Engineering graduates' development of competencies - Views from academic stakeholders

Engineering Graduates' Development of Competencies – Views from Academic Stakeholders

V.-P. Pyrhonen[1]
University Teacher, Tampere University
Tampere, Finland

S. Niiranen
University Lecturer, Tampere University
Tampere, Finland

E. Pajarre
Planning Officer, Tampere University
Tampere, Finland

Conference Key Areas: Lifelong learning, Sustainability reflecting the complexity of modern society

Keywords: Competency development, Accreditation, Engineering education research

ABSTRACT

This paper investigates importance and development of expertise and personal competencies of newly graduated engineers from the standpoint of academic stakeholders; namely, academic staff members, industrial employers and graduated engineers themselves. The aim was to discover which competencies are the most important ones in working life and in engineering curricula. It was also investigated which competencies have satisfactorily developed and which have not during university studies relative to their current importance. For such purposes, a national-wide graduate survey measuring the importance and development of 26 expertise and personal competencies on the scale 1–7 was used as a basis for research. Then, 69 academic staff members used FINEEC's (The Finnish Education Evaluation Centre) reference programme learning outcomes to evaluate the importance of competencies in their curricula. Finally, 24 industry representatives gave their evaluations on the importance of the 26 competencies of newly graduates.

The results from the study indicate that all stakeholders share similar opinions regarding to the importance of several competencies. However, engineering curricula puts more emphasis on theoretical foundation rather than in generic competencies, whereas industrial employers favour attitudinal factors and generic

[1] Corresponding Author
V.-P. Pyrhonen
veli-pekka.pyrhonen@tuni.fi, https://orcid.org/0000-0003-3313-127X

competencies. Furthermore, according to graduates' ratings, several competencies have been developed more than seems to be needed in working life. The same competencies are the most valued in engineering curricula. Similarly, competencies that are least valued in curricula are related to the competencies that are least developed in studies. Interestingly, several competencies that are least developed are also the most important ones for newly graduates.

1 INTRODUCTION

Inclusion of generic competencies into university graduates' curriculua has become increasingly important during the past 20 years [1]. For newly graduates' employment, possessing substance knowledge that are taught on students' study field is not enough. Instead, employers are putting increasingly more emphasis on graduates' generic competencies such as communication skills and team work skills [2]. In the engineering field, it has been argued that engineers are "not only expected to be technically proficient in the field but also to know how to behave and operate within an organization" [3]. It has been stated that 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 [4]. In spring 2018, the academic board of Tampere University community, in Finland, outlined a set of common learning outcomes for all its degree programmes. The common learning outcomes entail descriptions of generic competencies that every student should master by the time of graduation. These common learning outcomes and generic competencies should be integrated into all degrees by considering the perspective of the competency needs in the degree programmes. 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 them [2–3; 5].

In the field of engineering, educators are called upon to help learners to develop analytic, communication, and teamwork skills, while meeting ever increasing content demands and cultivating independent learners [6–7]. As the professional knowledge about teaching and learning processes expands, also new type of expertise is required. In order to develop engineering education and pedagogical approaches in engineering education practices, it is important to get an overview of the current state of students' competency development. Thus, this study is aimed to discover, which competencies are currently the most important ones in working life of Finnish engineering field, engineering curricula, and as regards to newly graduate engineers. It is also investigated how various competencies of newly graduates have developed in studies and in working life relative to their current importance. In this study, the importance and development of various competencies of graduated engineers from the standpoint of academic stakeholders was investigated during 2016–2018 using well-known surveys and questionnaires. Next, the results from a national-wide graduate survey, academic staff members' ratings and employers' ratings are presented along with some analysis and interpretation of the obtained results.

2 IMPORTANCE AND DEVELOPMENT OF COMPETENCIES ACCORDING TO GRADUATE SURVEY

In this section, the results of the TEK (Tekniikan akateemiset) graduate survey[1] [8] are displayed. First, newly graduated engineers[2] evaluated the importance of each competency relative to their current need in working life using integers on the scale between 1 ["Not at all (important)"] and 6 ("Very much") with an option 7 ("Cannot answer"). Then, the graduates evaluated how each competency has been developed in studies and in work, respectively, using the above scale. Hence, each engineering graduate gave each competency three numerical values in the range 1–6(7), which were then averaged and displayed in a single figure. This allows reader to quickly see the importance of each competency relative to their current need in working life, and how well each competency have been developed in studies and in work. The figure also displays if importance and development meet each other, or if differences between importance and actual development exists. In case of differences, the amount of mismatch and its orientation are also easily seen.

2.1 Results of the graduate survey

The results of the TEK graduate survey are depicted in *Fig. 1*. In total, 12 competencies have been more developed in studies than in work. Most of these competencies are related to traditional university study activities, and hence, the development profile is not surprising. In turn, 14 competencies have been more developed in work than in studies. Many of these competencies are outside the scope of traditional university study activities, and they are more related to the generic competencies rather than subject specific engineering activities.

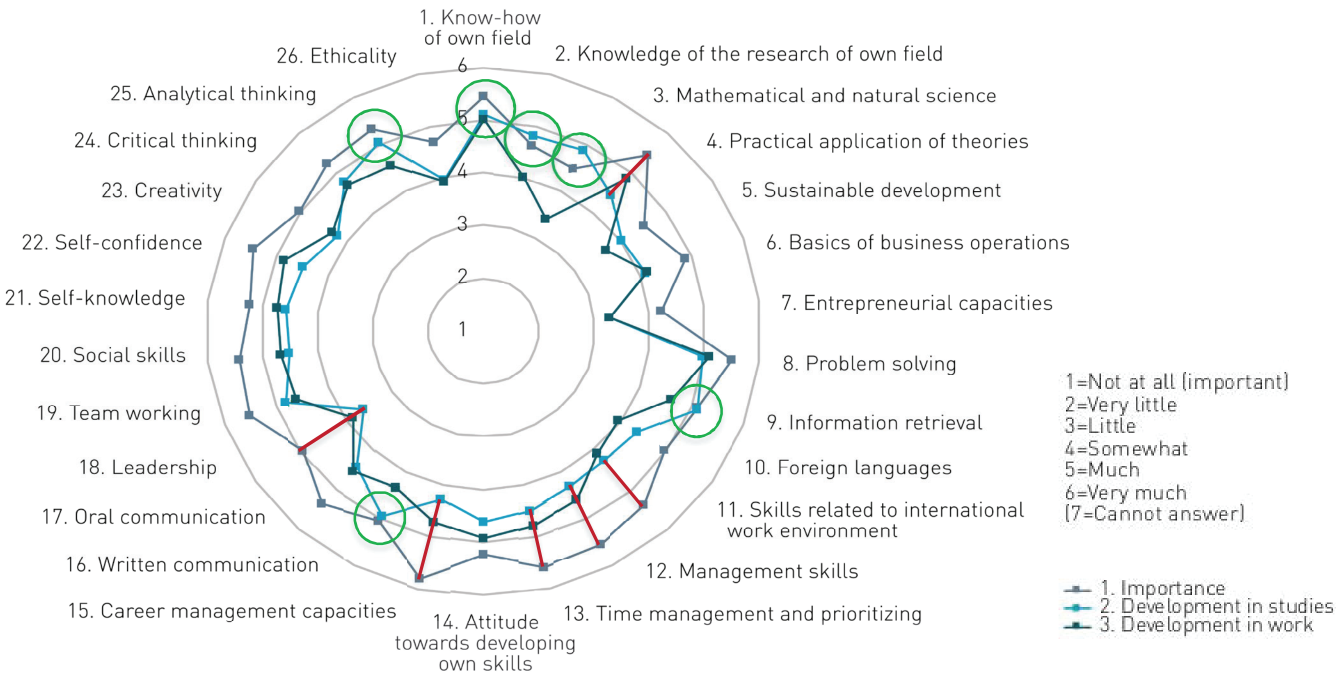

Fig. 1. Development of competencies in studies and in work relative to their current importance. Green circles = most developed, red lines = least developed [8].

[1] In the graduate survey, expertise and personal competencies are termed as 'skills and expertise'.
[2] A newly graduate engineer has just completed Master's degree in engineering and is required to participate in the survey.

According to graduates' opinions, the six most important competencies, in the *absolute sense*, are: 15. Career management capacities, 1. Know-how of own field, 19. Team working, 13. Time management and prioritizing, 8. Problem solving, and 4. Practical application of theories. The six least important competencies, in the *absolute sense*, are: 7. Entrepreneurial capacities, 5. Sustainable development, 3. Mathematical and natural science, 2. Knowledge of the research of own field, 26. Ethicality, and 6. Basics of business operations.

Furthermore, in *Fig. 1*, those competencies that have developed most, in studies, *relative* to their current importance in working life have been marked using green circles, whereas competencies that have developed least, in studies, *relative* to their current importance have been marked using red lines. According to *Fig. 1*, the six most developed competencies, in the *relative sense*, are: 3. Mathematical and natural science, 2. Knowledge of the research of own field, 9. Information retrieval, 16. Written communication, 25. Analytical thinking, and 1. Know-how of own field. Note that according to graduates' evaluations, the *absolute* developments of items 3, 2 and 9 in studies have been rated higher than their *absolute* importance in working life. Actually, no other competency has been rated such that their development in studies or in work shows larger values than their importance. Moreover, the *absolute* importance of 3 and 2 belong to the four least important competencies according to the graduates' ratings, while the development of 3 and 2 in work display very low ratings. These observations indicate that scientific fundamentals and theoretical foundations are learned during university studies, as they should be. More difficult issue is to argue, whether items 3 and 2 are nowadays too much emphasized in engineering education. After all, theoretical and scientific research is still one of the main functions of universities, and universities should educate researches as well.

The six least developed competencies, in the *relative sense*, are: 15. Career management capacities, 18. Leadership, 11. Skills related to international work environment, 12. Management skills, 13. Time management and prioritizing, and 4. Practical application of theories. It is quite interesting to note that theoretically oriented competencies like Mathematical and natural science, and Knowledge of the research of own field are the most developed, but Practical application of theories is one of the least developed. One possible explanation for such observation might be that engineering education in parts of former TUT (Tampere University of Technology)[3], including teaching and learning activities, assessment as well as intended learning outcomes, was practiced such that knowledge and understanding of science and theoretical matters were more favoured compared with engineering practice and applications.

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 5. Sustainable development, 7. Entrepreneurial capacities, 26. Ethicality, and 18.

[3] Tampere University of Technology no longer exists. It is now part of the new Tampere University.

Leadership, which are, *relatively*, the most unimportant skills and expertise regarding to newly graduates' opinions. Ethics, sustainable development and entrepreneurial capacities have just recently been included in planning of higher engineering education of Tampere University, and hence, they may also seem unimportant to newly graduates only because they have been explicitly missing from curricula.

Nonetheless, the most developed competencies are traditionally promoted in higher engineering education, and hence, it is reasonable that their development display large values among newly graduates. In the next subsection, it will be evident that these competencies were the most valued by the staff members of Faculty of Engineering Sciences of former TUT, and hence, these skills were fostered in their curricula.

2.2 Results from academic staff members ratings

In this section, the results from academic staff members' ratings are displayed. The data were collected during a teaching development event at Tampere University of Technology in 2017. In total, 69 staff members[4] participated in the event. The purpose of the ratings was to find out how various competencies are valued in faculty's engineering programmes. For such a purpose, FINEEC's (The Finnish Education Evaluation Centre) reference programme learning outcomes were adopted, which describe the knowledge, skills and competencies[5] that the learning process should enable engineering graduates to demonstrate *after graduation* [9].

The 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) Multidisciplinary competencies, 4) Knowledge and understanding, and 5) Communication and team-working. Each category has their own set of competencies, which can be found in [9] along with their descriptions. Nonetheless, staff members were divided into the field-specific groups, and each group rated the importance of each competency in their curriculum using options: 3 ("must have"), 2 ("should have") and 1 ("nice to have"). Group work method was chosen to ensure that each member shared mutual understanding of each rated item. Then, the results of each field-specific group were gathered together and averaged. Finally, the results of all groups were gathered together and averaged for easy reference. As a result, the maximum score a competency could achieve was 18 points, whereas the minimum score was 6 points.

It turned out that those competencies that received most points were related to the graduate survey's following items: 1) Information retrieval (18p), 2) Know-how of own field (18p), 3) Written and oral communication (18p), 4) Problem solving (17p), 5) Ability for life-long learning (17p), and 6) Mathematical and natural sciences (17p). In contrast, the least valued competencies were related to the following items: 1) Management skills (10p), 2) Leadership (10p), 3) Creativity (11p), and 4) Sustainable development (12p), 5) Ethicality (12p), and 6) Practical application of theories (12p).

[4] Staff members of this study consisted of faculty's teaching staff, researchers, Ph.D. students and professors.
[5] Knowledge, skills and competencies of FINEEC's learning outcomes are hereafter referred as competencies.

It is quite interesting to observe that most of the items that received the highest score belong to the competencies that newly graduates have rated, *relatively*, as the most well developed in studies. It is also interesting that many of the items that received the lowest score belong to the competencies that newly graduates have rated, *relatively*, as the least developed in studies. However, items related to “self” i.e., the psychological factors were missing from [9], and hence, also from the staff members’ ratings. That is, [9] mostly considers expertise competencies.

2.3 Results from industrial employers ratings

In this study, 24 industrial employers ranging from small and medium enterprises to large enterprises were interviewed in 2018 on the importance of the same competency set as in the graduate survey. The most important competencies according to industrial employers were: 14. Attitude towards developing own skills, 8. Problem solving, 19. Team working, 1. Know-how of own field, 16. Written communication, and 13. Time management and prioritizing. The least important competencies were: 7. Entrepreneurial capacities, 18. Leadership, 2. Knowledge of the research of own field, 5. Sustainable development, 15. Career management capacities, and 6. Basics of business operations.

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. Moreover, many employers highlighted several other competencies, which newly graduated lack but which were not captured by the survey’s items. The most commonly mentioned competencies were: 1) humility, 2) motivation, 3) respect towards other people, 4) manners, 5) adaptability to change, and 6) flexibility. Lastly, industrial employers were asked to list competencies, which they expect to be important in 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. Note that items 5 and 23 were two of the least valued competencies in the engineering curricula of the Faculty of Engineering Sciences of former TUT.

Nonetheless, the absolute importance (most and least) of various competencies according to all stakeholders as well as the relative development of graduates has been collected into *Fig. 2*. Several interesting observations can be made from *Fig. 2*: Items 1 and 8 seem to be the most important attributes to all stakeholders, but none of them exist in the most developed attributes of graduates. Item 3 seems to be one of the most important in curricula, but at the same time, it is one of the least important for graduates and relatively most developed. Item 4 seems to be one of the least important in curricula, but it is also one of the most important for graduates, and relatively, one of the least developed.

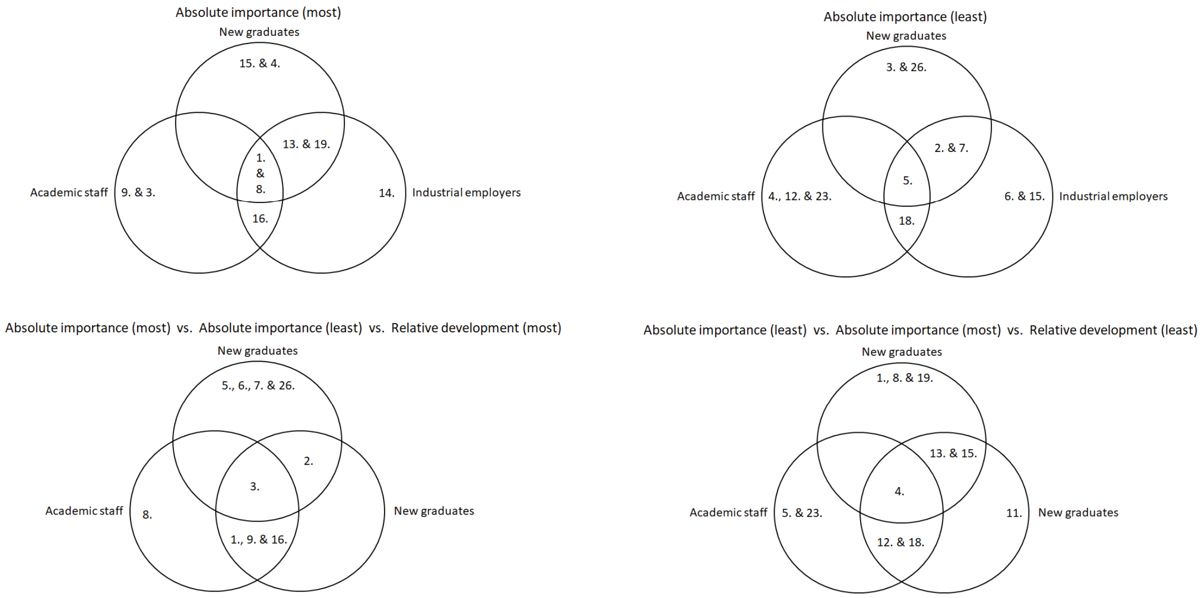

Fig. 2. Set diagrams of absolute importance and relative development.

Furthermore, items 1, 3, 9 and 16 belong to the set of most important items for staff members, and they also are, *relatively*, the most developed competencies of graduates. Also, items 4, 12 and 18 belong to the set of least important items for staff members, and they also are, *relatively*, the least developed competencies of graduates. Finally, it seems that industrial employers favor generic competencies and attitudinal attributes over subject specific competencies. In particular, items 13, 14 and 19 are the most important from their perspective. In what follows, research-based suggestions for developing higher engineering education is presented that are aimed to partly meet the desired needs for newly graduates.

3 DEVELOPING HIGHER ENGINEERING EDUCATION

Many of the major drivers of transformation currently affecting global industries are expected to have a significant impact on jobs, ranging from significant job creation to job displacement, and from heightened labour productivity to widening skills gaps [4, 10]. The findings of this study revealed that stakeholders of higher engineering education share similar viewpoints regarding to the importance of expertise and personal competencies. However, academia puts more emphasis on engineering specific technical knowledge, science and theoretical matters rather than on generic competencies. Industrial employers on the other hand highlight the importance of attitudinal factors, self-concepts and generic competencies, whereas graduates' views seem to overlap with those of academia and industrial employers. Furthermore, it seems that competencies that are most valued by engineering curricula are the ones that have relatively developed most according to graduates' ratings. Also, it can be observed that competencies that are least valued by curricula are related to the competencies that have relatively developed least in studies. Thus, the results seem to partly validate the outcome of educational efforts in higher engineering education in the former TUT.

When investigating the results in more detail, the industrial employers rated that competencies, which newly graduates lack most are e.g., team working, social skills, self-confidence and self-knowledge. In addition to those, they presented some competencies, which newly graduated lack but which were not captured by the graduate survey (e.g. motivation, adaptability to change, 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 [10]. Teacher can support this in many ways e.g., by activating students during teaching and moving towards student-centered teaching and learning practices.

It has been argued in previous studies that a deep approach to learning has stronger relations with academic competencies than the other approaches [11]. Students with a growth mindset embrace challenges, persist when facing some setbacks, see challenges and effort as a way to the mastery, learn from criticism and find inspiration in the successes of others [12]. Also, improving the level of student motivation and engagement by active learning can be seen resulting in deep learning. Pedagogical strategies of active learning are answering to changing economic demands and patterns of work, which underpin the ubiquitous discourse of the 'learning society' and 'lifelong learning' [10; 13]. In engineering discipline, it has been argued that situativity should be seen as a dominant perspective by emphasising the role of the environments that require extensive content knowledge and analytical skills to engage in learning [6; 14]. There has also been an increased concern about the need to develop a better understanding of how people learn engineering [15] and how they build engineering identity.

Teachers are those who are constructing bridges between the contents and actions during courses. Thus, a course designer must have the ability to understand the situational and contextual constrains and also analyse practical learning problems i.e. to understand the position of the learner [16]. During the past 15 years, universities have begun to provide pedagogical training that is aimed to improve the teaching practises and skills of university teachers. Thus, the university pedagogical training in engineering pedagogy aims to strengthen the participants' pedagogical expertise through self-reflection and collegial collaboration. The courses foster research- and development-oriented approach to teaching among the participants by exploring their personal experiences and theoretical perspectives. The aim is to enhance teachers' ability to engage in pedagogical discussions and promote actions that support students' deep-level learning. In summary, these are the main methods for developing higher engineering education and for trying to fill the observed skill gaps of newly graduates' engineers.

4 SUMMARY

This paper investigated the development of personal and expertise competencies of newly graduate engineers according to academic staff members', industrial employers' and graduated engineers' evaluations. The development profile of each competency was investigated relative to the competency's current need in working life. The results indicated that the most developed competencies of newly graduate engineers were strongly related to the competencies that are most valued by academic staff members. Similarly, the least developed competencies were related to the competencies that are least valued by academic staff members. Interestingly, some of the least developed competencies are the most important ones in working life, whereas some of the most developed competencies are the least important, according to newly graduates' evaluations. Moreover, it seems that industrial employers are looking for graduates having good generic competencies and personal attributes, while academia is emphasizing knowledge and subject specific engineering competencies. Undoubtedly, other possible implications can easily been drawn from the obtained data that can raise fruitful debates regarding higher engineering education and its development.

REFERENCES

[1] Fallows, S. and Steven, C. (2000), Building employability skills into the higher education curriculum: a university-wide initiative, *Education and Training*, Vol. 42, No. 6, pp. 75-83.

[2] Freitas, A., Garcia, P., Lopes, H. and de Sousa, A. (2018), Mind the gap: bridging the transversal and transferable skills chasm in a public engineering school, Proc. of 3rd International Conference of the Portuguese Society for Engineering Education (CISPEE), Portugal.

[3] Nguyen, D. (2008), The essential skills and attributes of an engineer: a comparative study of academics, industry personnel and engineering students, *Global Journal of Engineering Education*, Vol. 2, No.1, pp. 65-75.

[4] The World Economic Forum (2016), Executive summary: The future of jobs. Employment, skills and workforce strategy for the fourth industrial revolution. http://www3.weforum.org/docs/WEF_FOJ_Executive_Summary_Jobs.pdf

[5] Atlay, M. and Harris, R. (2000), An institutional approach to developing students' 'transferable' skills. *Innovations in Education and Training International*, Vol. 37, No. 1, pp. 76-81.

[6] Johri, A. and Olds, B. M. (2011), Situated engineering learning: Bridging engineering education research and the learning sciences, *Journal of*

Engineering Education, Vol. 100, No. 1, pp. 151-185.

[7] Millar, R. J., Keltikangas, K., Pinho, P., Vuorinen, V., Forsman, P., Belahcen, A. and Kyyrä, J. (2019), Development of working life competencies in a project course for master students at Aalto University, *Journal of University Pedagogy*, 2/2019. https://lehti.yliopistopedagogiikka.fi/2019/06/19/working-life-competencies/.

[8] Piri, A. (2016), TEK (Tekniikan akateemiset) graduate survey 2016 - Results. https://www.slideshare.net/ArttuPiri/tek-graduate-survey-2016-results

[9] Finnish Education Evaluation Centre (2015), Standards and procedures for engineering programme accreditation, *Finnish Education Evaluation Centre Publications*, pp. 7-13. https://karvi.fi/app/uploads/2016/03/KARVI_2215.pdf

[10] Drew, V. and Mackie, L. (2011), Extending the constructs of active learning: Implications for teachers' pedagogy and practice, *The Curriculum Journal,* Vol. 22, No. 4, pp. 451-467.

[11] Tuononen, T. (2019), Employability of university graduates, The role of academic competences, learning and work experience in the successful transition from university to working life, University of Helsinki. *Helsinki Studies in Education 46.*

[12] Alink, C. O., Schretlen, J., Stobbelaar, T. and Thomas, T. (2018), Deep or surface approaches to studying, which is applied? Comparing study skills of first year engineering students, Proc. of the 46th SEFI Annual Conference 2018 Creativity, Innovation and Entrepreneurship for Engineering Education Excellence, R. Clark, P. M. Hussmann, H.-M. Järvinen, M. Murphy and M. E. Vigild (Eds), pp. 31-38.

[13] Zepke, N. and Leach, L. (2010), Improving student engagement: Ten proposals for action, *Active Learning in Higher Education,* Vol. 11, No. 3, pp. 167-177.

[14] Pleasants, J. and Olson, J. K. (2019), What is engineering? Elaborating the nature of engineering for K-12 education. *Science Education*, Vol. 103, pp. 145-166.

[15] Johri, A., Olds, B. M., and O'Connor, K. (2013), Situative frameworks for engineering learning research, In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research*, New York, NY: Cambridge University Press, pp. 47-66.

[16] Ertmer, P. A. and Newby, T. J. (2013), Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective, *Performance Improvement Quarterly,* Vol. 26, No. 2, pp. 43-71.