The Engineers' Non-technical Competences

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Abstract: This study empirically tests a heuristic model of non-technical engineering competences. The results of factor analysis and regression analysis support the model proposing six non-technical competence domains consisting of 19 competences engineers use in their everyday work. Furthermore, the competence domains have a shared component with their neighboring competences. Engineers use more frequently these non-technical engineering competences that belong to the Personal competence domain (i.e. flexibility, learning, self-management, stress tolerance competencies), and to the Interpersonal competence domain (relationships/cooperation, communication, negotiations/conflict management), also personal and professional ethics competencies and innovation and creativity competencies. The findings indicate that the male engineers with the long professional work experience use the Innovation and entrepreneurship competences, and the Leadership, management, and administrative competences more frequently while the female engineers apply more often the Professional ethics competences, the Personal competences, and the Interpersonal competences. Development of these non-technical engineering competencies is highly recommended for the competence-based engineering education in the universities.

Key-Words: - Engineers' competence, non-technical engineering competences

1 Introduction

In recent years the engineering community has reached a strong consensus that the modern-day engineering profession requires not only technical excellence, but also some additional, non-technical competences. Employers have begun to draw attention to the demand for engineering non-technical competences [1], [2], [3], [4], [5], [6]. Moreover, empirical evidence was found for an existing link between non-technical competences and employability [7], [8], [9], [10]. Researchers have largely reached a consensus on the same matter [11], [12], [13], [14], [15], [16], [17], [18]. Professional bodies declare the importance of engineering non-technical competences [19], [20], [21], [22], [23], [24], [25], [26], [27]. Accordingly, engineers' educators have started to develop engineering curricula and to integrate into the curricula different "packages" of engineering non-technical competences [28], [29], [30], [31]. The OECD has carried out in-depth studies and described engineers' competence based on learning that includes engineering non-technical competences [32], [33]. Although the issue of engineers' competence has become the dominant theme in the field of engineering education, there is a lack of a generally accepted definition of engineering non-technical competences, as well no common understanding of what exactly engineering non-technical competences are in their content. This lack of coherence has led to a degree of fragmentation in engineering education literature and may explain, in part, why a variety of terms, definitions and concepts have been used.

In order to put much of the recent studies into the proper perspective, it is important to understand the terms and definitions regarding engineering non-technical competences.

First of all, the use of the words "skills" or "competences" is a matter of terminology. In the theoretical perspective, it is necessary to distinguish the terms "skills" and "competences". There is an increasing consensus that competence should be defined as "a learned ability to adequately perform a task, duty or role" [34], relating to a specific type of work to be performed in a particular work setting, and integrating several types of knowledge, skills, and attitudes in a dynamic way. Thus, skills are one component of competence. A skill does not develop on its own from nothing – skill is based on knowledge, and skills develop through the practical use and application of prior knowledge. Professional attitudes are understood as a person's readiness or willingness to act in accordance with his personal values i.e. attitudes provide a general frame for a person's decisions and actions.

Second, the ongoing debate about the meaning and definition of engineering competences follows the distribution of skills and/or competences in various combinations: technical and non-technical [2], [11], [15], [16], [35], [36], [37], [38] or basic and additional [39] or technical and soft [40]. As the term "non-technical" is already widely used in engineering, including in the engineering education, and non-technical competences include the fields of science that cannot be unambiguously defined as social e.g. law, ethics and innovation, it is reasonable to use the term "non-technical" competences. Based on the described understanding, non-technical engineering competences can be defined as a specific range of non-technical knowledge, skills, and attitudes needed to adequately perform the professional work and professional roles of engineer.

2 Problem Formulation

Based on a comprehensive review of research literature, analysis of qualification criteria for engineers prescribed by professional bodies, expected outcomes for engineering graduate programs, and different visions of the future of engineering, we offered a heuristic model of non-technical competence domains for engineers (Fig. 1). The discussions about a heuristic model will be held at 10th WSEAS International Conference on Engineering Education [41].

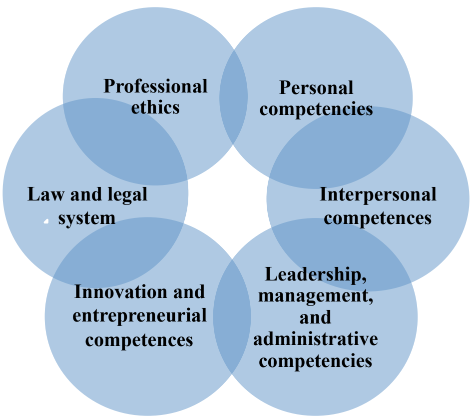


Fig. 1 A Heuristic Model of Non-technical Competences for Engineers

A heuristic model of non-technical competence domains for engineers draws six domains, namely
- Professional ethics competence domain (includes three competences: personal ethics, professional ethics, social ethics);
- Personal competence domain (includes four competences: flexibility, stress tolerance and coping with stress, self-management, learning skills and motivation);
- Interpersonal competence domain (includes four competences: communication, relationships/cooperation, negotiations and conflict management, influence/manipulation);
- Innovation and entrepreneurial competence domain (includes two competences: innovativeness, creativity, and entrepreneurship);
- Leadership, management and administrative competence domain (includes three competences: project management, organization / division management, and team leadership);
- Law and legal system competence domain (includes three competences: intellectual property law, knowledge of engineers' work legal issues, commercial law).

The domains of non-technical competencies could be depicted as the separate domains, yet they have a shared component with their neighboring competencies. For example, good communication skills considered as the interpersonal competencies are essential for the effective leadership and management. In turn, realizing an innovative idea and being entrepreneurial requires competence in law and legal system domain (protecting one's intellectual property). The competence in stress and self-management as well as the ability to be flexible (personal competencies) are related to the interpersonal competencies, as they enable a person to stay calm in conflict situations and cooperate with others in a productive way.

As far as the model described above is heuristic, we need to control whether this model is empirically valid i.e. transferable into real engineering work context.

3 Problem Solution

In order to examine a heuristic model of non-technical competences for engineers, as well as to develop our understanding of which non-technical competences are more or less important for the everyday engineering work, the empirical testing of the model is essential.

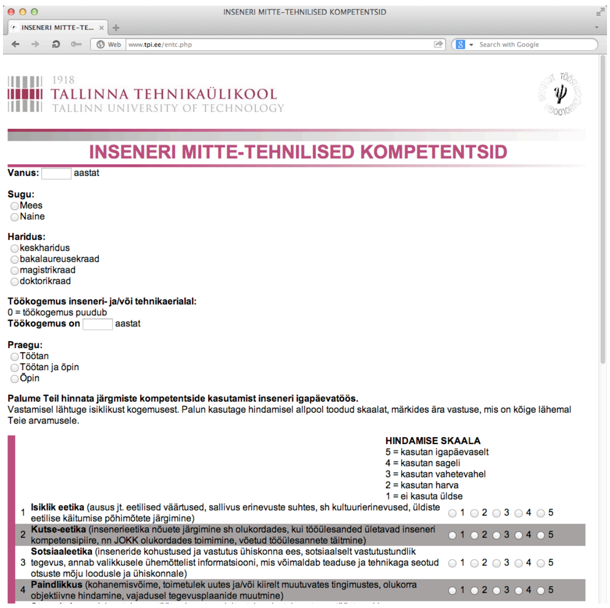
3.1 Method

The quantitative approach was chosen for empirical testing a heuristic non-technical engineering competences model. The questionnaire consisted of 19 items; each of them was a non-technical engineering competence name followed by a brief description i.e. explanation of the content-opening list of keywords. For example: Stress tolerance (tolerance of pressure, working in stressful situations, techno-stress, coping with occupational stress, and burnout).

Some socio-demographic data were added i.e. age (years), gender, education (high-school graduate, bachelor degree, master's degree, PhD), and work experience in engineering and/or technical specialties (years), and current status (employed, employed and also studying concurrently, engineering student).

In order to ensure that respondents have exactly the same understanding of the survey questions, we conducted the pilot study. The pilot study involved eight experts from different fields of engineering. According to the expert opinion, we corrected and changed the formulation of some questions.

The next step was for the Web-based survey to be designed (Fig. 2). The instruction to the participants was as follows: "Please evaluate usage of the following competences in an engineer's everyday work. Base your answers on your personal experience. Please use the scale below to mark the answer that is closest to your opinion." Following this instruction the response scale, and all 19 competences were listed.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doktorikraad

Töökogemus inseneri- ja/või tehnikaerialal:
0 = töökogemus puudub
Töökogemus on aastat

Praegu:
Töötan
Töötan ja õpin
Õpin

Palume Teil hinnata järgmiste kompetentside kasutamist inseneri igapäevatöös.
Vastamisel lähtuge isiklikust kogemusest. Palun kasutage hindamisel allpool toodud skaalat, märkides ära vastuse, mis on kõige lähemal Teie arvamusele.

HINDAMISE SKAALA
5 = kasutan igapäevaselt
4 = kasutan sageli
3 = kasutan vahetevahel
2 = kasutan harva
1 = ei kasuta üldse

1	**Isiklik eetika** (ausus jt. eetilised väärtused, sallivus erinevuste suhtes, sh kultuurierinevused, üldiste eetilise käitumise põhimõtete järgimine)	1 2 3 4 5
2	**Kutse-eetika** (insenerieetika nõuete järgimine sh olukordades, kui tööülesanded ületavad inseneri kompetensipiire, nn JOKK olukordades toimimine, võetud tööülesannete täitmine)	1 2 3 4 5
3	**Sotsiaaleetika** (inseneride kohustused ja vastutus ühiskonna ees, sotsiaalselt vastutustundlik tegevus, annab valikkusele ühemõttelist informatsiooni, mis võimaldab teaduse ja tehnikaga seotud otsuste mõju loodusle ja ühiskonnale)	1 2 3 4 5
4	**Paindlikkus** (kohanemisvõime, toimetulek uutes ja/või kiirelt muutuvates tingimustes, olukorra objektiivne hindamine, vajadusel tegevusplaanide muutmine)	1 2 3 4 5

Fig. 2 Engineers' Non-technical Competences Survey in Web (http://www.tpi.ee/entc.php)

For responses the Likert-type 5-point scale was chosen, as it is the most widely used approach to scaling responses in survey research. A Likert item is simply a statement that the respondent is asked to evaluate according to any kind of subjective or objective criteria; generally the level of agreement or disagreement is measured, but sometimes the frequency is measured. Usually five ordered response levels are used. The anchors we use are between "use every day" (5 points) and "never use" (1 point).

Response scale:

5 = Every day;
4 = Frequently;
3 = Sometimes;
2 = Rarely;
1 = Never.

The respondents' results were automatically sent to a database once the user clicked the button "SEND". The data was then removed from the Web environment, copied into and then kept in a database outside the web environment (security on RAID-6 level). This ensures that the data are not violated and the confidentiality of the user's results is guaranteed.

First of all, reliability statistics of the questionnaire were computed. The Cronbach's α (alpha) is a coefficient indicating on the internal consistency of measures and is commonly used for the estimation of the reliability of the psychometric tests. The six non-technical competences domains scales had the acceptable internal consistency assessed with the widely accepted alpha standard of 0.70 [42], accordingly $\alpha = 0.77$ in six domains, and $\alpha = 0.88$ in 19 items.

The statistical analysis was conducted using the SPSS software program. The robust statistical data analyses utilized various standard techniques including frequency distributions, percentages, means, ranges, and the standard deviations. The analysis of variance, factor and multiple regression analyses were used to constitute factors and analyze relations between the factors.

The sample consisted of 1011 engineers, 681 males and 322 females (8 respondents undefined), the average age was 28.11 years (SD=7.60); 199 engineers had professional engineering work experience of 0 - 0.9 years, 390 engineers had professional engineering work experience of 1 – 4.9 years, 233 engineers had professional engineering work experience of 5 – 9.9 years, 135 engineers had professional engineering work experience of 10 – 19.9 years, and 49 engineers had professional engineering work experience over 20 years (5 respondents did not answer). Distribution of the sample by education was as follows: 44% had a bachelor's degree, 34% had the master's degree, and 18% had the high school education, four respondents completed their doctoral studies.

3.2 Results

3.2.1 Engineers' Non-technical Competences

As it noted above, all 19 competences were involved to the model of non-technical competences for engineers. Table 1 shows the frequency of use of non-technical competences in professional engineering work i.e. how often engineers use non-technical competences in the order of frequency, with the most frequently used competences listed first.

Table 1 Non-technical Competences and Frequency of Use in Engineering Practice

Competences	Never do not use	Rarely Sometimes	Frequently Every day
Personal ethics	1%	11%	88%
Flexibility	1%	12%	87%
Learning	1%	14%	85%
Self-management	1%	17%	82%
Stress tolerance	1%	23%	76%
Relationships/ Cooperation	1%	25%	74%
Communication	1%	26%	73%
Professional ethics	2%	26%	72%
Innovation/creativity	1%	31%	68%
Negotiations/ Conflict management	1%	36%	63%
Social ethics	4%	40%	56%
Project management	7%	41%	52%
Influence	3%	45%	52%
Engineer' work legal issues	6%	47%	47%
Entrepreneurship	5%	51%	44%
Team management	15%	47%	38%
Organization/ Division management	17%	45%	38%
Intellectual property law	19%	52%	29%
Commercial law	26%	51%	23%

As it can be seen from the results presented in Table 3, all competences in a heuristic model are important for engineers in their professional work. It appears that approximately 2/3 of engineers use on a daily basis or frequently personal ethics and all the Personal competences (i.e. flexibility, learning, self-management, stress tolerance), and the Interpersonal competences (relationships and cooperation, communication, also negotiations and conflict management) as well as innovation and creativity competencies.

On the other hand, some competences from the Leadership, management, and administrative domain (organization/division management, team management), as well as from the Law domain (i.e. commercial law, intellectual property law) are used rarely or sometimes by approximately half of the engineers. The percentage of engineers reporting not using the competences is from 1% to 6% for the main volume of non-technical competences, and ranged between 15% and 26% for four competences, exactly the same as those competences that are used rarely or sometimes by engineers.

We calculated the average ratings of the competences in each domain and estimated the application of non-technical competences domains in the engineers' everyday work (Table 2).

Table 2 The Average Ratings of Non-technical Competencies Domains

Domains	N	Min	Max	Mean	SD
1 Ethics	993	1	5	3.94	0.71
2 Personal	971	1	5	4.23	0.62
3 Interpersonal	975	1	5	3.82	0.74
4 Innovation	997	1	5	3.57	0.89
5 Leadership	993	1	5	3.15	1.11
6 Law	998	1	5	2.88	0.97

Results show (see Table 2) that the highest ratings had the Personal competence domain. The average ratings of the Professional ethics and the Interpersonal competence domains are also high. The average ratings of the Innovation and the entrepreneurship competences and the Leadership, management and administrative competence are somewhat lower. This indicates that quite a lot of respondents in our sample have not applied these competencies quite frequently.

Professional Ethics Competences

The Professional ethics competence domain includes personal ethics, professional ethics, and social ethics competences.

There was found a small but statistically significant gender difference between male and female ($r = 0.13$; $R^2 = 0.02$; $p < 0.001$) regarding the Professional ethics competence domain. More specifically, the significant difference manifested in personal ethics ($r = 0.19$; $R^2 = 0.04$; $p < 0.001$) in this way, that the female commonly used the personal ethics competences more frequently in their everyday engineering work.

Despite the professional engineering work experience, the most commonly were used personal ethics competences, followed by professional and social ethics competences. Figure 3 shows how often the engineers with different professional engineering work experience used the competences incorporated into the Professional ethics competence domain.

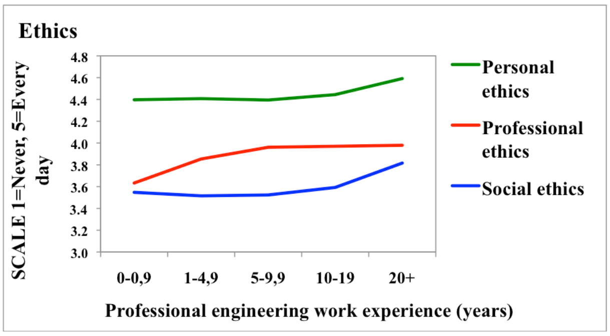

Fig. 3 The Professional Ethics Competences Regarding the Professional Engineering Work Experience

There was found a small but statistically significant difference regarding professional ethics competences ($r = 0.07$; $R^2 = 0.01$; $p < 0.05$), in this way that more experienced engineers used more frequently professional ethics competences.

Personal Competences

The Personal competence domain includes flexibility, stress tolerance and coping with stress, self-management, learning competences.

There was found a small but statistically significant gender difference ($r = 0.13$; $R^2 = 0.01$; $p < 0.001$) regarding the Personal competence domain. Unlike the male engineers the female engineers are using more often flexibility ($r = 0.08$; $R^2 = 0.01$; $p < 0.05$), and self-management competences ($r = 0.19$; $R^2 = 0.04$; $p < 0.001$).

Regarding professional engineering work experience there were not found significant differences in frequency of use the different competences included in the Personal competence domain.

Comparing the frequency of the application of the competencies within this domain, it could be said that the engineers use more often the flexibility competencies and the learning competencies in case their professional engineering work experience is longer (Fig. 4).

The data also show that the stress tolerance competencies and coping with stress competencies have the higher meanings for the engineers whose work experience has been from 4.9 to 19 years.

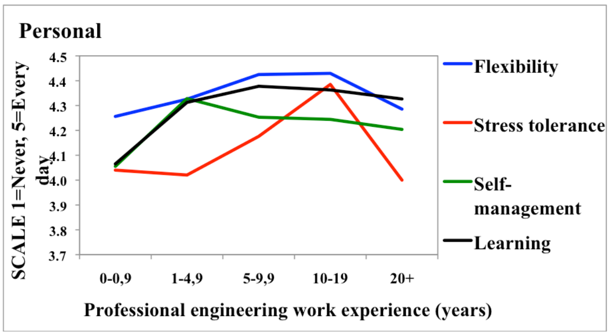

Fig. 4 The Personal Competences Regarding the Professional Engineering Work Experience

However, the meanings decrease when the professional engineering work experience is longer. Another trend is also apparent – the learning and self-management competencies are applied more often if the engineers have had little professional engineering work experience. In sum, the respondents with the short professional work experience (reported no work experience in engineering or have worked some months) have used the flexibility, self-management, learning and motivation competencies significantly not so often in everyday engineering work, compared to the respondents whose professional experience has been of one year and/or over one year.

Interpersonal Competences

The Interpersonal competence domain includes three competences, namely, communication, relationships/cooperation, negotiations/conflict management, influence/manipulation competences.

There was found a small but statistically significant gender difference between male and female ($r = 0.09$; $R^2 = 0.01$; $p < 0.01$) regarding the Interpersonal competence domain, which is principally related to female engineers' more frequent use communication ($r=0.14$; $R^2=0.02$; $p < 0.001$), as well relationship/cooperation competences ($r=0.14$; $R^2=0.02$; $p<0.001$).

The most frequently were used communication and relationships and cooperation competences (Fig. 5). A small but statistically significant relation was found regarding negotiation and conflict management competences in one hand, and professional engineering work experience ($r = 0.11$; $R^2 = 0.01$; $p > 0.001$).

Compared to the engineers with the professional work experience of over one year, the professionally inexperienced engineers have used these competencies significantly less frequently.

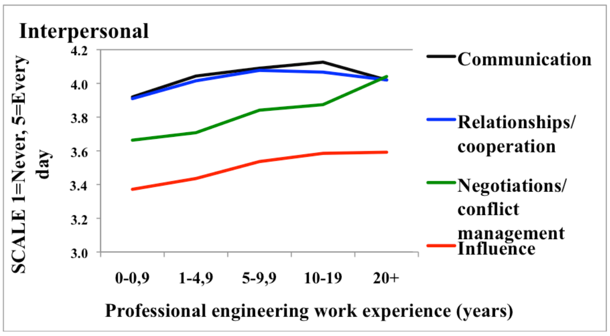

Fig. 5 The Interpersonal Competences Regarding the Professional Engineering Work Experience

Innovation and Entrepreneurial Competences

The Innovation and entrepreneurial competence domain includes two competences: innovativeness, creativity, and entrepreneurship competences.

There was found a small but statistically significant relationship between professional engineering work experience ($r = 0.10$; $R^2 = 0.01$; $p = 0.001$) and the Innovation and Entrepreneurial competence domain. Engineers with longer professional experience were used more often innovation and creativity competences ($r = 0.09$; $R^2 = 0.01$; $p < 0.01$) as well entrepreneurship competences ($r = 0.10$; $R^2 = 0.01$; $p < 0.001$). Compared to the engineers with the professional work experience of over one year, professionally the inexperienced engineers have used both competencies significantly less frequently.

Regarding innovation and creativity competences, there is a decreasing trend in the use thus competences by the engineers, who have over 19 years professional experience (Fig. 6).

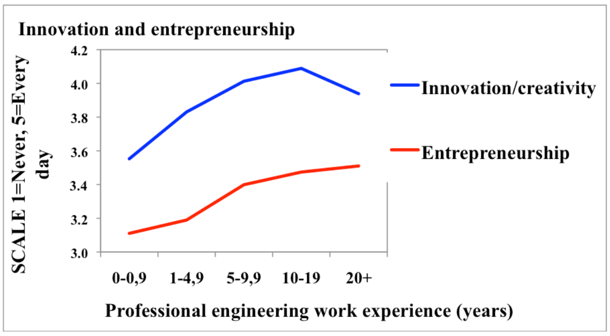

Fig. 6 The Innovation and Entrepreneurship Competences Regarding the Professional Engineering Work Experience

Leadership, Management, and Administrative Competences

The Leadership, management and administrative competence domain includes three competences i.e. project management competences, organization or division management competences, and team leadership competences.

There was found a small but statistically significant gender difference between male and female ($r = -0.13$; $R^2 = 0.02$; $p < 0.001$), in this way that male engineers more frequently used the competences from Leadership, management, and administrative competence domain. An inspection of the results showed that there were gender differences in all three competences in this domain i.e. project management ($r = -0.08$; $R^2 = 0.01$; $p = < 0.05$), organization/division management ($r = -0.11$; $R^2 = 0.01$; $p < 0.001$), and team leadership competences ($r = -0.13$; $R^2 = 0.02$; $p < 0.001$).

The most frequently were used project management competences followed by all the other competences from the Leadership, management and administrative competence domain (Fig. 7).

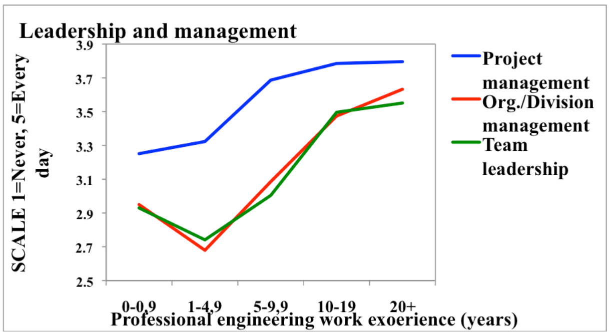

Fig. 7 The Leadership, Management, and Administrative Competences Regarding the Professional Engineering Work Experience

Furthermore, there was also found a small but statistically significant difference regarding the work experience ($r = 0.19$; $R^2 = 0.04$; $p < 0.001$). Engineers with longer professional experience used more often project management ($r = 0.15$; $R^2 = 0.05$; $p < 0.001$), organization/division management ($r = 0.22$; $R^2 = 5.0$; $p < 0.001$), and team leadership competences ($r = 0.20$; $R^2 = 0.04$; $p < 0.001$). The frequency of the application of the project management competencies in everyday work was rated much lower by professionally the inexperienced respondents, compared to those, who already had the professional experience. However, the engineers with the work experience of one to five years used organization/division management competencies and team leadership competencies less often, compared to the inexperienced engineers and also the engineers whose work experience extended five years.

Law and Legal System Competences

The Law and legal system competence domain includes three competences, namely, intellectual property law, knowledge of engineers' work legal issues, commercial law competences.

The most frequently used competences in this competence domain were engineer' work legal issues (Fig. 8).

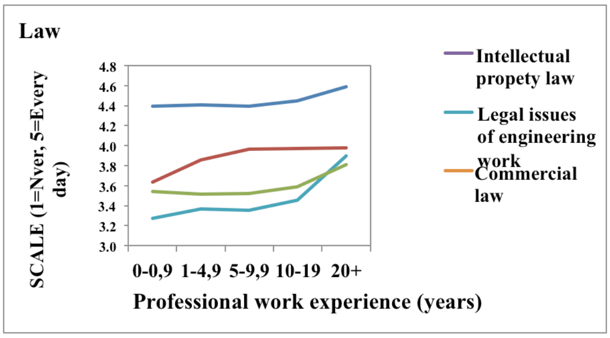

Fig. 8 The Law and Legal System Competences Regarding the Professional Engineering Work Experience

There was found a small but statistically significant difference regarding the relationship between professional engineering work experience and the Law and legal system competence domain ($r = 0.12$; $R^2 = 0.01$; $p < 0.001$). In details, engineers with longer professional experience were using more often their competences in engineer' work legal issues ($r = 0.11$; $R^2 = 0.01$; $p < 0.001$), as well as commercial law ($r = 0.11$; $R^2 = 0.01$; $p < 0.001$).

3.2.2 The Model of Non-technical Competences for Engineers

We examined the non-technical competence domains or, in other words, we tested empirically a heuristic model of non-technical competences for engineers. For that task we used factor analysis, a method of statistical data analysis that attempts to identify underlying variables, or factors, that explain most of the variance observed in manifest variables. Principal Axis Factoring method was used to extract factors from the original correlation matrix (uses squared multiple correlation coefficients placed in the diagonal as initial estimates of the communalities; these factor loadings are used to estimate new communalities that replace the old community estimates in the diagonal during iterations). Suggested by Kaiser it is a popular scheme for rotation, which cleans up the factors as follows: "for each factor, high loadings (correlations) will result for a few variables; the rest will be near zero" [43]. Described statistical method was used to obtain the initial factor solution of non-technical engineering competences model.

Rotation converged in seven iterations explaining 66.2% of total variance, 17 competences (variables) loaded into competence domains (principal components) as a heuristic model predicted (i.e. main loadings into one competence domain); five variables had main loadings < 0.80, seven variables had main loadings < 0.70, and five variables had main loadings < 0.50 (Table 3).

Table 3. Results of Factor Analysis

Domains / Items	Factor					
	1	2	3	4	5	6
Professional ethics competence domain						
Personal ethics		.253	.210		.484	
Professional ethics					.680	
Social ethics				.277	.533	
Personal competence domain						
Flexibility	.208	.624				
Stress tolerance	.279	.599				
Self-management		.575				
Learning		.507				.274
Interpersonal competence domain						
Communication		.341	.502			
Relationship/ Cooperation		.260	.882			
Negotiations/ Conflict management	.428		.466			
Influence/ Manipulation	.456	.265	.415			
Innovation and entrepreneurial competence domain						
Innovation/ Creativity		.298				.736
Entrepreneurship	.386	.204		.343		.461
Leadership, management, and administrative competence domain						
Project management	.644	.211				
Organization/Division management	.820			.253		
Team leadership	.764			.239		
Law and legal system competence domain						
Intellectual property law				.508		
Engineer' work legal issues				.611	.244	
Commercial law	.369			.662		

Factor loadings <0.2 were omitted from the table

The influence/manipulation competencies loaded almost equally into the Interpersonal competence domain (factor), and the Leadership, management, administrative competencies domain. Also the negotiations and conflict management competencies, the commercial law, and the entrepreneurship competencies had additional significant loadings in the Leadership, management, and administrative competencies domain. The communication and relationships/cooperation competencies are related to the Personal competencies domain and the entrepreneurship competencies are also related to Law and the legal system competencies domain, and Personal competencies factor.

The main loadings of 18 competences are in the competence domain (factor) as they should be according to the heuristic model. The main loadings are also notably higher than additional loadings presented in Table 3. So we argue that the competences surveyed in our study have been divided into six competences domain as the heuristic model suggests. As a fact, the boundaries between the non-technical competence domains are not rigid and all additional loadings are essentially justified. That is why it is possible to conclude that the model is valid and these 19 competencies reflect everyday work of engineers.

Next, the strength of the relationships between competency domains was estimated by using the coefficient of determination (R^2). In the case of paired data, this is a measure of the proportion of variance shared by the two variables, and varies from 0 to 1. Whether an effect size should be interpreted small, medium, or big depends on its substantial context and its operational definition. In interpreting our results we follow the logic of Cohen's conventional criteria small, medium, or big [6] that are near ubiquitous across many fields. Thus, we interpret $R^2 <0.09$ as referring to small effect, $R^2 = 0.1 - 0.23$ as referring to medium effect, and $R^2 > 0.24$ refers to large effect.

In addition, results presented in Table 3 and Figure 9 are based on responses from engineers with professional experience 1 year and more (n=812). The responses of professionally inexperienced engineers (n=199) we left out as we conclude from the results presented in section 3.2.1 that the presence or absence of professional engineering work experience is an important determinant when descibing the everday work of engineer.

Tab. 4 The Within-sample Correlations between the Non-technical Engineering Competences Domains

Domains	1	2	3	4	5	6
1 Ethics	-					
2 Personal	0.24	-				
3 Interpersonal	0.34	0.45	-			
4 Innovation	0.19	0.37	0.40	-		
5 Leadership	0.24	0.31	0.53	0.47	-	
6 Law	0.33	0.20	0.38	0.42	0.49	-

$p<0.001$

Firstly, we present the correlations between all six non-technical engineering competence domains (see Table 4), and the correlations range from 0.19 to 0.53 between the competences domains.

The strongest correlations were between the Personal competence domain and the Interpersonal competence domain, between the Law competence domain and the Leadership, management and administrative competence domain, and between the Interpersonal competence domain and the Leadership, management, and administrative competence domain. The lowest correlations were between the Personal competence domain, and the Law competence domain, and between the Professional ethics competence domain and the Innovation and entrepreneurship competence domain. On the other hand, all competence domains had significant positive relationship with each other.

Moreover, by analyzing an effect size we found that it well demonstrates support for a heuristic model of non-technical competences for engineers. Reporting effect sizes is considered good practice when presenting empirical research findings [44]. An effect size facilitates the interpretation of the significance of a research results. It allows us to move beyond the simplistic, "Does it work or not?" to the far more sophisticated, "How well does it work in a range of contexts?" Moreover, by placing the emphasis on the most important aspect of an intervention – the size of the effect – rather than its statistical significance, it promotes a more scientific approach to the accumulation of knowledge. For these reasons, an effect size is an important tool in reporting and interpreting effectiveness [45]. The coefficient, also commonly known as R-square (R^2), is used as a guideline to measure the accuracy of the model i.e. how well or tightly the data fit the estimated model.

The strength of the relationships between competency domains was estimated using the coefficient of determination or effect size (R^2). In the case of paired data, this is a measure of the proportion of variance shared by the two variables, and varies from 0 to 1. Whether an effect size should be interpreted small, medium, or big depends on its substantial context and its operational definition. In interpreting our results we follow the logic of Cohen's conventional criteria small, medium, or big [46] that are near ubiquitous across many fields. Thus, we interpret $R^2 < 0.09$ as referring to small effect, $R^2 = 0.1 - 0.23$ as referring to medium effect, and $R^2 > 0.24$ refers to big effect.

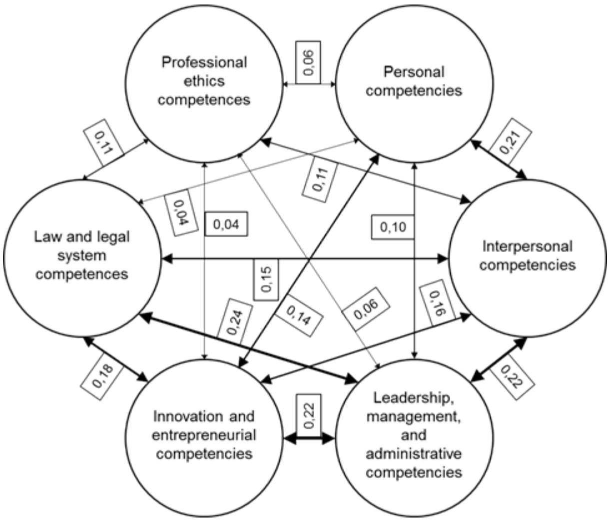

Fig. 9 Model of Non-technical Competences for Engineers (by using R^2)

Our findings indicate that the analysis of relationships demonstrates strong support for the heuristic model of non-technical competencies for engineers (see Fig. 9). In this sense all competencies domains are related to each other in the way we have depicted the sequence of circles in the Figure 2. Boldness of an arrow refers to the strength of the relationship between the competences domains.

The strongest relationship in the model is between the Leadership, management, and administrative competences and the Law and legal system competences sharing 24% of variance. The Innovation and entrepreneurial competences and Interpersonal competences both share 22% of variance with the Leadership, management, and administrative competences, and Personal competences share 21% of variance with Interpersonal competences. All these are effects of medium size.

A bit weaker but nevertheless of medium size is the covariance between Law and legal system competences and Innovation and entrepreneurial competences (R^2 =0.18), also there is significant proportion of variance shared by the Law competences and the Ethics competences (R^2 =0.11). The weakest but significant shared variance (6%) in a heuristic non-technical competence model circle is between Personal and Professional ethics competences.

Analyzing the relationships between the competence domains inside the circle it can be seen that the Interpersonal competences have shared variance also with Innovation and entrepreneurial competences (R^2=0.16), Law and legal system competences ($R^{2=}$0.15) and Professional ethics competences (R^2=0.11) (all these are medium size effects). Also Personal competences are significantly related to the Innovation and entrepreneurial competences (R^2=0.14) and the Leadership, management, and administrative competences domain (R^2=0.10). The effects of the Ethics competences domain onto the two aforementioned ones are small (4% shared variance with Innovation domain and 6% shared variance with Leadership, management, administrative competences domains).

Summing up, we found that the analysis well demonstrates support for a heuristic model of non-technical competences for engineers.

4 Conclusions

So the purpose of this study has been to examine empirically a heuristic model of non-technical competencies for engineers and assess the validity and reliability of six domains of non-technical engineering competences consisting of 19 non-technical engineering competences in total. The main conclusions of our study are as follows.

First, the model of non-technical competences for engineers is valid. There are six domains of non-technical competences the engineers use in their professional work, and these domains are related to each other. It means that (1) certain competencies from one competences domain are used in parallel domains or are a combination of the competencies from other domains. Another conclusion is (2) that acquiring or mastering some competences in one domain depend on the competences in some other domain, or (3) requires to obtain or master the competencies in some other domain. For example, communication, influencing and cooperation and relationship building competencies are needed in order to work together with other people for having support and other resources one needs when developing his/her ideas into the marketable assets.

Second, all 19 competencies involved in a heuristic model of non-technical competences have been used by the engineers in their professional work. However, the frequency of using concrete competencies is not the same for all groups of the engineers. Most frequently have been used the non-technical engineering competences that belong to the Personal competence domain (i.e. flexibility, learning, self-management, stress tolerance competences), and to the Interpersonal competence domain (i.e. relationships/cooperation, communication, negotiations and conflict management competences). The Personal and professional ethics competencies, also innovation and creativity competencies have been also frequently used by the engineers. There are some competencies e.g. intellectual property law competencies, commercial law competencies, organization/division management, and team management competencies that have been used rarely and/or sometimes by half of the engineers, and a small percent of engineers have never used them.

Third, the usage of non-technical competencies is related to the engineer's gender and professional work experience. The male engineers reported using the Leadership, management, and administrative competences more frequently, while the female engineers reported using more frequently the Professional ethics competences, the Personal competences, and the Interpersonal competences. Relationship between the professional engineering work experience and three competencies domains have been found, i.e. the Innovation and entrepreneurship, and the Leadership, management, and administrative competence, and the Law and legal system competence domains have been used more frequently by engineers with the longer professional work experience.

It can be concluded that the development of the competencies in the Personal, Interpersonal, and Professional ethics domains is highly recommended for competence-based engineering education in the university.

Finally, the further research on non-technical engineering competencies could be done from the cross-cultural perspective.

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