course show that students developed forensic knowledge, critical thinking skills, standard investigation methodology, hypothesis forming and interviewing [25].

At the University of South Australia, architecture and civil engineering undergraduates in a two-week course tackle a hands-on construction problem. The collaborative work and knowledge interaction between groups of 2 to 4 students of different disciplines, architecture and civil engineering students showed that students increase their multidisciplinary teamwork skills [26].

3.5 Lifelong Learning

Lifelong learning encompasses continuous personal and professional development. In a world full of changes and uncertainty in career paths, “learning how to learn” should be the goal of engineering studies in order to prepare students for constant and continuous learning [13]. To engage lifelong learning skills, the Center for Engineering Learning and Teaching at the University of Washington, provide a course where students are taught to plan their studies, to assess and monitor their learning, and recognise their strengths and weaknesses [27].

Lifelong Learning is becoming a key focus for many industries and governments alike. In order for a person to stay employed in their position they must be able to keep up with technological developments and changes in the way their industry carries out its business. An example is the retraining of the workforce at the Boeing Company for the production of the Boeing 787, Dreamliner. 2D Paper technical drawings were no longer used, only 3D computer models. The aircraft was to be manufactured primarily out of composites rather than aluminium. An intensive retraining schedule was created and successfully implemented [28].

3.6 General observation

Although many institutions eagerly implement transversal skills in their curricula with the aim to better prepare students for the labour market, a simple self-assessment of participants is often the only form of evaluation carried out. No longitudinal studies were found where students were followed in their years after graduation, or other forms of measuring the effectiveness of the skills education. This is an area that deserves serious attention in the opinion of the authors.

4 DISCUSSION

When examining the professional roles in the labour market of engineering graduates, a number of issues should be taken into account.

Firstly, in the 21st century labour market, the calls for interdisciplinarity grow louder and louder. In most cases, engineering graduates are no longer predestined to become part of an exclusive team of highly technical skilled peers but they are more likely to cooperate with colleagues from diverse professional backgrounds. This observation has important consequences for a research project focussing on professional roles of engineering graduates. In some roles, being part of an interdisciplinary team constitutes a fundamental aspect of the content of the role (e.g. project engineer) whereas for other professional roles the interdisciplinary scope is rather limited (e.g. service engineer).

Secondly, we should look at skills training. Previous research has shown that transversal skills are often not that role-specific [27]. They are needed for each role but with different emphasis. Also the effectiveness of skills training is hardly ever investigated beyond the point of self-assessment by the learners. It remains to be proven that exposure to skills training is effective but proving the gaining of skills is an area that has yet to be investigated.

Finally, of a more philosophical nature, we could debate the prime responsibility for a student's employability. Where does the responsibility of engineering education institutions stop and where does the student's responsibility takes over? Personal growth and career development are often considered a 'joint venture' between employer (e.g. through providing training opportunities) and employee (e.g. actively reaching out to new opportunities). For example, Colman and Wilmott [29] showed that 67% of the respondents (N=108) indicate that the development of soft skills for engineering graduates is a joint responsibility for both engineering institutions and students. Only 13% of respondents considered this only to be a responsibility for students. All partners of the PREFER consortium agree that engineering institutions should (1) give a first impetus to students' emerging self-awareness, and (2) contribute to students' empowerment potential for personal and professional growth.

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