

Newly graduate engineers' development of expertise and personal competencies

The case of Tampere University

This paper investigates importance and development of expertise and personal competencies of newly graduated engineers according to academic staff members, industrial employers and the graduated engineers themselves. The aim was to discover how graduated engineers perceive the importance of competencies at the time of graduation, and how various competencies have developed during their studies. For such purposes, a national-wide graduate survey was adopted as a basis for research.

The results show that engineering degree programmes highlight theoretical foundation rather than generic competencies, whereas industrial employers favor personal competencies and attitudinal factors. Furthermore, according to graduates' ratings, some competencies have developed more than appears to be necessary at the beginning of their career. These competencies were the most valued in degree programmes. Similarly, some competencies that were least valued in degree programmes were part of the least developed competencies in studies, but also part of the most important competencies for graduates.

Keywords: *Competency-based education, Curriculum development, Engineering education, Personal competences, Professional development, University-business cooperation*

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1. Introduction

Over the last decade, universities have shown growing interest in developing competence-based approaches and including generic competencies into their curricula (de Justo and Delgado 2015; Fallows and Steven 2000; Chan et al. 2017). For newly graduates' employment, possessing disciplinary knowledge taught on students' study field is not enough. Instead, employers are putting increasingly more emphasis on graduates' generic competencies such as communication skills and teamwork skills (Freitas et al. 2018; Nguyen 2008). Overall, social skills such as persuasion, emotional intelligence and strong social and collaboration skills will be in higher demand across industries than narrow technical skills (The World Economic Forum 2016).

However, even though the importance of generic competencies has been largely recognized, there are differences in how universities have adopted them into their curricula and how professors and faculty value those (Freitas et al. 2018; Nguyen 2008). It has been recognized that graduates often feel that they have not gained enough generic skills during their university education (Andrews and Higson 2008).

In engineering disciplines, it has been discussed how situativity should be seen as a dominant perspective by emphasizing the role of the environments that require extensive content knowledge and analytical skills to engage in learning (Johri and Olds 2011; Pleasants and Olson 2019). There has also been an increased concern about the need to develop a better understanding of how people learn engineering (Johri, Olds and O'Connor 2013) and how they build engineering identity. In addition, the interests towards active learning and activating instructional procedures have increased when studies have reported its' connections with greater achievements in student learning and, especially lately, in generic working life skill or competence development (Hartikainen et al. 2019).

2. Research Questions and Methods

The main contributions of this paper were to investigate how expertise and personal competencies of newly graduated engineers have developed during university studies relative to their perceived importance in the working life of Finnish engineering field, and how competencies were valued in the degree programmes of FES (Faculty of Engineering Sciences) of former TUT (Tampere University of Technology). FES consisted of the following degree programmes: Automation science and hydraulics, Mechanical engineering and Materials science. The study also investigated how important expertise and personal competencies are for industrial employers in Tampere area. To answer these research questions, a national-wide graduate survey of TEK (Tekniikan akateemiset, Academic engineers and architects in Finland) (Piri 2016)

that measures the importance and development of 26 expertise and personal competencies on the scale 1–7 was adopted as a basis for research.

First, newly graduated engineers evaluated the importance of each competence using integers on the scale between 1 [“Not at all (important)”] and 6 (“Very much”) with an option 7 (“Cannot answer”). Using the same scale, the newly graduate engineers also rated how each competence has been developed in studies and in work, respectively. These formed two development profiles; namely, “Development in studies” and “Development in work”. Then, the development profiles of each competence were compared to the perceived importance.

In 2017, a teaching development event was arranged among the staff members of FES. In total, 69 staff members consisting of teaching staff, researchers, Ph.D. students and professors who were all involved in teaching practices participated to the event. The purpose of the event was to find out how various competencies are valued in faculty’s engineering degree programmes. For such a purpose, FINEEC (The Finnish Education Evaluation Centre) reference programme learning outcomes were adopted. FINEEC framework describes the knowledge, skills and competencies that learning processes should enable engineering graduates to demonstrate *after graduation*. It was used to ensure that educators see how their degree programmes are benchmarked against an accreditation standard in Finland, and which competencies are valued in the degree programmes of FES. This was the first instance when competencies were closely examined throughout the faculty, which made the competency profile of the faculty more transparent. With the newly formed competency profile, it was possible to make judgements on the observed competency development of newly graduate engineers.

The FINEEC reference programme learning outcomes are based on EUR-ACE (European Accredited Engineer) framework standards of the ENAEE (European Network for Accreditation of Engineering Education). The reference programme learning outcomes are divided into the following five categories: 1) Investigations and information retrieval, 2) Engineering practice, 3) Multi-disciplinary competencies, 4) Knowledge and understanding, and 5) Communication and team working, which have their own set of competencies.

Nonetheless, staff members were first divided into six programme-specific groups to ensure that each group shared mutual understanding of each rated competence. Then all groups rated the importance of all competencies in their curriculum using options: 3 (“must have”), 2 (“should have”) and 1 (“nice to have”). The interpretation of the above labeling is: “must have” means that a competence is widely included into a degree programme and it must remain there in the future as well. In addition, “must have” competencies are emphasized in most of the individual courses within a degree programme. The label “should have” means that a competence is included into a degree programme and it should be there in the future as well. These “should have” competencies are found in several courses within a programme. The label

“nice to have” means that a competency is not meaningfully represented in a degree programme, but it could be a “nice” insertion there, although not in priority compared to the other types of competencies. Finally, the results of each programme-specific group were summed together so that the maximum score a competency could achieve was 18 points, whereas the minimum score was 6 points.

Furthermore, in 2018, 24 industrial employers ranging from small and medium size enterprises to large enterprises participated in interviews as part of ESF-funded Tyyli-project (Tyyli-bridging the gap between university studies and working life) that aimed to investigate, which competencies are important in their workplace and which competencies they expect newly graduates to master when they recruit them. There were 1–3 persons interviewed per each enterprise and each interviewee rated the importance of each competence within the set of 26 competencies.

3. Results

In this section, the results from the TEK graduate survey, FES staff members' ratings and industrial employers' ratings are presented along with some analysis and interpretation.

3.1. Results from TEK graduate survey

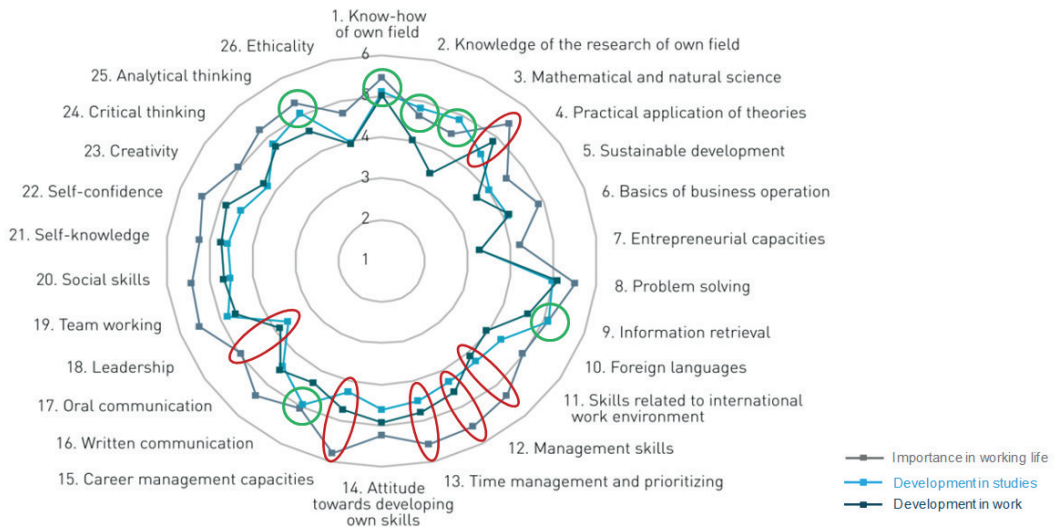


Figure 1. Newly graduates' ratings: Importance in working life, Development in studies and Development in work profiles of expertise and personal competencies, (Piri 2016)

The gathered importance and development values of each competence were averaged and then displayed in a single figure in-line with the others, which is depicted in Fig. 1. Then the development profiles of each competence were compared to the perceived importance, which revealed both similarities and discrepancies between the importance and development profiles. In case of differences, the amount of mismatch and its orientation were also captured. This study focuses especially on comparing the “Development in studies” profile of newly graduate engineers of FES to the educational competency profile of the FES itself.

In total, 12 competencies have been more developed in studies than in work. In fact, most of these competencies are expertise competencies, which are related to traditional engineering study activities. In turn, 14 competencies have been more developed in work than in studies. Many of these competencies are personal competencies, which are outside the scope of traditional university study activities. All competencies have been categorized in Table 1 according to their main source of development.

More developed in studies		More developed in work	
No.	Name	No.	Name
1	Know-how of own field	4	Practical application of theories
2	Knowledge of the research of own field	6	Basics of business operation
3	Mathematical and natural science	7	Entrepreneurial capacities
5	Sustainable development	8	Problem solving
9	Information retrieval	12	Management skills
10	Foreign languages	13	Time management and prioritizing
11	Skills related to internat. work environ.	14	Attitude towards developing own skills
16	Written communication	15	Career management capacities
19	Team working	17	Oral communication

24	Critical thinking	18	Leadership
25	Analytical thinking	20	Social skills
26	Ethicality	21	Self-knowledge
		22	Self-confidence
		23	Creativity

Table 1. Newly graduate engineers' development of competencies according to their source

Furthermore, the six most and least important competencies in working life of newly graduated engineers are collected into Table 2, respectively.

Most important competencies		Least important competencies	
No.	Name	No.	Name
15	Career management capacities	7	Entrepreneurial capacities
1	Know-how of own field	5	Sustainable development
19	Team working	3	Mathematical and natural science
13	Time management and prioritizing	2	Knowledge of the research of own field
8	Problem solving	26	Ethicality
4	Practical application of theories	6	Basics of business operations

Table 2. Most and least important expertise and personal competencies for newly graduate engineers

In particular, competencies that have developed most, *in studies*, relative to their perceived importance in working life have been marked using green

circles in Fig. 1, whereas competencies that have developed least, *in studies*, relative to their perceived importance have been marked using red ellipses. These competencies have been collected into Table 3.

Most developed competencies		Least developed competencies	
No.	Name	No.	Name
3	Mathematical and natural science	15	Career management capacities
2	Knowledge of the research of own field	18	Leadership
9	Information retrieval	11	Skills related to internat. work environ.
16	Written communication	12	Management skills
25	Analytical thinking	13	Time management and prioritizing
1	Know-how of own field	4	Practical application of theories

Table 3. Most and least developed expertise and personal competencies, in studies, relative to the perceived importance

According to Fig. 1, the developments of competencies 2, 3 and 9 in studies have been rated higher than their importance in working life. No other competence has been rated such that its development in studies or in work shows larger value than its perceived importance. Moreover, competencies 2 and 3 are simultaneously part of the most developed and least important competencies for newly graduates, while the developments of 2 and 3 in work display very low values. These observations indicate that scientific fundamentals and theoretical foundations are mostly learned during university studies. A much more difficult issue is to argue, whether competencies 2 and 3 are nowadays too much emphasized in higher engineering education. After all, theoretical cornerstones and scientific research form the basis of academic thinking, which is one of the main function of universities, and universities must educate researchers as well.

Note that theoretical-oriented competencies like 2 and 3 are one of the most developed, but Practical application of theories (4) is one of the least developed, which was an unexpected result. One possible explanation for such observation might be that engineering education in parts of former FES, including

teaching and learning activities, assessment as well as intended learning outcomes, was intentionally practiced such that knowledge and understanding of science and theoretical matters were much more favored compared with engineering practice and practical application of theories. In addition to 4, competencies 13 and 15 belong simultaneously to the set of most important and least developed competencies according to graduates' ratings.

However, it should be noted that the results in Fig. 1 represents viewpoints of newly graduate engineers only. At the time of answering the survey, competencies that may seem unimportant to them, or with respect to their current job description, may well become important in future, say, five years later. These could e.g. be sustainable development, entrepreneurial capacities, and ethicality, which belong to the set of least important competencies according to newly graduates' ratings. Ethics, sustainable development and entrepreneurial capacities have just recently been included in planning of higher engineering education of Tampere University, and hence, they may seem unimportant to newly graduates only because they have been explicitly missing from the degree programmes.

3.2. Results from staff members ratings

Competencies that received most and least amount of points during the teaching development event are collected in Table 4, respectively. The results provide an insightful view for the educational competency profile of the whole FES. Furthermore, there were additional competencies included in FINEEC reference program learning outcomes and one of them received notable amount of points: Ability for life-long learning (17p).

Most valued competencies		Least valued competencies	
No.	Name (points)	No.	Name (points)
9	Information retrieval (18p)	12	Management skills (10p)
1	Know-how of own field (18p)	18	Leadership (11p)
16	Written communication (18p)	23	Creativity (11p)
17	Oral communication (17p)	5	Sustainable development (12p)

8	Problem solving (17p)	26	Ethicality (12p)
3	Mathematical and natural sciences (17p)	4	Practical application of theories (12p)

Table 4. Most and least valued expertise and personal competencies for staff members of FES

It is interesting to observe that four out of the six most valued competencies (1, 3, 9 and 16) according to staff members' ratings are the same competencies that graduates have evaluated as the most developed in studies. Similarly, three out of the six least valued competencies (4, 12 and 18) according to staff members' ratings are the same competencies that graduates have evaluated as the least developed in studies. These observations partly validate the learning outcomes of the degree programmes of FES, because some of the most valued competencies have been most developed in studies and vice versa.

3.3. Results from industrial employers' ratings

The most and least important competencies according to industrial employers in Tampere area have been collected into Table 5.

Most important competencies		Least important competencies	
No.	Name	No.	Name
14	Attitude towards developing own skills	7	Entrepreneurial capacities
8	Problem solving	18	Leadership
19	Team working	2	Knowledge of the research of own field
1	Know-how of own field	5	Sustainable development
16	Written communication	15	Career management capacities
13	Time management and prioritizing	6	Basics of business operations

Table 5. Most and least important expertise and personal competencies for industrial employers in Tampere area

Note that competencies 1, 8, 13 and 19 exist in the set of most important competencies for industrial employers and for newly graduate engineers. The same observation holds for the competencies 2, 5, 6 and 7 as part of the least important competencies. In addition, competencies 1 and 16 exist in the sets of most important competencies for academic staff and for industrial employers. Similarly, competencies 5 and 18 are part of the least important for both stakeholders. It is quite surprising that the importance profiles of graduate engineers and industrial employers have many common competencies as opposed to the importance profiles of academic staff members and graduated engineers.

Furthermore, the industrial employers were also asked to list competencies that newly graduates lack most. These were: 19. Team working, 20. Social skills, 13. Time management and prioritizing, 6. Basics of business operations, 22. Self-confidence, and 21. Self-knowledge. It seems that industrial employers in Tampere area favor personal competencies and attitudinal attributes over expertise competencies. In particular, 13, 14 and 19 are the most important from their perspective. Moreover, many employers highlighted several other competencies, which newly graduated engineers lack but which were not captured by the graduate survey's items. The most commonly mentioned competencies were: humility, motivation, respect towards other people, manners, adaptability to change, and flexibility. Lastly, industrial employers were asked to list competencies, which they expect to be important in near future. The six most frequently occurred competencies were: 19. Team working, 20. Social skills, 5. Sustainable development, 23. Creativity, 11. Skills related to international work environment, and 13. Time management and prioritizing.

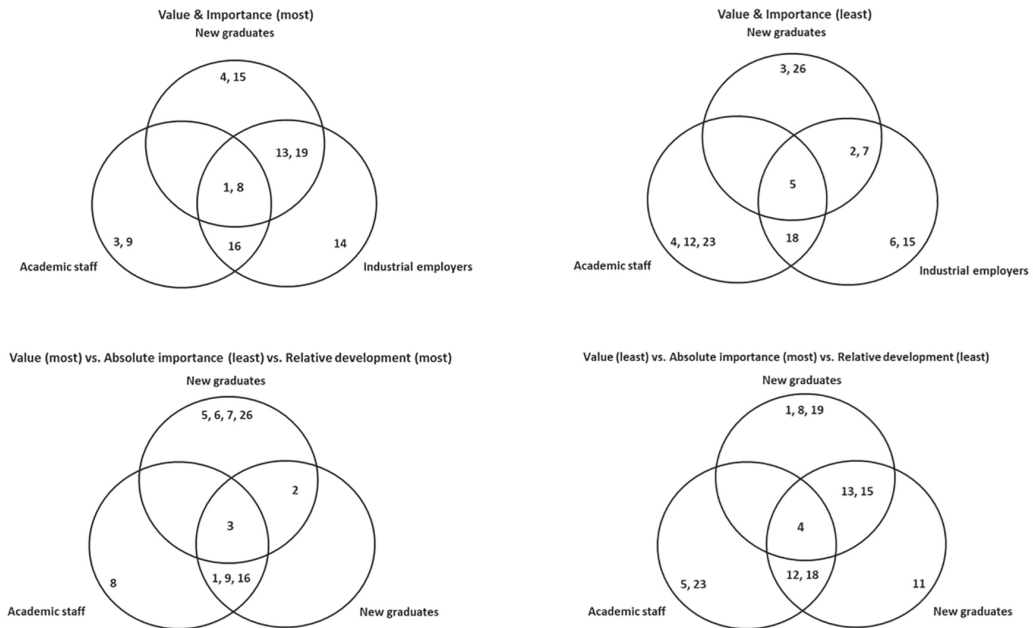


Figure 2. Set diagrams of absolute importance and relative development

Nonetheless, set diagrams showing overlaps between important competencies for all stakeholders as well as relative development of graduates have been collected into Fig. 2.

Several interesting features can be extracted from the figure: Know-how of own field (1) is one of the most important competence for all stakeholders (upper left diagram), and it also is one of the most developed, in studies, relative to the perceived importance in working life. Sustainable development is one of the least important competence for all stakeholders (upper right diagram). Mathematical and natural science (3) is one of the most valued in degree programmes, but it is also one of the least important for newly graduates and relatively most developed in studies (lower left diagram). Practical application of theories (4) is one of the least important in degree programmes, but it is also one of the most important for newly graduates, and relatively, one of the least developed in studies (lower right diagram). Problem solving (8) is one of the most important for all stakeholders, but it does not exist in the set of most developed competencies of newly graduate engineers.

4. Discussion

There are many driving forces currently affecting industries that are expected to have a significant impact on jobs but also to widening skills gaps (The World Economic Forum 2016). Thus, educators at the university are increasingly challenged with engaging students in lifelong learning agenda, which has emerged as a global concern within education policy and is a focus in several educational contexts (Drew and Mackie, 2011). The findings of this study revealed that all stakeholders of higher engineering education in Tampere region share similar viewpoints regarding to the importance of engineering graduates' expertise and personal competencies. However, there are some differences in these views: academia puts more emphasis on engineering specific knowledge, science and theoretical matters rather than on generic competencies. On the other hand, industrial employers highlight the importance of attitudinal factors, self-concepts and personal competencies. Surprisingly many competencies were found within the sets of most and least important competencies of industrial employers and graduates engineers. Unfortunately, some of the most important competencies for newly graduate engineers were also least developed in studies, whereas some of the least important competencies were most developed in studies. Furthermore, many competencies that were most valued in the degree programmes were also the most developed in studies and vice versa.

In relation to some exact competences, it was shown that industrial employers rated competencies, which newly graduates lack most e.g., team working, social skills, self-confidence and self-knowledge. In addition to those, they presented competencies, which newly graduated lack but which were not

captured by the graduate survey e.g., motivation, adaptability to change and flexibility, and suggested several competencies, which they expect to be important in future working life e.g., team working, social skills, creativity, time management and prioritizing. In order to provide students' education that would help them to achieve these skills, new type of educational strategies should be adopted into higher engineering education. Students should be seen more and more as learning agents of their own learning, who engage in a continual process of 'retooling' their knowledge and skill base by taking more responsibility for their own learning (Drew and Mackie 2011).

Previous studies have shown that a deep approach to learning has stronger relations with academic competencies than the other approaches (Postareff 2007; Tuononen 2019). Students with a growth mindset embrace challenges, persist when facing some setbacks, see challenges and effort as ways to the mastery, learn from criticism and find inspiration in the successes of others (Alink et al. 2018). Teacher can support this in many ways e.g., by activating students during teaching and moving towards student-centered teaching and learning practices. However, a course designer must have the ability to understand the situational and contextual constraints by analyzing the practical learning problems i.e. one must understand the position of the learner (Ertmer and Newby 2013).

Learning of competences leads naturally to an actualization of knowledge and methods, bringing them closer to professional practice (de Justo and Delgado 2015). Thus, attention should be given to alignment between the course learning outcomes or aims, activities and learning tasks during the course and assessment methods in the course. Furthermore, by investigating engineering education competencies, our aim was to provide valuable insights for the development of teacher trainings in engineering education and for trying to fill the observed skill gaps of newly graduates' engineers.

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