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Identification of Top Competencies Required from Engineering Graduates: A Case Study of Saudi Arabia*

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The rapid industrialization of the oil rich country of Saudi Arabia has lead to the expansion of its engineering colleges. However, it is perceived by local industrial and academic sectors that changes in the curriculum are not dynamic enough to keep pace with a rapidly-changing marketplace. The objective of this study is to shed some light on these perceptions. This paper reports results of a study carried out in Saudi Arabia for the purpose of ranking generic competencies required from engineering graduates. A questionnaire was designed and sent to engineers working in industry or in academia. The questionnaire included fifty competencies that were grouped into four domains: knowledge and understanding, personal and professional skills, interpersonal skills, and practicing skills. The analysis of the survey data has identified the competencies that are valued by industry and academia. The overall analysis showed that non-technical and attitudinal competencies are being perceived as equally important as technical ones. This is consistent with studies carried out elsewhere in the world. However, some issues such as communication in English language and computer literacy are deemed equally important. The findings of this study may be helpful in identifying the critical soft skills that need to be carefully addressed in any tuning of the current engineering curriculum.

Keywords: engineering competencies; ranking; surveys; soft skills

1. Introduction

The higher education environment is changing as information and communication technologies are having greater impact, and innovation is becoming increasingly essential. New skills have to be developed and adapted to fit new emerging occupational contexts. Engineering education is in the forefront of fields that need to adapt to these changes. Companies today operate in a highly competitive environment, and in order to stay ahead of competitors, they are more inclined to value graduates who possess a variety of skills and personal qualities, in addition to the technical know-how for the job. Features of the rapidly changing engineering environment also include a movement of engineering work from in-house to consultancies, globalization, and development of technical specializations as well as an increased concern for environmental issues [1–2]. The future role of engineering requires therefore that social, ethical, and cultural dimensions are to be added to the technical dimension of engineering education. Some studies even suggest that 75% of long term job success depends on soft skills and only 25% on technical knowledge [3]. In this rapidly changing environment, a successful engineering curriculum must produce graduates that are adaptable and highly competitive to succeed in meeting the expectations of modern industry. However, changes in the engineering curriculum are not always dynamic enough to keep pace with a rapidly-changing marketplace. This contributes to gaps between competencies developed during engineering education and competencies required for engineering work [4]. These gaps were highlighted in a number of studies and surveys carried out around the world [5–8]. The SPINE "Successful Practices in International Engineering Education" study [9] was particularly a useful benchmark study that focused on the analysis of successful practices in engineering education in a number of leading European and U.S. universities. Most of the gaps in engineering competencies were found to be associated with non-technical abilities such as communication, team

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work, creativity, innovation and entrepreneurship skills. These gaps are likely to be even more severe in third world countries.

Higher education in the kingdom of Saudi Arabia, for instance, is less than half-century old. However, with the large expansion of the industrial sector as result of oil revenues, the country has increased the number of its higher education institutes, and engineering colleges in particular. This rapid expansion was however not met with adequate changes in the engineering curriculum. Consequently, there are sustained complaints from the industry about the unsuitable quality of the educational product compared to the demands and expectations of the labor market. Together with this situation, the Kingdom has recognized the need to move from a natural resource-based economy to a knowledge-based economy. The kingdom is also becoming more integrated into the world economy, as illustrated by its participation in the World Trade Organization. In order to compete internationally, the Kingdom's industries need the national engineering graduates to be competitive. In the coming decades, Saudi's young engineering generation will need to acquire new skills and capabilities to meet the current diversification objective. Undoubtedly, this issue will present a big challenge to educators to design and implement effective learning strategies for soft-skills education into the engineering curriculum.

Before reaching the stage of curriculum re-design, it is important to have information on the type of competencies sought by the industry and the academia. This paper reports the results of a study, the first of its kind, in the country. The first objective of this research is to provide feedback from industry and academia on the type of competencies they seek. The second objective is to rank the importance of the surveyed skill attributes. These objectives are achieved through the collection of data using survey questionnaires.

It should be noted that the issue of competencies ranking in the engineering field has been receiving increasing attention in the literature. Previous studies carried out included those designed to develop accreditation criteria [10–15] as well as quantitative studies across many parts the world [16–22].

A final point is to be made about the terms "competencies","attributes" and "skills" used in this paper. There is a considerable debate in the literature with regard to the meaning of these terms and how they relate to each other. In this paper we have adopted the conceptual framework for competencies developed by a multidisciplinary international project (OECD) [23]. Competencies are understood to represent a combination of attributes in terms of knowledge and its application, skills, responsibilities and attitudes.

2. Research methodology

Competencies that were likely to be important to engineers were identified from a broad range of literature in the field of engineering education. Significant sources included the various frameworks for accreditation such as the Accreditation Board for Engineering and Technology (ABET) in the United States [10], Engineers Australia (EA) [11], European Network for Accreditation of Engineering Education (EUR-ACE) [12], the UK Standard for Professional Engineering Competence (UK-SPEC) [13], Conceiving-Designing-Implementing-Operating (CDIO) initiative [14] and Tuning-AHELO frameworks [15]. Sources for generic competencies were also obtained from Tuning project [24] and other studies carried out in the literature [25-28]. The total number of competencies covered in the questionnaire is 50, divided into the following categories:

- Knowledge and understanding (9 competencies, as shown in Table 1)
- Personal and professional skills (16 competencies, as shown in Table 2)
- Interpersonal skills (11 competencies, as shown in Table 3)
- Practicing skills/engineering practice (14 competencies, as shown in Table 4)

The questionnaire included two main parts: The first part contained general information about the

Table 1. Ranking of the Knowledge and Understanding Skills

No	Competence	Rank according to Industry	Rank according to Academia
1	Sciences and mathematics including statistics	5	2
2	Engineering fundamentals	1	1
3	Advanced engineering knowledge, methods, and tools	4	6
4	Knowledge of contemporary issues	9	9
5	Analytical skills	3	4
6	Experimental skills	7	7
7	Design skills	6	5
8	Investigation and Research skills	8	8
9	Computer literacy	2	3

Table 2. Ranking of Personal and Professional Skills

No	Competence	Rank according to Industry	Rank according to Academia
1	Problem solving skills	1	1
2	Critical thinking	10	6
3	Innovation	14	11
4	Creativity, imagination, and idea generation	6	8
5	Integrity and self critic	11	9
6	Responsiveness, accountability, and openness	8	10
7	Stress management and ability to deal with tense situations	7	15
8	Time and resource management	2	5
9	Adaptability in a changing environment	13	12
10	Sensitivity to public and worker safety	5	3
11	Sensitivity towards environmental issues and sustainability	15	14
12	Lifelong learning and educating	9	7
13	Motivation/concern for quality and continuous improvement	3	2
14	Initiative and entrepreneurial spirit	12	13
15	Personal drive, Perseverance, and will to succeed	4	4
16	Information management skills	16	16

Table 3. Ranking of Interpersonal skills

No	Competence	Rank according to Industry	Rank according to Academia
1	Teamwork	1	2
2	Leadership	5	8
3	Appreciation of diversity in opinions	4	5
4	Adaptability and ability to multi-task	7	7
5	Multidisciplinary within and beyond engineering	9	9
6	Strong work ethics	3	3
7	Awareness of Islamic cultural context	8	6
8	Awareness and appreciation of Saudi heritage and traditions	11	11
9	Communication in Arabic language: in writing, orally, and graphically	10	10
10	Communication in English language: in writing, orally, and graphically	2	1
11	Awareness of electronic/multimedia communication means	6	4

Table 4. Ranking of Practicing Skills

No	Competence	Rank according to Industry	Rank according to Academia
1	Technical competency in the practical aspects of engineering in the area of specialization	1	1
2	Awareness of current computer-based tools and simulation packages, and competence in the use of a representative selection of these.	11	7
3	Integration of analytical, problem solving, and design skills	5	2
4	System thinking	8	10
5	Selection and using appropriate equipment, tools, and methods	14	4
6	Practical ingenuity: capacity for planning, combining, adapting, coordinating, and organizing	6	6
7	Synthesizing engineering, business, and societal perspectives	13	13
8	Project management, financing, and business practices	12	14
9	Decision-making	3	9
10	Working effectively in the global engineering profession	9	11
11	Working effectively with clients, suppliers, and the public.	10	12
12	Awareness of the role of engineers and their responsibility to society including the non-technical implications of engineering practice.	7	8
13	Ethical responsibility in a global, social, intellectual, and technological context.	4	3
14	Awareness of codes of practice and industry standards	2	5

respondent that was used solely for statistical purposes. The general information included the age, year of graduation, the institution where the degree was obtained and the type of degree. This information also included whether the respondent was working in the academic or engineering/industrial field. The respondent was then asked to evaluate the importance of the competency by marking one of the five choices: (1) if the skill is not applicable, (2) if the skill is not important, (3) if the skill is of medium importance, (4) if the skill is very important and (5) if the skill is critical. The questionnaire was distributed by hand and by E-mails as well as posted on the web site. A total of 500 copies were sent out, 362 of which were completed and returned to the research team for processing.

In selecting engineers working in the industry, attention was made to contact large companies that were likely to hire engineers from various specialties. Within these companies, the targeted participants comprised experienced senior/principal engineers. For the academic community, professors working in various engineering colleges across the country were contacted. Attention was also made to ensure that various programs within each college were represented.

3. Results and discussion

Out of the 362 respondents who completed the survey, 62% were engineers and 38% were from the academia. Fig. 1 shows the distribution of years of experience of the engineers who participated in the survey. It can be seen that the survey was answered by engineers who have experience ranging from 1 year (fresh) until 35 years (senior). The engineers with experience less than 20 years represented 66% of the respondents. Based on the results of questionaires, the frequency of the answers of participants was calculated based on the following weigthing system: A value of 0 was assigned for the answer (the skill is not relevant), a value of 1 was assigned to the answer (the skill is not important), a value 2 for the answer (the skill is of medium importance), a value 3 was assigned for the answer (the skill is very important) and a value of 4 for the answer (the skill is critical). The results showed that there are notable variations of the importance of skills in the opinion of different stakeholders (engineers and academics). In this section, an attempt is made to rank the skills using the PARETO analysis technique.

Table 1 shows the ranking results for Knowledge and Understanding Competencies. The same is done for the Personal & Professional skills (Table 2), for Interpersonal skills (Table 3) and finally for Practicing skills (Table 4). Table 1 shows that the industry considers that knowledge and understanding of engineering fundamentals is the top required competency, followed by computer literacy, analytical skills, advanced engineering knowledge, and science & mathematics. Least important for industry are knowledge of contemporary issues, investigation and research skills, and experimental & design skills. The academic community seems to agree with the industry on four of the top five competencies, although there is disagreement on their relative ranking. Academics seem to value design skills more than advanced engineering knowledge. They also agree with the industry on the three least important competencies. It should be noted that design and experimental skills, that received lower ratings by industry, have been central to engineering curricula. Computer literacy and analytical skills seem to be appreciated by both the industrial and academic spheres. As far as computer literacy is concerned, the curricula in most Saudi engineering schools include at least one module devoted to teaching a selected computer language. Instructors are also encouraged to apply computer

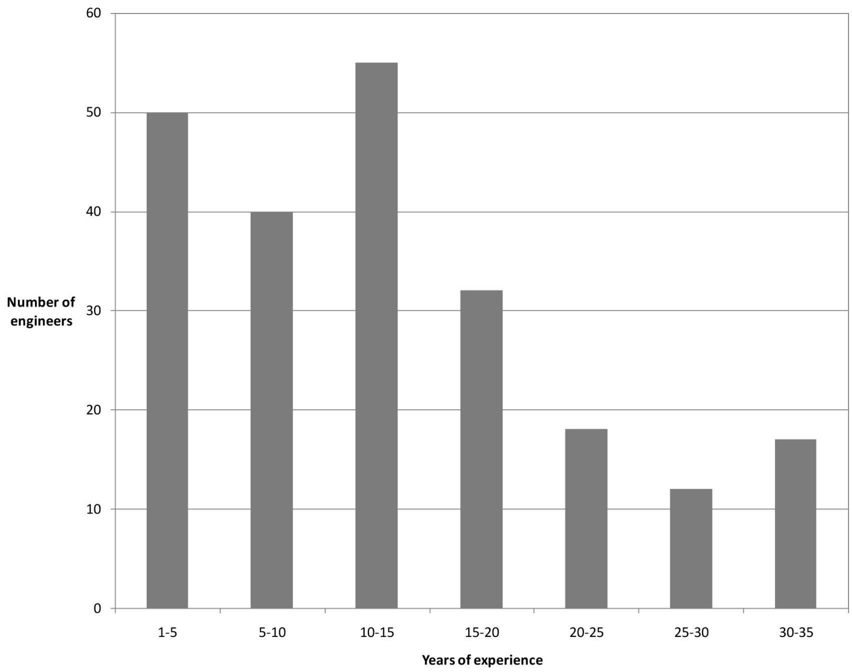

Fig. 1 Distribution of years of experience of the engineers who responded to the survey

programs in various design courses. The inclusion of analytical skills in the curriculum represents, however, a real challenge, since it depends closely on the ability of the instructor to engage his students to apply logical thinking to solve complex problems. We may conclude at this stage that this study does not necessarily question the usefulness of design and research skills. However, by elevating computer literacy and analytical skills to higher ranking, industry and academia seem to stress the importance of non-technical competencies for the success of an engineer.

Table 2 shows the ranking summary for personal and professional skills. The industry estimates that problem solving, time and resource management, motivation, personal drive, and sensitivity to safety issues are the top five competencies. Least important for them are information management skills, sensitivity towards environment and innovation. Interestingly enough, the academic community seems to agree with industry on the top five competencies although there is a slight disagreement on their ranking. In the same time, academics seem to agree on the least important competencies, although they rank stress management lower than it is ranked by industry.

The issue of safety, valued by both industry and academia, is well covered in Saudi engineering curricula. Students are exposed to safety principles during various lab sessions that are mandatory in all engineering curriculum. However, the other important competencies (motivation, personal drive, and time and resource management) are all non-technical skills that would present a real challenge in implementing them directly or indirectly in the curriculum.

As for interpersonal skills (Table 3), it can seen that team work, communication in English language, work ethics, appreciation of diversity and leadership are the top five competencies according to the industry. Least important for them are awareness of Saudi heritage, communication in Arabic language and multidisciplinary skills. Academics agree with four of these competencies but favor awareness of electronic communication means over leadership. The three least important competencies are identical to those viewed by the industry.

In this era of globalization, English has become one of the most important languages of communication. Thus, it is very important that future engineers be able to communicate well in English. Low confidence and inability to speak well in English can hinder one's chances of being hired in a company [29]. The Saudi engineering curriculum is based on English language. However low English levels of students coming from high schools push instructors to use Arabic in the class, which contributes to the further deterioration of English communication skills. A number of engineering colleges in the Kingdom have started addressing this issue through a number of measures, including setting up preparatory years, the hiring of native English speaking instructors as well as the mandatory inclusion of oral presentation in labs and selected courses.

Team work, which ranked first in competencies, also requires the use of effective communication by engineer. Appreciation of diversity, also listed in the top five competencies, has been always an issue with Saudi industry. Since Saudi companies rely heavily on foreign work force at different levels, it is important that Saudi graduates know how to communicate and be sensitive to the different ethnic and cultural groups that constitute the labor force.

Most engineering colleges in the Kingdom have included in their curriculum a mandatory training period in which final year students spend two months in a selected industrial plant, and have the opportunity to be exposed to safety issues, team work and a diversified work place.

Finally, Table 4 shows the ranking for practicing skills. For the industry, the top competency is the technical know-how followed by awareness of codes of practice, decision making, ethics, and integration of analytical & design skills. Least important are the skills associated with using appropriate tools & methods, project management, financing, and business practices. Academics agree on four of the top priorities but consider that using appropriate tools & methods is more important than decision making. They, on the other hand, agree on the least important competencies. The table highlights again the disagreement between industry and academia on the importance of using appropriate tools & methods in the design, a central issue in engineering curriculum.

Surprising in these results is the low ranking received for competencies related to project management, finance and business practices. This is against the trend observed in surveys carried out in many parts of the world. This issue requires certainly further investigation.

4. Conclusions

The main objective of the paper was to provide some initial insights into the relative importance of various competencies required from engineering graduates in the kingdom of Saudi Arabia. Fifty competencies were selected and grouped into four domains: knowledge and understanding, personal and professional skills, interpersonal skills, and practicing skills. These competencies were included into a questionnaire that was sent to individuals from the industry and academia.

The analysis of the survey data allowed the ranking of the selected competencies in each group and also allowed a useful comparison between the industry and academia perspectives. The findings of this study were also helpful in identifying the critical soft skills that need to be carefully addressed in any tuning of the current engineering curriculum.

Overall, the results of the survey are in agreement with the general world trend of the need to equip engineers with a high proficiency in both technical and non-technical skills. Interestingly enough, both industry and academia seem to agree on the ranking of the most important competencies as well as the least important ones. This overall agreement of the two parties was a pleasant result and points to evident benefits for the future tuning of the engineering curriculum.

The real challenge to be tackled in the future is to devise approaches to implement changes in engineering curriculum to address needed soft-skills such as analytical skills, time and resource management, motivation, leadership and decision making. These may involve mentoring and engaging students in problem-based or project-based case studies, which should provide students with opportunities to be exposed to some of these soft skills.

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