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*Varietas delectat...*

Complexity is the new normality

SEFI 47th Annual Conference

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# IMPRINT

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# Analysis of Estimated Useful and Mandatory Engineering Skills for Innovative Product Design

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Conference Key Areas: Engineering Skills; Innovation as the context for Engineering Education; Sustainable Development Goals in Engineering Education.

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## INTRODUCTION

Globalization and rapid technological development lead to radical changes in the national and regional economy. This process also changes client behavior, demand structure and has crucial influence on the labor market. In order to ensure employability and competitiveness of future engineers, it is necessary to continuously improve the study process in engineering education in accordance with the research, technology and labor market development tendencies. Engineers are expected to have not only specialized technical knowledge but also personal skills such as teamworking and leadership abilities. Moreover, they should have critical and creative thinking, ability to communicate effectively, as well as capability to handle and manage complex and unfamiliar problems and proficiency to utilize acquired skills to contribute to local community and society in cooperation with institutions and business.

The present study specifies and analyses the relevance of the skills for engineering education that are based on the convergence of project/problem-based learning, product design using rapid prototyping and computer-aided design methods. The main research methods employed are literature review, internet survey and descriptive statistics. 1115 respondents answered to the survey by 16th April 2018, when the results were gathered for analysis. The survey audience included industry representatives, academic staff, students and members of community authorities.

The study was carried out in the framework of the Erasmus plus strategic partnership project No 2017-1-LV01-KA203-035426 “Education, Business and Community Cooperation Model for a Creative European Engineering Education” under the Erasmus+ Program. There are five partners in this project: Riga Technical University (Latvia, coordinator), Institut Supérieur de Mécanique de Paris – Supméca (France), Aristotle University of Thessaloniki (Greece), Établissement public territorial Plaine Commune (France), and the European Society for Engineering Education – SEFI (Belgium).

The results are already used within the EBCC project, and it is expected that the study results will contribute to the engineering education among SEFI members and other engineering universities.

## LITERATURE REVIEW

European Federation of National Engineering Associations considers skills as the ability to apply knowledge and use know-how to complete tasks and solve problems that in the context of the European Qualifications Framework are either cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments) [1]. Previous studies on engineering skills confirm the significance of both technical (hard) and nontechnical (soft) skills. It is important to determine the optimal proportion between hard and soft engineering skills and the required level of these skills.

The "Future of Jobs" report presents information and data collected by the World Economic Forum [2]. It provides specific information and analysis about middle-term trends in global industry and their impact on job functions, employment levels and required skills. The selected skills are based on O*NET Content Model. The report shows that 33% (share of jobs requiring skills family as part of their core skill set) of jobs in the industry group entitled "Basic and Infrastructure" are expected by the survey respondents to require complex problem-solving as one of their core skills in 2020. Other skills have following shares: social skills – 17%, process skills – 19%, systems skills – 26%, resource management skills – 15%, technical skills – 20%, cognitive abilities – 19%, and content skills – 13%. The complex problem-solving skills dominate also in total, 36% of all jobs across all industries needs them, but data are different for other skills: social skills – 19%, process skills – 18%, systems skills – 17%, resource management skills – 13%, technical skills – 12%, cognitive abilities – 15%, content skills – 10% and physical abilities – 5% [2].

Employers expect that engineering graduates have acquired both technical and soft skills that together form the overall engineering competency needed for graduates' employability and successful professional career [3]. The study curriculum should ensure the qualitative fit between the outcomes of the learning process and expected skills of newly employed engineers. Ability to manage projects, people and activities has same importance as technical skills. Many studies prove that the ability to manage technology projects is one of the fundamental competencies of engineers [4]. There are evidences that person's gender and experience in industry influences judgements on the importance of professional skills but particularly in relation to the importance of pure technical skills over soft skills. For example, female respondents consider non-technical skills more important than male respondents [5].

Some publications describe practical procedures for integrating in the educational process activities aiming to support local community in solving real problems related to local area. Such complex learning involving not only academic theory, contextual problem analysis and problem solving, but also awareness of possible societal impacts. For example, the National Institute of Technology, Maizuru College offers practical engineering education that teaches how to utilize engineering skills to contribute to local area in cooperation with local society. The students apply their practical engineering skills and propose solutions to real problems related to local area by fabricating prototypes needed for problem solutions. The authors recognize difficulties to contribute to local area directly by educational activity [6].

Also, students can feel themselves less at ease with some kinds of skills. A self-assessment experiment was conducted at ISMEP-Supméca in France to track how students' perceptions of their abilities changed. It has shown that the students self-assessed easily progresses during a project period in methodological and technical skills (9 skills – 40.1% increase over the 3 modules where the experimentation took place), then in management and communication skills (5 skills – 34.6% increase), and finally in behavioral and cultural skills (6 skills – 19.3% increase) in which some rare students even felt worse at the end of a project period than in the beginning. So, it is also interesting to compare if key-skills according to the survey conducted could be considered by students as difficult to acquire and enforce [7].

## METHOD

A survey was developed in order to determine to what extent students should acquire skills considering the research, technology and labor market development tendencies and needs of local community. It assessed the overall perception on the requested level of skills through close-ended questions. The survey was anonymous. The questionnaire was written in four languages (English, French, Latvian and Greek) and uploaded to an on-purpose built site to allow for easy participation. The English version is shown in Appendix.

A random sampling technique was employed. The authors used primary data analysis techniques including a quantitative method of descriptive statistics analysis to evaluate the survey results.

The survey consists of two sections: The first section includes evaluation questions about the essential engineering skills whereas the second one includes information about the respondents' profile.

Concerning the first section of the survey, a list of 14 skills was created taking into account previous studies on skills for engineering education, especially, results and outcomes of projects PLACIS [8] and EPICES [9]. 29 main skills for engineering students that could be acquired during engineering courses have been specified and applied in these projects. The skills covered the three main groups: methodological and technical skills, management and communication skills, behavioral and cultural skills. Then, at ISMEP-Supméca, this 29-skill grid was reduced to a 20-skill grid and used especially for self-assessment, as already stated previously. In the current study, a refreshed, more compact grid was developed. It was made up of the following 14 skills: technical problem analysis skills (SK01), ability to assess technical solution alternatives (SK02), ability to substantiate and present technical problem solutions (SK03), project management and control (SK04), resource identification and rational use (SK05), product manufacturing management skills (SK06), general IT skills (SK07), specialized IT skills (SK08), technical creativity (SK09), communication skills (SK10), leadership skills (SK11), self-assessment skills (SK12), learning skills (SK13), and teaching skills (SK14). The survey form contains a more detailed explanation of these skills, for example, self-assessment skills are characterized as the ability to conduct self-analysis, to evaluate accurately their own level of knowledge and performance of skills.

In the questionnaire, the respondents had eight choices to pick from: proficiency level (PL), advanced level (AL), upper intermediate level (UIL), intermediate level (IL), elementary level (EL), beginner level (BL), not needed anymore (NN) and not sure (NS). If a respondent has selected 'not sure', then this answer was not taken into account in the future analysis. Each answer option had a numeric value ranging from 0 to 10. The answer ‘proficiency level’ had value 10, but the answer ‘not needed anymore’ – 0. The survey form included also a field for comments.

The profile section provided information on age, gender (female or male), position (enterprise or human resource (EHM) manager; enterprise employee (EMP); city, department, region manager or human resource manager (LG); member of academic staff (ASF); doctoral student DS); master student (MS); bachelor student (BS)), country and some additional information.

The survey was conducted from 1st January till 16th April 2018. Based on the answers gathered, the authors conducted an exploratory statistical study. The Kolmogorov-Smirnov test was applied to determine whether the survey answers followed the normal distribution having a bell-like shape [10]. The significance level of the test was set to 5% for the all respondents’ groups.

## RESULTS AND DISCUSSION

A total of 1115 respondents participated in the survey. 558 or 50.0% respondents come from Latvia, 262 or 23.5% from Greece, 168 or 15.1% from France, and 127 or 11.4% from other countries. Respondents provided information on their occupation: the largest group is enterprise employees with a share of 457 respondents, followed by bachelor students – 275, members of academic staff – 190, master students – 177, enterprise or human resource managers – 118, doctoral students – 60, and local government representatives – 50. 190 respondents marked that they have 2 or 3 occupations simultaneously, including 149 which were both employee and student or member of academic staff.

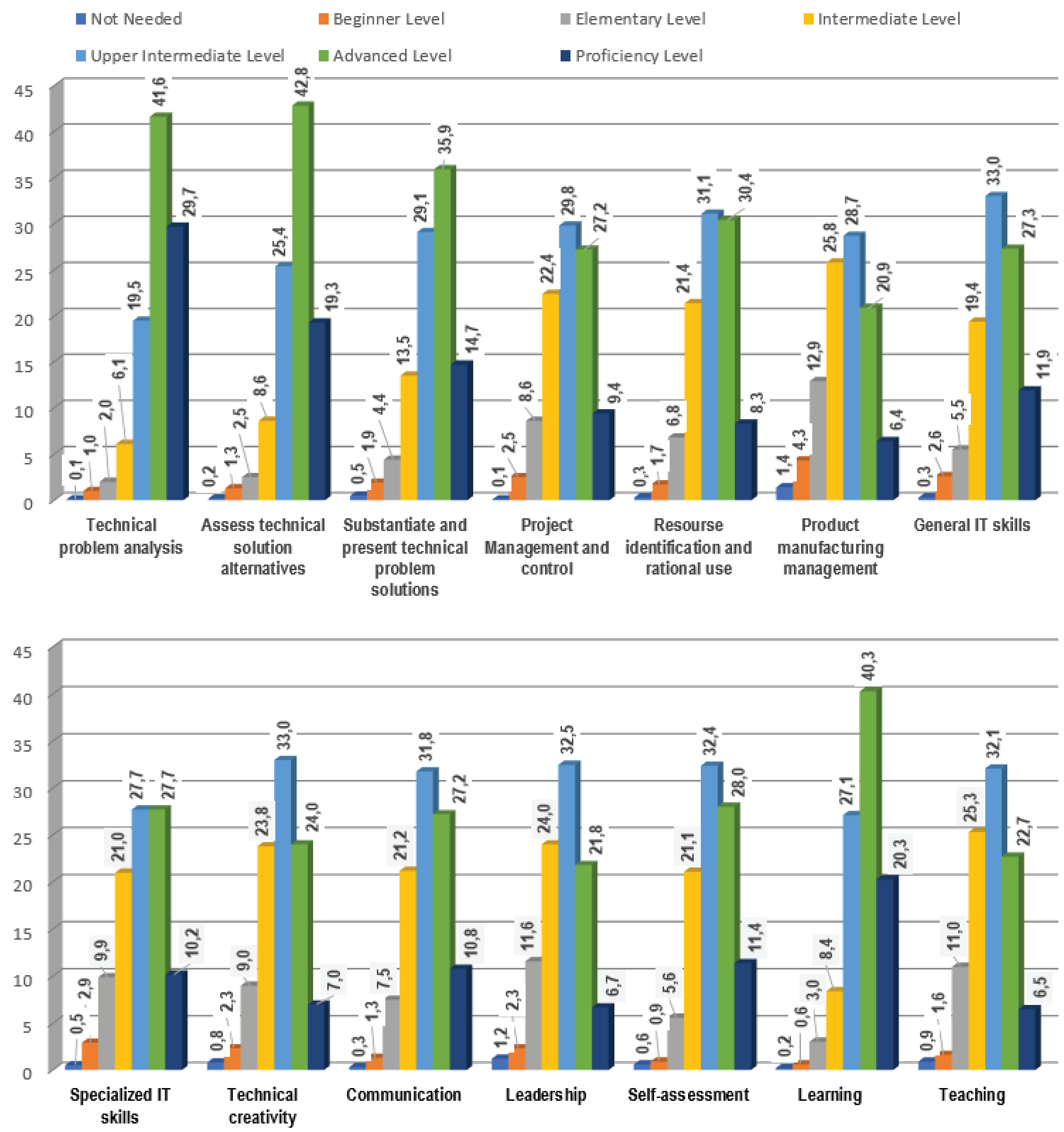


*Figure 1*. Summary of the survey results

The summary of all responses to the questions on the needed level of the acquired skills is shown in the *Figure 1*.

The Kolmogorov-Smirnov test demonstrates that the provided answers do not match to the normal distribution. The maximum value $D_{max}$ for each skill answer is bigger than corresponding critical value $D_{crt}$ for 5% significance level. The maximum values $D_{max}$ are between 0.119 and 0.172, but the critical values $D_{crt}$ are close to 0.041. Hence, the distribution seems to be asymmetrical. The median values MD range between 8.33 and 6.67, whereas the mean value M of the skills varies in the range from 6.05 for the product manufacturing management skills to 8.13 for the technical problem analysis skills.

The respondents recognize the need to acquire at a higher level the problem analysis skills (M = 8.13; MD = 8.33), the learning skills (M = 7.73; MD = 8.33) and the ability to assess technical solution alternatives (M = 7.72; MD = 8.33). 71.3% of the respondents suggest the proficiency level or the advanced level for the problem analysis skills.

Students should be able to identify a problem, determine the factors that influence it and creatively assess the interconnections.

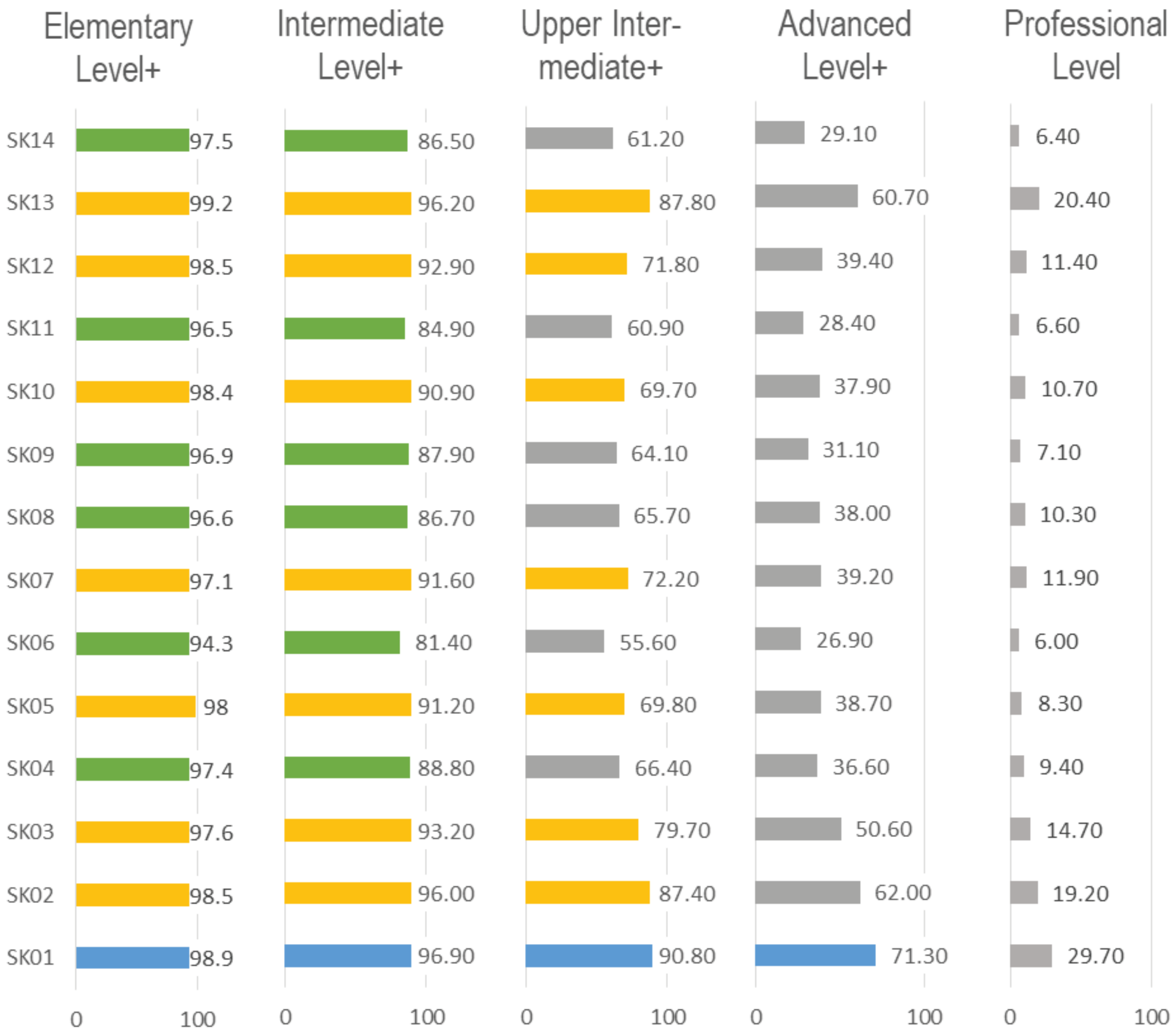


*Figure 2.* The suggested level for acquired skills and cumulative percentage of answers

About ten percent fewer respondents advocate the proficiency or the advanced level for the learning skills (60.7%) and the ability to identify technical solution alternatives and conduct their comparative assessment (62.1%). The survey shows that the learning skills are just as important as technical skills in all sample groups. The strong learning skills are required for success in professional career and during studies in a university or non-formal learning in various professional development courses.

Among the skills with a lower recommended level are the product manufacturing management skills (M = 6.05; MD = 6.67), the leadership skills (M = 6.27; MD = 6.67), and teaching skills (M = 6.34; MD = 6.67). Less than one third of the respondents suggests the proficiency or advanced level for these skills, respectively 27.0%, 28.5% and 29.2%. So, the respondents believe that product manufacturing management skills could be advanced in the next workplace and according the business needs and specifics. However, more than 81% respondents think that these skills should still be acquired at the intermediate or higher level.

The so-called “soft” and “hard” skills can be found among the ones with a higher as well as with a lower recommended level. So, if looking back to some skills where students self-assess not really well, these ones are distributed among both very valued and less valued.

SK03, meaning the ability to substantiate and present technical problem solutions, has a mean value above 7, but if we look at the median value, the result is lower. This indicates a distribution more concentrated in the lower levels. Hence, around 50% of responses are situated between BL and UIL, whereas for the SK01 (technical problem analysis skills) only 27.6% of the responders consider it as less important.

*Figure 2* shows the cumulative percentage of answers by skill level starting from the elementary level towards higher levels. Consequently, the value next to the bar shows how many respondents advise the level of this column or higher for the skill. If the value is equal or bigger than two thirds, then the authors count that level as required for the skill.

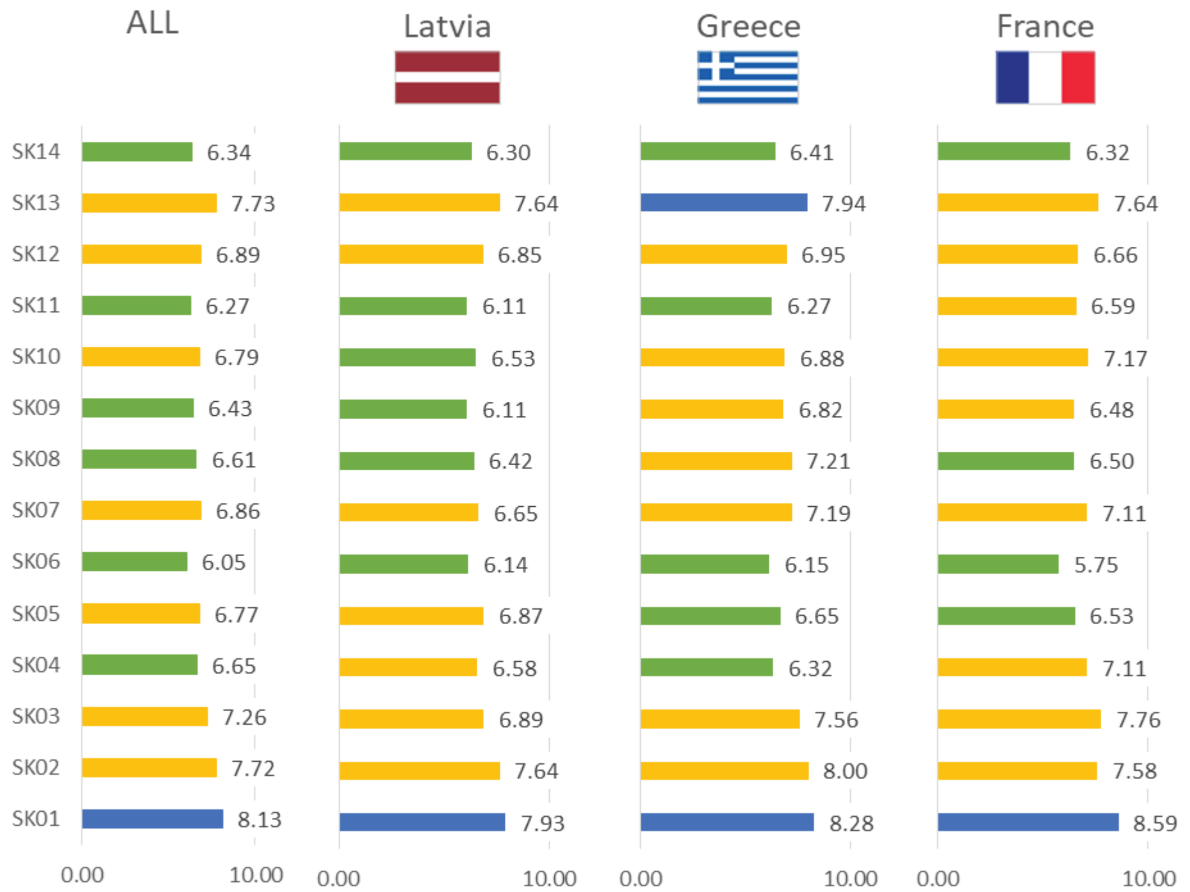


*Figure 3.* The suggested level for acquired skills and the mean value of the skills by the sample groups

There are 4 levels for the 14 selected skills: advanced level (light blue), upper intermediate level (light gold), intermediate level (light green) and professional level (light grey). The survey indicates the top position of the technical problem analysis skills (SK01) that is requested at the advanced level. The upper intermediate level needs 7 skills: the ability to assess technical solution alternatives (SK02), the ability to substantiate and present technical problem solutions (SK03), the resource identification and rational use (SK05), the general IT skills (SK07), the communication skills (SK10), the self-assessment skills (SK12), and the learning skills (SK13). Other 6 skills are needed at the intermediate level.

The study includes data processing and analysis for the sample groups by country and occupation. The authors compared the answers of the sample groups with answers of all respondents (see *Figure 3*). There are generally no substantial opinion differences between the sample groups and survey respondents in total. The differences in the requested skill level do not exceed one level and the mean values have usually differences less than 5% (the maximum is 8.3%). The views of all groups are identical for the upper intermediate level to the ability to substantiate and present technical problem solutions, to the general IT skills, and to self-assessment skills as well as for the intermediate level to the teaching skills.

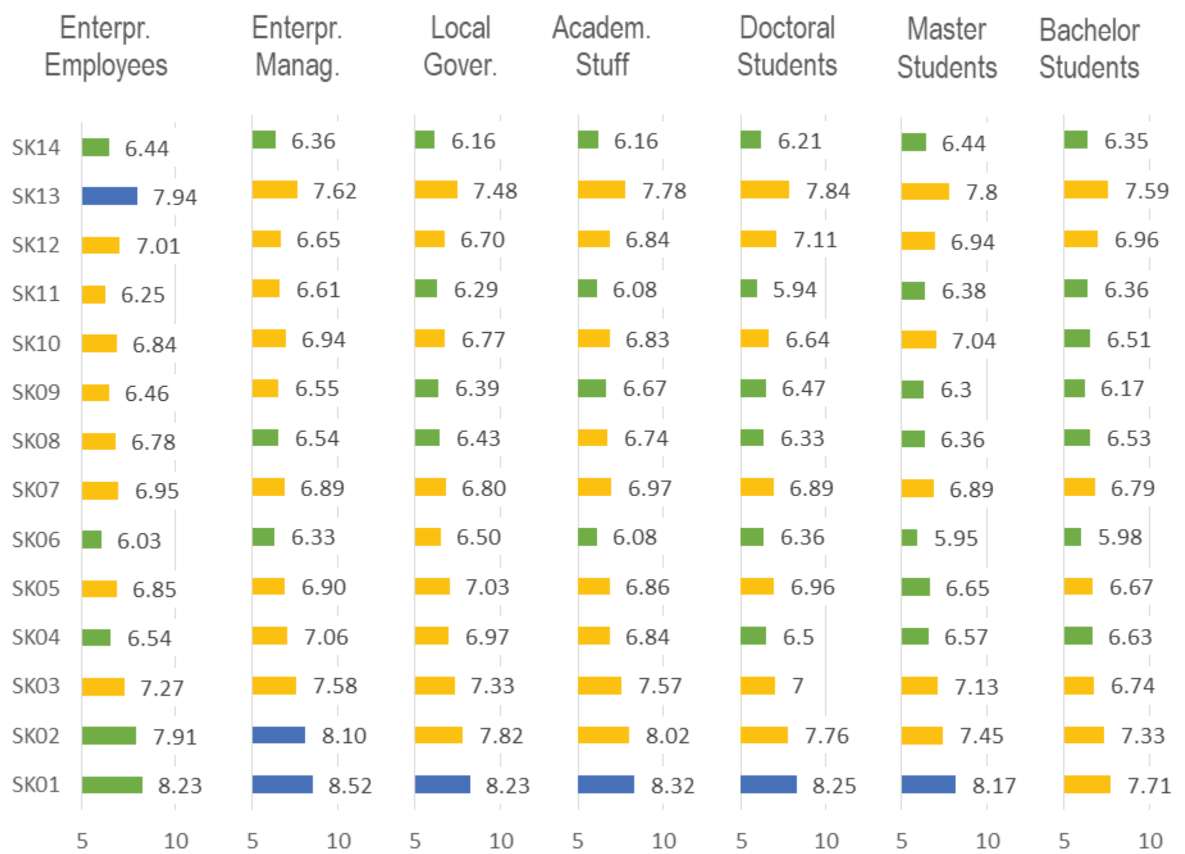


*Figure 4.* The suggested level for acquired skills and the mean value of the skills by the sample groups

The opinions are clearly divided only for four skills: The project management and control (SK04), the resource identification and rational use (SK05), the specialized IT skills (SK08), and the technical creativity (SK09). Management of enterprises and public institutions as well as academic staff appraise the project management and control skills higher than the employees and all students' groups, including doctoral students. The bachelor students evaluate almost all skills less important than other groups excluding the leadership and the self-assessment skills. The enterprise employees and academic staff suggest (*Figure 4*) acquiring the specialized IT skills to the upper intermediate level, but other example groups and in total – to the intermediate level.

The share of the doctoral students in the survey is 5.4%, but their assessment of the skill levels completely matches to the results of the whole survey.

Concerning the difference of opinions among countries, there are some particularities that can be highlighted: the ability to substantiate and present technical problem solutions (SK03) is obviously more valuated by respondents from France, whereas specialized IT skills (SK08) are more valuated in Greece.

## CONCLUSIONS

The survey assesses the overall perception on the acquired level of 14 skills through close-ended questions. It employs a random sampling technique and the questionnaires were distributed through online. The study authors use primary data analysis techniques including a quantitative method of descriptive statistics analysis to evaluate the survey results. The survey data processing and analysis for the sample groups by countries and occupation to explore opinion differences between the sample groups and survey respondents in total. The performed Kolmogorov-Smirnov test demonstrates that the provided answers do not match to the normal distribution. The survey results indicate the crucial role of the methodological and technical skills. More than two thirds of respondents believe that technical problem analysis skills should be acquired at the proficiency or advanced level, whereas more than half of respondents think that the ability to assess technical solution alternatives and the ability to substantiate and present technical problem solutions should also be at the proficiency or advanced level. The learning skills also reach high approval rate. More than 60% respondents consider them as key skills that need to be acquired at the proficiency or advanced level. The survey data processing and analysis of the sample groups by country and occupation show that there are no substantial opinion differences between the sample groups and survey respondents in total. All groups consider the upper intermediate level for the ability to substantiate and present technical problem solutions, the general IT skills, and self-assessment skills as well as for the intermediate level to the teaching skills. The differences in the requested skill level do not exceed one level and the differences of the mean values are negligible. The study results will contribute to future development EBCC project, especially in writing guidelines in order to improve the implementation of selected skills. They will also contribute to the development of the engineering education among SEFI members and other engineering universities.

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