The transition from engineering education to work

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INTRODUCTION

International research on engineering education has identified a major problem in the transition from higher education to work. The latest McKinsey report indicates that these so-called skills gaps are far from being bridged [1]. Also Royal Academy reports identify the same problem in so far as engineering graduates are not able to go straight into a job and work, but that companies and organisations have to invest in this transition process [2, 3]. In Denmark, similar discussions have been raised by both professional associations and corporate organisations [4].

Internationally, employability is an issue that has garnered increased attention. Very few studies have systematically followed students' transformation from student life to professional life [5, 6]. In Sweden, however, several studies on transition have been

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conducted which show that generic skills play an important role in the transition from study to work, even though technical professional skills dominate. Although students learn generic skills during their time of study, there is still a process of adjustment to working life [7, 8]. One study shows that both the transition to working life, and especially generic skills, are highly dependent upon an individual's readiness to change and that this is a new set of skills which is not normally addressed in education [6]. Research also shows that the integration of activities in education, i.e. targeted employability, is irrelevant to getting a job, but that it has an impact on the performance of the job [9]. The complexities of the relationship between work and education are great and there is a need for further studies [10, 11]. This article will present results from a longitudinal study which has been addressing this need.

The research project PROCEED (Programme of Research on Opportunities and Challenges in Engineering Education in Denmark) (2009–2013) was established for the purpose of identifying challenges and analysing potential development of Danish engineering education. PROCEED was financed by the Danish Research Council and is the first Danish Research Council project on engineering education. The focus has been on the history of engineering education, curriculum design and learning outcomes, modelling and simulation, design and engineering practices, and contextual knowledge. One of the subprojects conducted a longitudinal study on the progression in student learning outcomes in a number of areas, including the importance of orientation towards work and the engineer's role in relation to societal challenges such as sustainability. The methodology employed in this subproject was primarily a survey of all Danish engineering students enrolled in 2010, and data was collected in 2010 and 2011.

In 2015 a follow-up project, called PROCEED-2-Work, was established [12]. Its scope was to identify the possible gaps in the transition from engineering education to work life. In particular, we wanted to focus on Danish engineering students' expectations of an upcoming work situation and follow them into the labour market in order to uncover their experience of the transition from education to business. In analysing the transition from education to work in PROCEED-2-Work, two survey studies have been conducted: 1) a 2015 survey on expectations and preparedness, and 2) a 2016 survey on experiences from the early job start.

RESEACH QUESTION AND METHOD

In this paper we study the transition from higher education to work by focusing on the following research question:

What expectations do engineering students in the last stage of study have regarding future work life and how prepared do they consider themselves to be in order to enter the professional engineering practice?

This research question will be addressed based on the PROCEED-2-Work 2015 survey.

In May 2015, questionnaires were sent to 3969 engineering students in their 10th semester of study. 1141 engineering students responded, giving a response rate of 29%. The focus of the survey was: 1) identification of expectations for working life and students' perceived readiness as it relates to both technical-professional and generic competences, 2) expectations for the future profession, 3) identification of elements in the educational programme which have contributed to working life readiness, and 4) the notion of innovation, entrepreneurship and opportunities for change.

The analyses in this article will be based on frequencies and factor analysis of the students' experienced expectations and readiness. An inductive factor analysis strategy with Varimax rotation has been used, combined with a theoretical validation of the factors.

FINDINGS

In the following the findings related to students' expectations of future work life and their preparedness to face the competencies needed in professional engineering practices will be presented and discussed respectively.

Expectation of future work life

In order to study the expectations students have concerning future work life, students were asked to rate the importance of different types of job characteristics to ascertain which priorities students would have when applying for a future job. The results are presented below in figure 1.

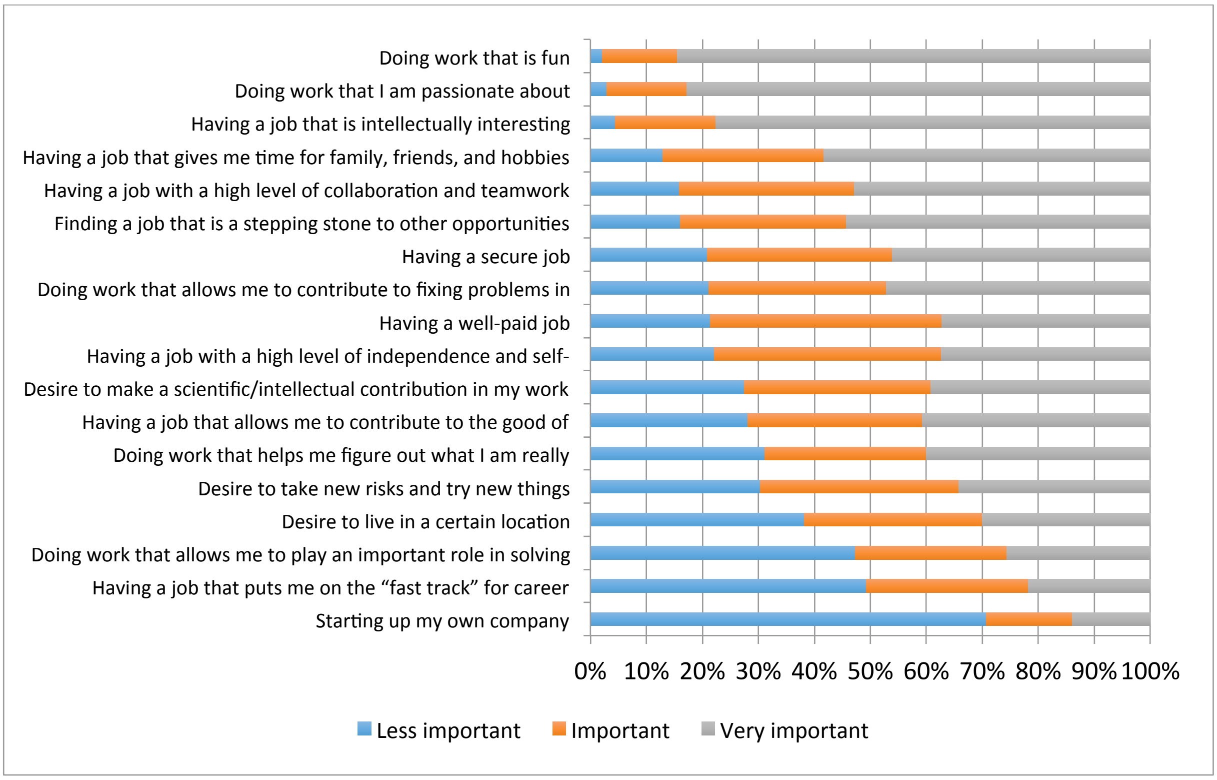

Fig. 1. The importance students assign to job characteristics entering working life, N = 1046–1074. Less important includes the answer "not important" and very important include the answer "extremely important", N = 1029–1047.

The results in figure 1 show that personal engagement—doing something that is fun, one feels passionate about or is intellectual stimulating—is in the top three with respect to importance for a future job. These characteristics are thereby more important than having a well-paid job, secure employment, or the location of the future work place. On the other hand, the possibility of starting up a new company or career advancement are characterised as the least important of the specified job characteristics.

Five factors with a Kaiser-Meyer-Olkin measure of sampling adequacy at 0.78 were suggested. The following Cronbach alpha test of the five factors, however, showed that one of the factors had a Cronbach alpha below 0.6. The variables from this factor were integrated in a meaningful way from a theoretical perspective, and in the other four factors, four clusters of variables with a Cronbach alpha above 0.6 were introduced. The four constructed factors were:

- Social and academic engagement ($\alpha = 0.721$; N = 1039). Social engagement includes considerations for the broader social context (contributing to fixing problems in the world, for the good of society and solving social problems) and engagement in social relations (a high level of collaboration and teamwork). Academic engagement includes a desire to contribute to the scientific/intellectual field.
- Career ($\alpha = 0.699$; N = 1029). The career factor includes economic advancement (having a well-paid job), career planning (seeing the job as a stepping stone, a try-out or a fast track to other opportunities) and entrepreneurship (taking new risks and trying new things, or starting up a company).
- Family and leisure ($\alpha = 0.640$; N = 1047). This factor includes work-life balance (including time for family, friends, and hobbies), location of the job and job security.
- Personal commitment ($\alpha = 0.606$; N = 1044) including a sense of freedom (independence/self-direction), enjoyment (work is fun and aligned with passion) and intellectual stimulation.

The average of importance is illustrated in figure 2. As can be seen from the factor analysis, sources of intrinsic motivation are highly valued by future engineers.

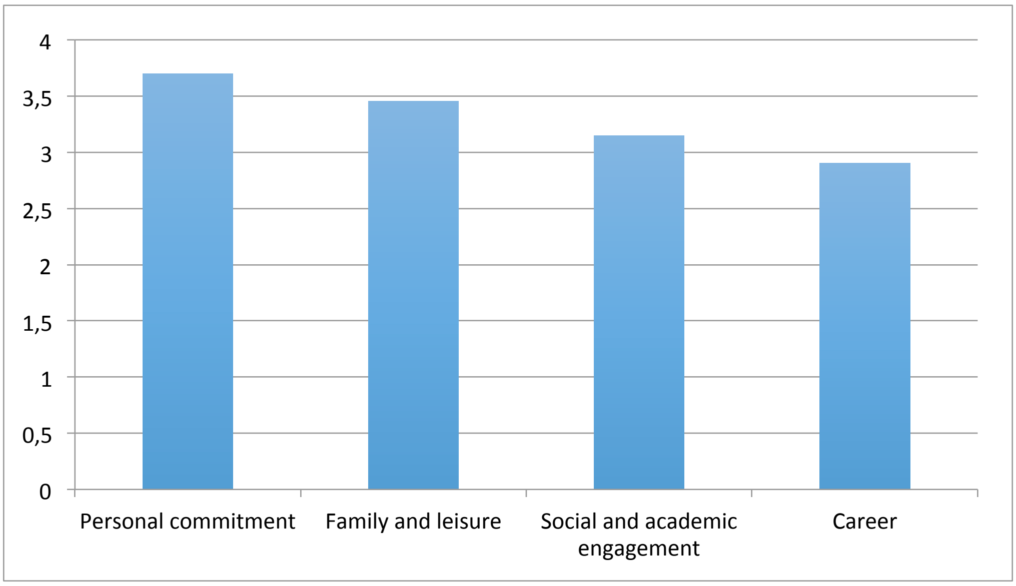

Fig. 2. Factors of importance. The average is represented on an ordinal scale from 1–5 where 1 is not important, 2 is less important, 3 is important, 4 is very important and 5 is extremely important.

The results are in alignment with those of the Academic Pathways Studies of People Learning Engineering Survey (APPLES) prepared by the Centre for the Advancement of Engineering Education. This survey was distributed to more than 4200 students at 21 universities in the USA. The findings showed that the psychological motivational factor (studying engineering for its own sake in order to experience enjoyment inherent in the activity) was the second highest motivator, right after the behavioural motivation factor related to the practical and hands-on aspects of engineering [13]. On a scale of 0–100 where 100 indicates a major motivator, and 66 indicates a moderate motivator, the psychological motivational factor scored 80, whereas the financial motivational factor was only at a moderate level [13:34].

In terms of formal education, the challenge is then to align the sources of extrinsic motivation with internal intrinsic motivation covering interest, enjoyment and inherent satisfaction [14]. As emphasised by Ryan and Deci, based on a review of studies that specified the social conditions that support intrinsic motivation and facilitate internalisation and integration of extrinsically motivated tasks [14]:

"*we saw that social contextual conditions that support one's feelings of competence, autonomy, and relatedness are the basis for one maintaining intrinsic motivation and becoming more self-determined with respect to extrinsic motivation*".

A possible means of creating autonomy could be pedagogical models focused on self-directed learning, in which relatedness and a sense of belonging to a given person or group is aligned with team work and collaboration with research staff as well external partners from industry. Last but not least, the feeling of competence can be related to peer and staff feedback and the selected curriculum content.

Preparedness for future work life

In the study of students' preparedness to enter into future work life we asked students how prepared they perceived themselves to be when confronted with a list of knowledge, skills and competence items (see figure 3). The items that the students were to rate in terms of preparedness are adopted from the Academic Pathways Studies of People Learning Engineering Survey (APPLES) [13].

More than four out of five feel very well prepared to face the challenges of teamwork and problem solving when about to enter work life, and more than half of students feel very well prepared to handle engineering tools, professionalism, data analysis, engineering analysis, science, math, to conduct experiments and to handle the more generic aspects of creativity and communication. On the other hand, more than one out of 4 students feel not at all prepared to address environmental impacts, ethics, the global and societal contexts, contemporary issues, in addition to design, business knowledge and leadership.

It is notable that the preparedness of students to enter into design tasks is remarkably low—3 out of 10 students do not at all feel prepared, which contrasts with the Danish knowledge-based economy. In the US study, there is a higher rating of preparedness for design compared to the Danish study.

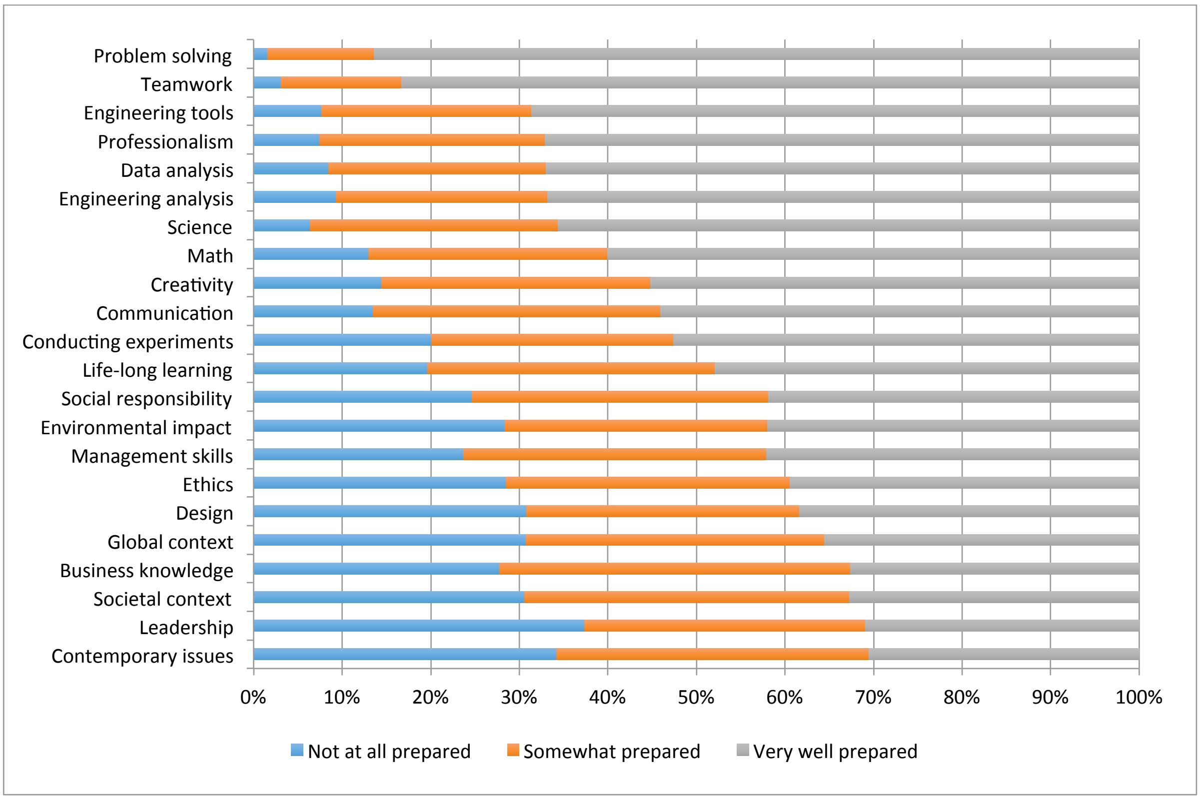

Fig. 3. The degree to which students feel prepared to apply the stated items in engineering work, N = 1000–1009.

According to the US criteria for accrediting engineering programmes, the programme must have documented a list of student learning outcomes including [15:3]:

"*an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*".

In the Danish context, the need for design thinking in engineering is not as explicitly stated.

In the following inductive factor analysis four factors were suggested with a Kaiser-Meyer-Olkin measure of sampling adequacy at 0.859. One of the factors proposed a cluster of variables, which was too hard to connect in a meaningful way from a theoretical perspective. The variables stemming from this factor were integrated more appropriately in the three other factors, with a subsequent Cronbach alpha test on each of the constructed factors having $\alpha > 0.6$. The following inductive factor analysis thereby resulted in the following three clusters of variables:

- Society and the environment ($\alpha = 0.851$; N = 986). This factor includes ethics, contemporary issues, global context, societal context, environmental impact, and social responsibility.
- Technical terms ($\alpha = 0.774$; N = 976). This factor includes conducting experiments, data analysis, engineering analysis, engineering tools, problem solving and science.

- Business and organisation (α = 0.752; N = 980) This factor includes business knowledge, communication, creativity, design, leadership, lifelong learning, management skills, professionalism and teamwork.

The factor analysis (see figure 4) supports the idea that the students feel prepared when we consider their technical knowledge, skills and competences, whereas they are less prepared to address the sustainability aspects of their future engineering practice. Even though we have just passed the UN decade of Education for Sustainable Development (ESD), the challenge of preparing engineering students to contribute to a more sustainable society seems still to remain.

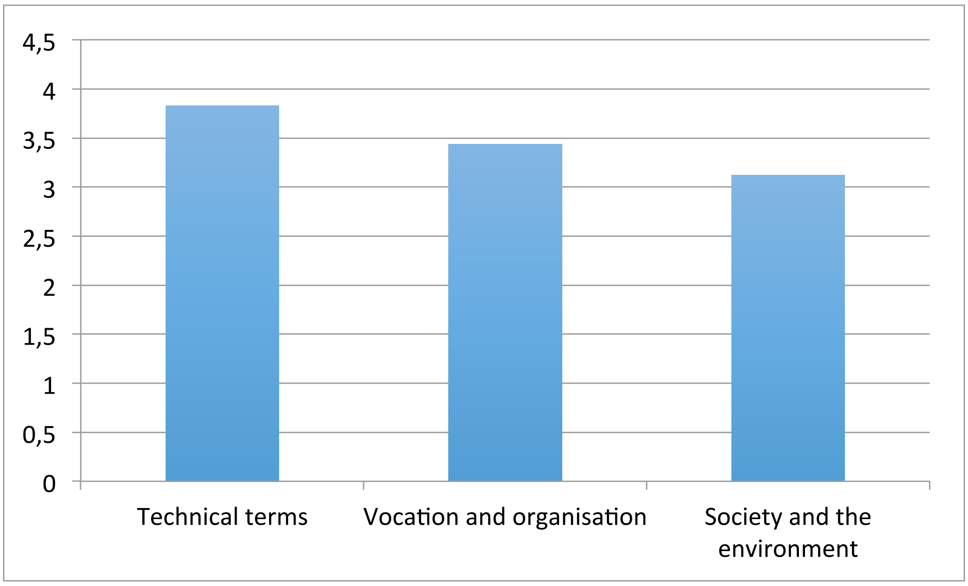

Fig. 4. Level of preparedness considering the three constructed factors. The average is represented on an ordinal scale from 1–5 where 1 is not at all prepared, 3 is somewhat prepared, and 5 is very well prepared.

CONCLUSIONS

The findings from the mean values show that engineering students educated at Danish engineering institutions prioritise a high level of personal commitment, and both expect and experience that they are ready to join team-based professional problem-solving processes. It is clearly a recurring result from the study. The students expect the work to be fun, engaging and intellectual, and that they are able to have a balance between family and work life. They find themselves most prepared in relation to problem solving, teamwork and technical expertise.

The students have lower expectation and consider themselves to be less prepared in relation to 1) business orientation and a career, and 2) social responsibility and the environment. On a general level, it provides an opportunity to discuss upcoming competency profiles for engineers and question whether the lower expectations and readiness with respect to these two aspects are satisfactory. The rating of preparedness of design competences is lower in the Danish study than in the comparable US study, thus stressing the need for an explicit focus on design thinking in engineering education. Both in Denmark and in the US, preparing students to face societal and global contexts seems to be a challenge.

Engineering education cannot encompass all aspects, and there will always be a division of qualifications between academia and contextually applied knowledge in business and society at large. However, the societal expectations for new graduates are that they are ready to function effectively after a relatively short transition period. And, if the global society is to cope with sustainability challenges from a technical perspective also, the question is whether our candidates are sufficiently prepared to make the sustainable sound innovations that society calls for.

REFERENCES

[1] Mourshed, M., D.D. Farell, and D. Barton, *Education to employment: Designing a system that works*. 2012.

[2] Spinks, N., N. Silburn, and D. Birchall. *Educating Engineers in the 21st Century: The Industry View*. 2006; Available from: http://www.raeng.org.uk/news/releases/henley/pdf/henley_report.pdf.

[3] Royal Academy of Engineering. *Educating Engineers for the 21st Century*. 2007; Available from: http://www.raeng.org.uk/news/publications/list/reports/Educating_Engineers_21st_Century.pdf.

[4] Kolmos, A. and J.E. Holgaard, *Responses to problem based and project organised learning from industry.* International Journal of Engineering Education, 2010. **26**(3): p. 573–583.

[5] Markes, I., *A review of literature on employability skill needs in engineering.* European Journal of Engineering Education, 2006. **31**(6): p. 637–650.

[6] Senior, C., R. Cubbidge, and S. Nilsson, *Enhancing individual employability: the perspective of engineering graduates.* Education + Training, 2010. **52**: p. 540–551.

[7] Dahlgren, M.A., et al., *From senior student to novice worker: learning trajectories in political science, psychology and mechanical engineering.* Studies in Higher Education, 2006. **31**(5): p. 569–586.

[8] Stiwne, E.E. and T. Jungert, *Engineering students' experiences of transition from study to work.* Journal of Education and Work, 2010. **23**(5): p. 417–437.

[9] Støren, L.A. and P.O. Aamodt, *The quality of higher education and employability of graduates.* Quality in Higher Education, 2010. **16**(3): p. 297–313.

[10] Akkerman, S.F. and A. Bakker, *Crossing boundaries between school and work during apprenticeships.* Vocations and Learning, 2011. **5**: p. 153–173.

[11] Konkola, R., et al., *Promoting learning and transfer between school and workplace.* Journal of Education and Work, 2007. **20**(3): p. 211–228.

[12] Kolmos, A. and S. Bylov, *Ingeniørstuderendes forventning og parathed til det kommende arbejdsliv. Arbejdsrapport no. 1.* 2016: Aalborg Universitet. p. 56.

[13] Atman, C.J., Sheppard, S.D. Turns, J., Adams, R.S., Fleming, L.N. Stevens, R., Streveler, R.A. Smith, K.A., Miller, R.L., Leifer, L.J., Yasuhara, K. and Lund, D., Enabling Engineering Students Success: The Final Report for the Centre for the Advancement of Engineering Education. CAEE-TR-10-02. Centre for the Advancement of Engineering Education. San Rafael, CA: Morgan & Claypool Publishers, 2010. Available from: http://www.engr.washington.edu/caee/final_report.html.

[14] Ryan, R.M. and E.L. Deci, Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 2000. **25:** p. 54–57.

[15] Engineering Accreditation Commission, Criteria for accrediting engineering programmes—Effective for Reviews during the 2015–2016 Accreditiation Cycle, ABET, USA, 2014.