Engineering Students' expectations about skills and competences for jobs versus what is expected by companies and organizations. What is the need for continuing education after graduation (an European overview)?

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO	**Alfredo Soeiro** **avsoeiro@fe.up.pt** **University of Porto**
AALBORG UNIVERSITY DENMARK	**Bente Nørgaard** **bente@plan.aau.dk** **Aalborg University**
Metropolia University of Applied Sciences	**Katriina Schrey-Niemenmaa** **katriina.schrey@metropolia.fi** **Metropolia University of Applied Sciences**
DE HAAGSE HOGESCHOOL	**Ellen Sjoer** **e.sjoer@hhs.nl** **The Hague University of Applied Sciences**
BME 1782	**Aniko Kalman** **drkalmaniko@gmail.com** **Budapest University of Technology and Economics**
Imperial College London	**Mervyn Jones** **m.jones@imperial.ac.uk** **Imperial College London**

ABSTRACT

The paper tried to address a series of recommendations for a continuing education model to attempt to fill the gap between engineering graduates learning outcomes and the need of companies for a better employability. These proposed guidelines are based on some European case studies. Many engineering students have employability as a high priority after completion of their studies. Nevertheless, surveys point out to the existence of competence gaps between education learning outcomes and work requirements of competences. Then some recent engineering candidates have a perception of not feeling ready to enter the labour market. This paper reports on engineering students' expectations of what they believe will become their most important skills and competencies as they enter their first jobs versus what

companies and organisations identify as important skills and competences among young engineering employees.

Keywords

Skills gap, young engineers, employability, competences.

INTRODUCTION

The data and information for the current study have been collected from surveys and case studies from Denmark, Finland, Hungary, Portugal, Great Britain and the Netherlands. From the analysis of these sets there is the intention to draw a scenario of the European employability among young engineering candidates and to try to define the gaps that are believed to exist between engineering education learning outcomes and work requirements of competences. Some recommendations in the case studies are made on how to create continuing engineering education models to reduce the consequences of the identified gaps.

1 - DENMARK

In Denmark, a recent survey, the PROCEED2WORK, was conducted based on the overall assumption that both better and more engineers are needed - and that the global labour market brings new challenges for both Danish engineers working abroad and foreign engineers working in Denmark. Overall the survey aims to identify the future's competence for industry and to point out what implications this will have for education and further training of professional engineers.

Specifically, over the last 10 years, engineering studies have focused on having a closer relationship with industry. This can be seen e.g. through an increasing number of study plans based on a CDIO approach (Conceive, Design, Implement and Operate) [1]. In Denmark, engineering studies have mainly used the CDIO approach in combination with the problem-based learning (PBL) approaches [2]. However, the transition problem remains a key element in developing future engineering education programs.

The PROCEED2WORK project [3], which is a study of transition problems from education to work. It consists of two parts, first an analysis of engineering students' expectations for future work, and second a response from the same engineering students after 3/4 years of work in industry. Questionnaires were sent to 3969 civil engineering students in May 2015, just before their graduation. 1141 engineering students responded, which gave an answer percentage of 29%. Across a series of questions, a picture is drawn of the student's expectations of getting a job in which they can have fun, be committed and intellectual inspired further they value a balance between working and family life. Students find themselves most prepared in terms of innovation and critical thinking, technical professionalism and teams and cooperation. The students have both fewer expectations and less willingness in terms of business orientation and career, society and social responsibility as well as the environment.

Generally, throughout the report there are a number of differences between female and male students. The female engineering students have higher expectations about family and social commitment, and there is also a difference in the degree of readiness where the female

students generally find themselves more prepared for society and the environment as well as project organization. Conversely, the male students have expectations about career and experience more readiness in technical professionalism. Transition problems and students' eligibility in the labour market are also linked to quality development of future engineering education and the future engineers. What competences are needed and in what way must engineering studies change to meet the needs of the future? These are question still to be answered.

2 - HUNGARY

In Hungary, the case study explored the perception of graduate engineering students' competencies that are relevant for their employability. Focusing on freshly graduated engineers' employability perspectives, engineering graduates were asked about what was their vision of future employment and their perceived ability to meet the employers' competency requirements. In 2016, the Budapest University of Technology and Economics (BME) got involved in an international comparative study. The objective of a research project launched in 2008 was to get a comprehensive picture of the competencies acquired by new graduates of technology. The repeated research launched in 2016 was a longitudinal continuation of the one conducted in 2008 [4]. The target group comprised new graduates of engineering with focus on their employability, employment opportunities and demands. The students selected belonged to two groups: those participating in the traditional engineering programmes and those who aim for a degree in management parallel to their engineering studies.

The applied research methodology was to make personal interviews with 29 graduating engineering students using a structured questionnaire. Interviews were planned to last 30-40 minutes, but turned out to vary greatly depending on personal motivation level and the individual's personality. Many of the interviewees identified professional knowledge, adaptability, language proficiency, flexibility, problem solving and good communication skills as the competencies/skills most required by employers. Irrespective of faculty, volunteers were of the opinion that only their basic disciplinary knowledge must be really solid because students have diverse interests and therefore believe that they acquire the necessary skills/competencies by working for various companies.

The results of the interviews supported our assumptions about time management. With the exception of a single student, each pointed out time management as the field in need of major development. In their own view, they are likely to procrastinate, especially at home where they are under no direct supervision. There were some who would be scared of flexitime working hours due to procrastination. The second most frequently mentioned field to be developed was communication skills. The reason for this was seen in the special nature of the programme, which requires in 90% of the cases individual work from students, and they rarely need to give presentations. This problem leads straight to the third most problematic shortcoming, i.e. teamwork. Many thought that at the beginning, they would find it hard to work in a team because communication between team members would be difficult and university studies did not prepare them for this scenario.

The fact that they are struggling with the above shortcomings is of particular interest since the respondents completely agreed on the utmost significance of good communication skills, and of the ability of presenting and promoting themselves and being convincing. To summarise

the opinions, having good professional knowledge was considered most important alongside with the ability 'to sell themselves' as well as being proficient in English and presentation skills (in English, too) while German language skills were considered an advantage. Every interviewee reported that their individual skills had developed greatly in the last year, particularly underlining that subject courses were much more professional and field-specific. The components started to fall into place, and the bachelor programme courses, the necessity of which had been questioned before, started to make sense. At the end of the BA programme, most emphasised their development in presentation, communication skills and time management. Generally, they found the last two semesters of the seven-term programme the most useful.

In recent years, employers have experienced that the knowledge of newly graduated technical professionals has been lacking in the fields of business and social sciences. This is why they give preference to graduates who have also had such training during their university studies. Furthermore, employers require excellent communication skills in addition to professional knowledge, and the ability to work in teams. Often, however, graduates do not meet these requirements. Employers suggest that by requiring them to do more 'compulsory' teamwork during their studies, students could overcome the lack of communication skills and their inability to work in teams.

Although the research is still ongoing, some results have already become clear:

a) Students of engineering are much less interested in the amount of salary they can get than the students of technical management. The former consider obtaining experience as well as studying of primary importance but they think that in the future, they will probably attribute more significance to the amount of money they can make.

b) Both 'traditional' engineering students and technical managers struggle with time management issues: they are unable to plan and use their time adequately. Many make the mistake of underestimating the time required for a certain task. Many have the problem of procrastination, sometimes they suffer from a lack of motivation to carry out a task or assignment. Most often they experience the negative consequences of this: they run out of time during the day, which they try and adjust in the evening, and this in the end has a harmful effect on the amount and quality of sleep. Another problem is that many do not have the communication skills employers require. Most European companies are looking for innovative graduates with ideas and initiatives, who are proactive and driven by the wish to bring about a change.

c) Engineering students submit considerably fewer job applications than their fellow students of technical management. Characteristically, they work for longer periods of employment at a workplace and do not want to change jobs if not necessary. In contrast, technical managers like variety and wish to try themselves with different employers of various kinds. They often look for a new job if they are dissatisfied with something. In some cases, they change jobs every few months.

3 - FINLAND

In Finland, graduating students are expected already to have a significant amount of work experience and hence have acquired work-based competences. However, those graduates that do not obtain employment in the narrow area of their work experience, may need special

continuing education to reach the required level of competences. Additionally, the employability depends partly on the values of the company and of the graduate. Studies have shown that in their expectations the young graduates seem to lay greater emphasis on the content of the work than on the prestige or financial reward.

Engineering education in Finland is divided between two main types of tertiary level institutions: universities and universities of applied sciences. Both types of university are regularly evaluated and accredited by the national body (FINEEC) [5]. Additionally, the degree programmes need to be accepted by the Ministry of Education.

In the universities the aim is to study a five-year master's programme directly that enables graduates to either be employed as Master of Science MSc (Tech) or continue their studies in doctorate programmes. These MSc (Tech) studies provide the graduates with a good background for many different jobs as the fundaments are wide and deep for building job-needed competences. In the universities of applied sciences the students of engineering are selected to four-year Bachelor of Engineering B (Eng) programmes. These programmes have a more applied orientation and thus give a high readiness for immediate productive employment. If a graduate of B (Eng) wants to continue to a master level there are two possibilities: to apply to the university for a two-year MSc programme or get three-year practical experience and then apply for one-year M(Eng) programme in the university of applied sciences.

The role of professional institutions in Finland is primarily to support the individuals in their professional development, give advice in career planning and influence policymaking at a national level rather than accredit individuals. It is not compulsory to belong to the professional body and they are not keeping record of the "accepted engineers". However, the professional bodies are part of the European organisation FEANI from where one can apply a recognition of EUR ING title. Instead of accreditation and recognition, Finnish professional bodies are concentrating today on the dual challenges of the rapidly changing needs of industry and the current high unemployment figures - how to make the workforce and industry meet locally and with appropriate competences? The mission statement of Academic Engineers and Architects in Finland TEK is to support TEK members in their careers, to promote professional community spirit and competence and to build a sustainable welfare society [6].

Structured carrier coaching services including advice in areas of continuing education are offered by the professional bodies. Professional bodies are not organising the continuing education activities themselves, but directing members to appropriate providers. Today's continuing education needs for engineers seem to focus on the "non-engineering" skills such as project management, quality management, communication, finances etc. One might think that one reason could be that the technical knowhow and advancement is being developed on the job as the foundation is strong enough. On the other hand, the degree programmes are not giving that wide understanding of the non-technical skills.

4 – THE NETHERLANDS

In The Netherlands, due to robotics, digitalization and globalization, there is a lot of attention to the creation of a culture of lifelong learning and the acquisition of up-to-date skills. Although skills levels in the Netherlands are high, 'investing in the right skills will create opportunities to capitalise on the possibilities of new technology and actively shape the contribution to the

global value chain' [7]. The OECD has identified three priorities for the Netherlands: a) fostering more equitable skills outcomes, b) creating skills intensive workplaces, c) promoting a learning culture. In 2018, many national initiatives such as the Top Sectors, Team ICT, Smart Industry and Building Agenda work together to put (part of) these recommendations into practice via the roadmap "Human Capital Top Sectors 2016 - 2020".

Work changes rapidly. The research group Smart Industry of Saxion University, and Windesheim University interviewed 31 technological companies and revealed several developments [8]. Work will be more complex and less predictable among others because of automation and robotization of the processes within the company and in the rest of the supply chain, the increased possibility and necessity for tailor-made products and the emergence of new business models. In a study of the research group Sustainable Talent Development of The Hague University and HRM of Inholland University it was also observed that work changes and the classic professional image no longer exists [9]. They revealed a large variety of job fulfilment, depending on the sector and the value proposition of the organisation or company. Due to this variety, it is hard to generalize the need for certain competences or '21st century skills'. Overall, companies should value the (proactive) adaptability and lifelong learning capability and motivation of their employees, to keep them employable in the future [10]. The employers in the smart industry study mention expert knowledge, (the increasing importance of knowledge in the field of sensor technology, mechatronics, robotics and nanotechnology), the need for knowledge of other disciplines, knowledge about 'data integrity and security', 'continuous and integral process optimization over the entire supply chain'. Furthermore, the increasing importance of business insight and project management (principles of lean, scrum, six sigma) for engineers was stressed and analytical skills in order to interpret complex data and converting data into action. As in many other studies they also emphasized the ability to communicate and working together with colleagues of other disciplines, suppliers and customers, as well as flexibility (in working hours and attitude) [8].

Only half of the technology and engineering students, however, decide on a career in the technology sector. According to the 'Mind the gap' research project a particular group of students is opting for these careers [11]. Students with professional identity profiles 'that entail more stereotypical characteristics such as nerds or loners are much more likely to aim for a career in the technical sector than students with profiles with less stereotypical traits, such as security seekers and hipsters'. The 'nerdy engineer', having strong analytical and research skills while scoring very low on socially oriented interests, may find it difficult to connect to (some of) the 21st century skills described above. Moreover, it is of course unfortunate that students with a different identity profile do not choose for a technical career, although they might be qualified for the current tech market. A better and more challenging collaboration between university and companies should make a difference for the talent development of all groups of students, and their career choice.

5 – UNITED KINGDOM

In the UK, an appropriate masters level degree from a university department, recognised by the professional institute, is a necessary requirement to functioning as a full professional engineer, i.e. to be chartered. Then, following the university studies, the graduate must initially follow a specific route, e.g. by taking employment with a company offering a graduate scheme. Over an initial period of 3 – 5 years this involves a combination of on-the-job training, further

continuing education studies, maintaining a reflective log and being interviewed by a panel to assess competence. The chartered engineer status is awarded by the Engineering Council, devolved to the respective engineering institute.

Although unfortunately in the English language the word engineer gets used too liberally, such as to include anybody undertaking work of a technical nature or of holding a job in technical area, we are concerned here specifically with professional engineers. These are recognised as being 'Chartered Engineers' which confer on the individual certain privileges and responsibilities, such as the ability to approve appropriate design drawings or calculations. (This is more important in some positions than others, for example approving the designs of a steel structure required for a new building or the underpinning necessary to support the structure of a subsiding building or the implementation plan for an electrical installation.) Chartered Engineers are recognised by the Engineering Council, which then delegates the responsibility for each category of engineers to its appropriate institution, e.g. civil engineers to the Institute of Civil Engineers, mechanical engineers in the Institute of Mechanical Engineers etc. These institutions have diverse missions, including admission into the profession, granting of chartered status, developing and assessing professional competences, monitoring professional conduct, arranging professional meetings and networking events, publishing academic papers establishing technical standards, e.g. building regulations, wiring regulations, etc. Professional institutions play an important role in admitting to, educating, regulating and upholding their professionals.

The first step in the process of becoming an engineer is for a student to obtain a recognised Masters level degree from a university. However, this is not quite as arbitrary as it might read and the significant word here is recognised. Any university that grants degrees is subject to regular academic assessments, which are undertaken by panels of experts. This panel is usually composed of appropriate external subject experts from other peer universities and also members completely outside of the academic orbit, for example, a historian not associated with a university for a degree in history, etc. The focus of such an assessment is to validate the quality of the syllabus being taught, of the type and level of the examination, weighting given to coursework, diversity of assessment methods etc.

While what has been described in the foregoing paragraph applies to any degree, that is insufficient for an engineering degree, as it might be for other professionally related jobs, for example medicine, veterinary science etc. If a degree programme is to be recognised for the initial training required to become an engineer, that degree programme has also to be approved by the relevant engineering professional body, with a review being undertaken on a rolling regular basis by a panel – say every five years. This panel will also include several individuals who are or were practicing engineers in their discipline. This panel will be looking at a wider perspective than just the academic one. It will address issues such as the development of professional skills, for example communication training, exposure to management training, ethical issues etc. In addition, undertaking appropriate industrial placements during the longer summer vacation is essential element of the programme. An engineering degree programme may not necessarily be accredited by the professional institution, thus both academic approval and professional recognition are required. However, this should be seen as an essential first step, but of itself is not sufficient to become a chartered engineer.

Following these university studies, the graduate must follow a specific route, e.g. by taking employment with a company offering a graduate scheme, and as with the degree, this again

must be approved by professional institution. Over an initial period of 3 – 5 years such a scheme requires a combination of on-the-job supervised work and training, further specified amounts of continuing education/professional development studies, and for the graduate to maintaining a reflective log of their experiences and the lessons learnt. Finally, at the end of this period the totality of the candidate's performance is assessed by a panel, with this assessment also including a face-to-face interview. The successful conclusion of this process is the award of a chartered engineer status by the Engineering Council, devolved to the respective engineering institute. From then onward the individual can be considered as a professional engineer.

Of key interest here are the continuing education/professional development studies. These are not nationally proscribed and can vary between engineering institutions, both in their nature and extent. They will usually involve a mixture of courses, for example involving management, or professional skills, in addition to further technical specializations. The specific choice will probably reside with the individual and his/her supervisor. In larger companies the courses may be given entirely within the company, but in smaller companies these might need to be contracted externally to a commercial concern or an academic institution. There is no specific need to involve an academic institution, so an academic institution has to evaluate if such activities should form part of its mission, if so what, whether or not they should be integrated in anyway with the other teaching activities, and indeed whether they make economic sense to undertake. Inevitably there is a broad spectrum of university responses to this and no single definitive statement can be made.

6 – PORTUGAL

In Portugal, the professional engineering association in cooperation with some academics has developed a system where the competences acquired with CEE (formal, non-formal and informal) are registered. The system allows the transparency in terms of employability, curriculum definition of undergraduate studies and personal development of engineers. A brief description of the templates and of its contents may help the analysis of the possible benefits to engineering graduates trying to be employed.

Concerning higher education the legislation allows academic institutions since the decade of 1980 to validate competences and concede equivalence to part of the academic program. The process consists in registration, an interview to analyse curriculum and candidate motivation, a test of knowledge in specific areas and access to the academic program with eventual approval of parts of the program. The process is led by a jury from each institution. The candidates for this informal and non-formal recognition of competencies have to be over twenty-three years of age. The candidates cannot have a previous degree form a higher education institution.

Considering professional engineering organizations members need to have an academic degree in engineering from a higher education institution. In Ordem dos Engenheiros [12] it is possible to be an honorary member without an academic degree in engineering as a consequence of a decision of the organization board. There are no mechanisms to validate Non-formal and Informal Learning towards a professional qualification.

Concerning continuing professional development there is a system to record the achievements of each engineer in terms of acquisition of competencies. That exists in Ordem dos

Engenheiros Região Norte and is the system VALORIe [13]. The VALORIe recording system is an online system available for members. The system can be used for validation, by an external body like an employer or an accreditation agency, of the achievements of each engineer. It has a list of activities of engineers and graduates that may contribute to the development and valuation of competences of engineers.

These records are a) accredited courses, b) participation in congress, conferences and conventions, c) participation in workshops and seminars, d) development of regulations, codes and norms, e) registration of brands and patents, f) communications in congresses, conferences, conventions and seminars, g) publications (opinion article, technical paper, reviewed technical paper, report of technical work, technical book), i) engineering research, j) design, revision of a project, k) manufacturing, construction, production, l) evaluation, inspection, quality control, safety, m) auditing and n) coordination and management.

This approach to promote the professional recognition of graduates was included in the Erasmus project funded by the European Commission and coordinated by VDI – Association of German Engineers. The project produced a report with the proposal of a system to record, to analyse and to validate the competences of engineers and students of engineering. The report is available at FEANI – Federation of Engineers National Professional Associations [14].

CONCLUSIONS

From the analysis of the six case studies the paper has addressed examples and conclusions relative to each one. From these six case studies one can choose a series of measures trying to contribute to the solution of the problem that motivated the current paper. The six examples provided qualitative and quantitative data about the situation with graduates and with companies, about some existing procedures to alleviate the consequences of the mismatch between academic programs and professional requirements.

Some new proposals envisaging the impact reduction, for companies and for engineers of the identified gaps were presented and discussed. Some of these guidelines may help the definition of the shape, the content and the workflow of innovative continuing engineering education models that can be used by professional organizations, companies, universities, government agencies and lifelong centres to address the identified needs of recent engineering graduates and of their employers. A short conclusion section is to be presented and should itemize specific outcomes of the research.

REFERENCES

[1] – CDIO, www.cdio.org – accessed 28Feb18.

[2] – Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. European Journal of Engineering Education, 39 (5), 539-555. doi:10.1080/03043797.2014.895703.

[3] – Kolmos, A.; & Byllov, S. (2016), Ingeniørstuderendes forventning og parathed til det kommende arbejdsliv, www.ucpbl.net/digitalAssets/154/154582_proceed2work_arbejdsraport1.pdf, accessed 28Feb18.

[4] – Kálmán, A. (2017), Hungarian engineering students' perceptions about their employability shortly before graduation, Proceedings of the 45th SEFI Annual Conference, Angra do Heroísmo, Portugal, pp. 568-575.

[5] – Finnish Education Evaluation Centre, https://karvi.fi/en/higher-education/, accessed 28Feb18.

[6] – TEK Strategy, https://www.tek.fi/en/strategy, accessed 28Feb18.

[7] – OECD Skills Strategy Diagnostic Report: The Netherlands, OECD skills studies, http://www.oecd-ilibrary.org/education/oecd-skills-studies_23078731, accessed 28Feb18.

[8] – Corporaal, S. & Alons, M. & Vos, M. (2016), Werken in de nieuwe industriële realiteit. Een verkennend onderzoek naar de verwachtingen van werkgevers over jonge technici. http://www.arbeidsconferentie.nl/uploads/submission/document_1/97/2015 - Corporaal et al werken in de nieuwe industriele realiteit MvR.pdf accessed 28Feb18.

[9] – Biemans, P., Sjoer, E., Brouwer, R. & Potting, K. (2017), Werk verandert, 21st century skills in de praktijk, https://www.dehaagsehogeschool.nl/onderzoek/lectoraten/ /duurzame-talentontwikkeling#publicaties-en-projecten, accessed 28Feb18.

[10] – Walma van der Molen, J. & P.A. Kirschner (2017) Met de juiste vaardigheden de arbeidsmarkt op. NSvP: Innovatief in Werk. https://www.innovatiefinwerk.nl/innovatie-inzetbaarheid-employability/2017/07/whitepaper-met-juiste-vaardigheden-de-arbeidsmarkt-op, accessed 28Feb18.

[11] – Endedijk, M.D., Van Veelen, R. & Möwes, R. (2017), Not always a nerd: exploring the diversity in professional identity profiles of STEM students in relation to their career choices, Proceedings of the 45th SEFI Annual Conference, Angra do Heroísmo, Portugal.

[13] – Ordem dos Engenheiros Regiao Norte, http://valore.oern.pt, accessed 28Feb18.

[14] – Kiefer, T., Videncova, Z., Golith, K., Krstelj, V., Bochar, D. and Soeiro, A., A system for the documentation and validation of non-formal and informal learning of engineers (NFIF),https://www.feani.org/sites/default/files/IO5%20Final%20Concept%20for%20the%20Documentation%20and%20Validation%20of%20nfif-learning%20of%20engineers.pdf, accessed 28Feb18.