Industry perception of new engineering graduates: the gap between requirements and reality

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INTRODUCTION

Over the last few decades we have witnessed an increase in the number of high skilled occupations all over Europe [1] especially in the engineering sector. This increase was generated on the one hand by the transformation of the industrial structure and on the other by fast growing technological development.

The ongoing transition of industry from the traditional manufacturing sectors to the highly innovative industrial service sector shifted the employment proportion. We can observe a constant change of inter-industry division of workforce with the increasing share of the service industry [2]. This transition profoundly modified the industry's requirements for engineering workforce skills and competencies. In addition to more and more specialised technical knowledge they need new multidisciplinary skills and competencies. However, the availability of an engineering labour force with these new skills and competencies is often limited on the labour market. Despite the continual rise in a highly qualified engineering workforce, in several industries employers who are looking for a specific set of skills and competencies have difficulties in finding the right person for numerous vacant occupations. There is a real mismatch between the industry demand and the labour market offer. In particular, industry is asking for more and more flexibility with constantly updated competencies and knowledge.

In today's knowledge based global economy, fast evolving progress in technology has also made profound changes on the labour market. Regardless of this growing demand for highly skilled graduated engineers, industrial companies will recruit young candidates only if they perceive them to be adequately skilled and capable to be integrated into their organisation. Therefore, they require them to have not only a solid technical background but also non-technical skills and competencies. In the age of digital technology, these new priorities and requirements for engineering graduates competencies are clearly perceptible in the industrial sector. New graduate engineers have to be able to use skills like social intelligence, sense-making, design mind-set, convergent and reflexive thinking or virtual collaboration [3]. Consequently, the development of these new skills sets by including them in the existing course content is really essential for fostering their employability and future career.

In this paper we focus on skills and competencies from the perspective of the industries as future employer of new graduate engineers. What set of skills and competencies do they really need when recruiting? What are their priorities between these skills and competencies? What are their expectations and main concerns? We would like to explore these required new sets of skills and competencies and highlight the importance attached to them.

1. THEORICAL BACKGROUND

1.1. Evolution of required skills and competencies

Historically, the main requirement by industries for engineers is to have good technical knowledge and competencies. Therefore, engineering education was traditionally strongly focused on the development of these core technical knowledge and competencies until the early 80s when the industry environment radically changed. Technological advances have generated a deep restructuring in the traditional structure of industries and emerging globalisation trends enhanced the competition at the international level. As a consequence, the engineering practice has extensively changed, as from this time 'engineers must supplement technical mastery with business and communication skills, and an understanding of the ethical and societal impact of engineering solutions' [4:43].

This emergence of required skills and competencies remains an ongoing tendency with a constant extension of future engineering work skills. Still, this extension concerns predominantly not the technical knowledge but the addition of new non-technical skills and competencies. In their study, Connor et al. [5] explored core competencies that future creative technologists should possess for better employability. They identified nine distinct categories: three of them are related to knowledge (technical, human factor and media knowledge), three of them are connected to skills (communication, interpersonal and self-management skills) and the last three are situated in the overlap between them (attitudes, problem solving, leadership and management). This result suggests that future graduates 'need more than a toolset; they need a mindset as well as working knowledge of communication, culture and technology' [5:18]. For Davies et al. [3] the ten most important competencies needed for employees by 2020 are non-technical competencies like sense-making, social intelligence, novel and adaptive thinking, cross-cultural competency, computational thinking, new-media literacy, transdisciplinary, design mindset, cognitive load management and virtual collaboration. Their foresight study highlights the necessity for the development of non-technical skills and competencies that became a key element of new engineering graduate employability.

The common characteristic of these extended set of skills and competencies is that they need a very high level of adaptability to fulfil these constantly changing expectations. To obtain this high level of adaptability during their professional careers, engineering graduates have to able to constantly update their skills and knowledge 'becoming more self-directed and self-reflective in their learning and development' [6:7]. In addition to the extended set of skills and high level of adaptability, the rapidly changing modern knowledge and technology demand a growing level of reactivity from engineers. They have less and less time to make this adaptation that is an important challenge of engineering profession in the future.

1.2. Industry needs for work-ready graduates

Industrial companies' requirements are closely related to their expectation to have work-ready graduates [7]. This tendency appears in their recruitment and selection: they look after young graduates who can adapt easily to their corporate culture and have appropriate skills and competencies to evolve the organisation. Traditionally, employee selection is based on new graduates' academic performance and technical knowledge. 'However, academic and technical ability does not necessarily predict long term future capability. Nowadays, more importance is being placed on graduates possessing a range of generic skills and attributes required across all jobs' [7:18]. According to Hager [8] these generic or non-technical skills became progressively more important as they include not only skills but various attributes such as attitudes, values and personality. The combination of these skills and attributes is defined as the capability of graduates.

Companies' priority between soft skills varies considerably regarding the industrial and professional context but the skill that is always mentioned in this category is communication skills [9]. From language proficiency to presentation there is a wide range of communication skills generally in relation with other social skills (e.g.: conversation skills). The importance of social skills is incontestable for young graduates as 'most employers view social skills and personality type as more important than their degree qualification' [10:7]. These social skills closely related to their capacity to be a good team player or network builder have an indirect influence on their work performance. Furthermore, in the context of today's global economy they have to develop cross-cultural skills and competencies to work in different cultural settings. If they have to work in international collaboration or in changing geographical regions [3] these skills and competencies became predominantly important.

Skills related to the ability to understand and manage objects, people and ideas like abstract thinking, problem solving or sense-making are particularly relevant for engineering graduates [11]. These intellectual or cognitive skills have a key role in their professional activity in which 'the emphasis is not on proficiency with the tool, but on types of intellectual activity performed by a person'[12:61]. Engineers have an ever-growing necessity to develop the most flexible and extensible set of cognitive skills to facilitate their adaptation to fast changing technical environment. Moreover, in a complex environment, they are required to be able to think in a holistic way and apply system thinking [13].

According to Coballero and Welker [14:56], 'graduates are often selected for their perceived general potential rather than for a specific role within the company'. For the assessment of these future potential, industrial companies take into consideration a range of personal attitudes like motivation, ambition, enthusiasm, optimism, curiosity, maturity or proactivity. The growing importance of personal attitudes is explained by the fact that they helps to predict graduates' general potential for the company. Moreover, they are indispensable for work readiness of young graduates requested by industries.

2. RESEARCH METHODOLOGY

In order to provide a detailed picture based on the integration of experiences of various actors, a qualitative research methodology was applied. We adopted a qualitative approach as our main objective is not the explanation but the exploration of the research subject. This methodology is appropriate to interpretivist paradigm as we intend to explore concepts like attitudes and relations in a broader way and from various points of view.

In our research we intended to collect empirical evidence of the actual skills needed by companies in Hungary in relation to young engineering graduates. In the framework of this study we have carried out 15 semi-structured interviews with different stakeholders. Our sample was carefully chosen in order to ensure the heterogeneity of different experiences. Several companies employing proportionally high number of engineers and representing different industries were selected for sampling. Regarding the composition of the interviewees, we intended to integrate both the vision of the senior management and the view of newly employed graduated engineers[1] so these different categories are included in our sample. For technical reasons the sample is biased in favour of large, multinational companies.

For the development of the final interview structure we used the results of two pilot interviews and findings from our literature review [15]. After a brief introduction the following issues were explored: work experiences with new graduate engineers, their perceived competencies, internal training system and 'the ideal' young graduate engineers. We have exclusively focused on skills and competencies mismatch excluding the potential qualification mismatch in these companies related to young graduate engineers [16]. All interviews averaged about 60 minutes and were digitally recorded and transcribed to facilitate data analysis.

We carried out a thematic analysis that 'is a method for systematically identifying, organising, and offering insight into, patterns of meaning (themes) across a dataset' [17:58]. We had a very high level of heterogeneity of the answers so we needed a flexible and practical methodology for identifying common issues in the textual data. From the interviews, we identified different patterns based on the related literature and devised them into sub-themes and analysed the emergence of each pattern to have a comprehensive understanding.

3. RESULTS

In our study, we have separated traditional technical competencies related to the sciences of engineering and non-technical competencies (i.e.: communication, attitudes, interpersonal skills, etc.) related to the operational practice of the engineering profession.

[1]We discussed with senior managers and freshly graduated engineers have been employed for less than three years in the company.

3.1. Technical competencies

We consider technical competencies as the aggregation of technical knowledge and functional competencies. These functional competencies concern the application of this knowledge in practice.

Technical knowledge consists of a strong basic technical background in engineering sciences (e.g.: mechanics, electronics, etc.) that represent the core competencies of engineering. For industrial companies, this basic technical background is an indispensable condition for the engineering profession. As a senior research engineer pointed out '*we mainly give companies practical knowledge through mostly young engineers, students and so on, but the theory must be taken from the university…we can no longer to teach it to them'*. As a consequence, young graduate engineers must have a solid technical background when they are recruited into a company as '*it is important to have theoretical knowledge*' and also it is '*important to have an engineering mind-set'*. This engineering mind-set involves the way of thinking and implies a 'professional technical creativity': '*to invent new things, to be open-minded to try new solutions and to be able to learn from our proper mistakes'*.

They highlighted the importance of these functional competencies by the fact that several companies included verification in their recruitment process. This verification could be only the confirmation of strong basic technical background but in several cases industrial employers indicated a two stage process with the confirmation of specialized technical knowledge (e.g.: for electrical engineers' knowledge of speech coding). In these highly specialized technical fields, freshly graduated engineers have in general only a basic theoretical background without any experience in the practical application of it. Nevertheless, in the recruitment process, industrial employers include short case studies with the practical solution of a problem that needs the application of this theoretical knowledge. As explained by a senior manager in a multinational telecommunications company, '*when we see that someone has less knowledge but solved the task, even with our help, it is more positive'*. In this case, the specialized technical knowledge has a secondary role; the most important is young graduate engineers' problem-solving capacity.

With a high level of industry specialization companies are aware that the specialized technical knowledge of young graduate engineers would be rarely suitable to their activity. For this reason, they involve nearly always an internal '*on board training*' system to teach them this specific knowledge. The main objective of this internal training is to teach new employees this basic background of these specialized technical fields. After this introductory training period new technical knowledge is '*acquired during the practical work in informal ways as well, with the help of a contact network during the problem solving process*' as explained by a senior manager. The specific technical knowledge transfer is included, in a formal or informal way in the training process.

The lack of '*system vision*' of young engineers was mentioned by a senior software engineer illustrated through an example where a young graduate engineer employed in the company and '*have to test for an entire system, but they don't even know the basics of the system*'. However, this lack of a holistic vision of technical knowledge could be explained by the existing separation between the different scientific subjects during the years of their engineering training. Often they do not have the opportunity to work on vast projects handling a complex system that demand the active use of knowledge and competencies concerning divers scientific subjects at the same time.

On the contrary, in a real working situation the separation of these subjects has no meaning as engineers have to be able to handle a complex system in its integrity. The only exception was the case of higher apprenticeship engineering graduates who have the opportunity to work on complex projects in a real working environment.

3.2. Non-technical skills

When analysing the recent developments in the world of work many authors conclude that in terms of skills there has been a shift from the 'technical to the social' in the last decades [18]. It means that those elements of the interpersonal relationship, like communication, empathy, aesthetic appearance and emotional control, attitudes and predispositions etc., that were conceived as personal characteristics in the past, have been re-labelled as 'skills'[19]. Going beyond the debate whether these are personal attributes, real skills or just disciplined way of behaviour, it seems to be obvious that employers want employees who have sophisticated soft skills in order to be able to provide high-quality work. In our research we devoted special attention to the soft or social skills and competencies. The results can be summarized as follows.

The interviewees' general experience was that the relatively high level of technical expertise of the young graduates is in several cases accompanied by the weakness in soft skills or social competencies. The term 'soft skill' was often used by the interviewees, its meaning, however, remained unclarified. Despite the conceptual heterogeneity, based on the interview results we have identified three main areas of soft skills that are of particular importance in meeting high quality work targets. The first set of soft skills is related to general attitudes and relation to work and the specific abilities to organize it.

3.2.1. Relation to work

The most important skill or ability the interviewees perceived as a general shortage or weakness of young graduates is their readiness to work independently. A typical complaint was that most of the junior engineers are not able to work alone and their work requires close supervision, which does not mean the shortage of their technical knowledge but is rather concerned with their general relation to work. The most often mentioned critique in this respect was that new entrant engineers often lack willingness to engage in new work tasks challenging their skills. According to the managers interviewed, young engineers perform their prescribed work more or less precisely and at a high professional quality, but when they finish with the tasks delegated to them, they stop and go no further. *'They're not self-sufficient at all. They do not ask questions when they have doubts or even ask the same question five times or more. It indicates to us then, that they have understood nothing.'*

With regard to that problem two basic general patterns of work attitudes were identified. People representing the *narrow* or *restricted* attitude to work approach the labour process as being a linear system of discrete and specialized work tasks, even of high complexity. Those with more *holistic* or *expansive* attitudes, however, treat work as a complex system of interdependent tasks and actions. A decisive amount of young engineers belong to the first ideal type.

Our interviewees complained about the lack of proactivity and initiative in the case of new graduate engineers. These, however, require taking more responsibility and risk, autonomous decision making, ability to leave the personal 'comfort zone', to cope with uncertainty and willingness to learn. It is strongly connected to individual capabilities as well as to institutional/organizational factors. The attitude of work depends on the way of professional socialization, the patterns of behaviour transmitted by the educational institutions and such innovative organizational practices that support autonomous work, like learning-friendly work environment, collective knowledge sharing, adequate incentive system, lack of blame culture, etc.

The problem around work attitudes has other consequences, as well. Both the theoretical literature and empirical evidence suggest that autonomy in work is associated with increased innovation capacity both at the individual and organizational level [20]. The willing rejection of autonomy and responsibility taking we observed in the case of young engineers may act as a serious barrier in enhancing creativity and boosting innovation. Our findings challenging the argument that innovative work organizational practices (like lean production, HPWS, project-based work, etc.) are the most important prerequisites of increasing firms' innovation capacities not exclusively in procedural issues but also in case of development of new products and services [21, 22, 23, 24]. According to our results innovative work organization practices do not lead *automatically* to the increase in innovative capacity. We have to stress that they rather serve as important frames and inhibitors but individual contributions and development of soft skills (including such personal attributes like work attitudes) are also needed for exploiting the possibilities they offer.

The other work-related skill-shortage strongly connected to the problems presented above was the lack of experiences in project-based work and project-type thinking. Most of the entrants have no routines in planning and managing projects in order to achieve specific objectives. The most important skill-deficits are in leadership, coordination and control, collaboration and information and knowledge sharing. Project-based work experiences could serve, however, as a solid basis for changing work attitudes, learning process-oriented way of thinking and taking the perspective of others.

3.2.2. Mode of cognition

The second group of soft skills are related to the mode of cognition of the young graduates. The most common shortage mentioned here was the weakness of 'engineer style cognition'. We identified the following dimensions of this relatively fuzzy term of cognition:

- Analytical thinking: this term means a coherent and logical frame of cognition and the ability to reduce complex things into single components.
- Structured problem-solving: most of our interviewees emphasized as one of the most attribute of the engineer the constant effort to identify and solve complex problems. These efforts include critical attitude, sequential problem analysis and the ability to transform problems into alternative possibilities and the systematic evaluation of them. It also requires innovativeness, e.g. producing new ideas based on the analysis of technological processes and providing solutions to improve them. It is based on the effective and systematic utilization of all available information, especially the achievements and failures of prior work.
- Systematic and holistic perspective: contrary to analytical skills presented above, holistic approach requires the synchronous and system-level interpretation of problems, structures and facts and the recognition of the interconnectedness of various patterns and objects that form larger systems. Planning skills also belong here.

One more skill was emphasized in the interviews, namely the ability to learn. This ability encompasses the absorption of new knowledge, the application of theoretical knowledge in different and concrete situations and the new combination of different knowledge sources (e.g. knowledge creation).

3.2.3. Interpersonal skills

Parallel to technological development, engineering knowledge and the division of labour in the organisations has become more complex and sophisticated. As a consequence there is more intensive need for interpersonal rather than individual actions in the workplace. It, however, requires the ability to work collectively and the readiness for 'inter-professional' communication. Perspective taking, understanding and tolerating the opinion and experiences of others is a must. In this respect this area is rather problematic in some cases. *'Sometimes I have the feeling that they* (e.g. young engineers) *fight against the world. They always know best and can't take criticism. It makes communication and cooperation extremely difficult and often leads to bad solutions.'*

One other important aspect of interpersonal relations is the ability that may be labelled as cultural awareness and adaptability and covers the ability to accommodate various situations with culturally different environments and people with different backgrounds. This skill refers to the essential understanding and proper interpretation of codes, rules, costumes, habits and perspectives different environments provide and the quick adaptation to the changes of them. It also serves as an important prerequisite of project-based work.

Communication is also an important part of interpersonal relations. Accordingly, the importance of both oral and written communication skills has been emphasized with a light critical attitude towards the perceived erosion of the written communication standards. The most important shortage in this respect was poor presentation skills. Presentation is a complex term with various aspects, but in this context it means to get the message concerned to new ideas and/or work results across to the listeners in an effective and persuasive manner. In this sense it is strongly similar to sales activities. The next quotation represents the introverted attitude that is perceived to be typical among fresh engineering graduates and acts as a serious barrier to effective presentations. *'Have you done the job? – Yes. – Does it work? – Yes. – Please may I ask you to present it to us, then? – What shall I tell you? It works.*

CONCLUSION

This study allowed us to explore the competencies and skills expected by industries and the importance that they attached to them. Our findings confirm the prominence of technical competencies for industrial companies as a basis of engineering practice and non-technical competencies as an essential element to the practice of their profession. We see that there is a trend for increasing importance given to non-technical competencies by industries explained by their expectations of recruiting work-ready young engineers.

We must emphasise that there is complex and multifaceted interaction between these skills and competencies (e.g.: to be able to create a new composite material supposes a high level of creativity and innovation skills that are closely related to curiosity). Consequently, non-technical skills and competencies should be involved in course design in relation to technical competencies recreating similar conditions as we have in a real working environment.

Concerning technical competencies, industries have positive perceptions about young graduates' scientific backgrounds. In spite of this, they were not entirely satisfied with their ability to apply this technical knowledge. It was highlighted that industries require not only a strong theorical background but the ability to manage a complex system and an engineering mind-set. However, during their engineering training most of subjects are taught separately and students rarely have the opportunity to relate them despite the fact that in a real working situation they are strongly related. Therefore, it would be beneficial to introduce more multidisciplinary courses in engineering training to make a connection between traditionally separated subjects.

The lack of non-technical competencies remains the main concern of industrial companies when employing young, inexperienced engineers. It would be valuable to put more emphasis on teaching these practical competencies [25] in an integrated way with more collaboration between universities and industries, accompanied by new, innovative training methods (problem-based learning, project-based learning, business games, etc.). The relation between engineering education and industries needs to be reconsidered in order to reduce this gap and meet expectations. Better integration of these non-technical skills and competencies into their curriculum would facilitate the transition of their students from the educational system to the work place.

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