International Journal of Business and Management Study– IJBMS
Volume 1: Issue 2 *[ISSN: 2372-3955]*

Publication Date : 25 June 2014

What Engineer's competencies for innovation market?

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Abstract — Technical competencies and specific engineering skills alone are not sufficient in the modern labor market but employers expect engineers to actively promote the products they create. Engineers often perceive their skills differently than employers do. Insufficient university training in a number of fields including the development of social, management and communication skills leads to an objective and understandable gap between the perceived and the required levels of such competencies. Based on the results of a survey of 3158 engineers conducted in 2011 in the Russian Federation, the study shows a number of deficits in the perception of innovation skills and the respective demand for these.

Keywords — competency, engineer, innovation, skill; vocational education and training

I. Introduction

It is assumed that successful modernisation of economies is directly correlated with the availability of skilled personnel, thus it's necessary to study the relevant dimensions of human capital. This can include studying the skills of those working in the research sphere and creating inventions, and those in industrial and other organisations who apply these and develop them into innovations.

Human capital is recognised as one of the most valuable resource of organisations and economies. But comparative evaluations of human capital often are limited to applying general indicators of formal qualification levels – specifically the number of people with higher education diplomas. Even suing such metrics has required substantial efforts in assessing the comparability of qualifications across different national education and training systems the number (or the share) of people with diplomas does not provide precise information about the quality and content of their education. Nor do the qualifications tell us much about what skill levels are required at particular jobs, and data on outputs of the educational system will be shaped by macroeconomic and policy trends in specific regions or countries [2, 5, 7, 9, 10, 18].

At this stage of study we still lack adequate tools for evaluating the competencies or skills, and researchers in various countries keep trying to develop such tools. Measuring competencies is rather complicated due to the complex nature of the phenomena.

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In current literature on skills and competencies, many definitions and distinctions apply. For example, skills are in fact treated as one of the constituent elements of competencies, along with motivation, character traits, knowledge and behaviour. And competencies at their turn can be defined as the «abilities to successfully meet complex demands in a particular context through the mobilization of psychosocial prerequisites (including both cognitive and non-cognitive aspects)» [17].

In the context of the European Qualifications Framework the «skills» are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments) and means the ability to apply knowledge and use know-how to complete tasks and solve problems. As for «competencies», they are described in terms of responsibility and autonomy and mean the proven abilities to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. The competency deals with the potential and special attributes that enable a person to perform his job well and to access knowledge and skills. Although in the current policy discussions on the employability and training of engineers the term «skills» is generally referred to, it would be more accurate to adopt the definition of «competencies» in this paper.

The traditional approach to assessing how necessary and sufficient competencies are acquired in the course of education and training is to look at how people's formal qualifications match the requirements imposed by the work they actually do; to evaluate higher education institutes' graduates' needs for further training to successfully compete on the labour market; to measure how often formally qualified professionals apply for various forms of upgrading, and their overall needs for further knowledge (and willingness to acquire it) [8, 11, 12].

At the same time, a functional skills-based approach is more suitable for the development of professional, not educational standards – though it appears there are very few studies specifically aimed at developing a skills set for highly qualified science, technology and innovation (STI) personnel. As Ian Miles pointed out, the policymakers responsible for improving the skill base needed for future economic development must assess the implications of radical technological change in the future [15, 16].

Although many discussions are hold around the topic of skills for innovation major unanswered questions remain:

1. Innovation workers, e.g. engineers, doctorates etc, often perceive their skills differently than recent or potential

employers do. Hence there is presumably a gap between the perceived competencies of innovation workers and the demand for competencies.

2. The labour force is diverse. Diversity refers to the individual but still the education level and the education field can be used as a proxy to identify perceived and required competencies.

3. In many countries policy makers initiate measures targeted at improving the competencies and skills of innovation workers. However it can be assumed that the chosen approaches by policy makers to close the gap between skill demand and supply do not necessarily match.

4. Innovation is an undertaking with a global dimension still skills demanded and supplied are region and country specific. This is due to the national and cultural characteristics and training of innovation workers in these systems.

The paper is organized as follows. First, the data collection approach and analysis methodology are introduced and results discussed. Second, engineering education and application of acquired skills are analyzed. The paper concludes with a summary of the major findings that show the important role of 'general' competencies required from engineers at their jobs, such as self-organization, openness to new information, the ability and willingness to learn, and communication skills.

II. Methodology and Approach

A survey of engineers conducted by the National Research University Higher School of Economics in 2011 aimed at dealing with issues described and studied STI-related skills.[1]

The sample represents two large groups of STI personnel: staff of research, development, design etc. organisations whose responsibilities include R&D (n = 1,473); engineering and technical personnel with high qualifications employed by industrial enterprises (n=1,685). The total sample amounted to 3,158 respondents.

To assess the skills or competencies, three major methods are currently in use by researchers:

1 – indirect question addressing the value of diplomas, scientific degrees, experience;

2 – assessment of skills via descriptors of different practices;

3 – addressing competencies directly by self-assessment.

In the survey of Russian Engineers the self-assessment was applied as a major assessment method. Measuring levels of competencies by using self-assessment has disadvantages (self-awareness) but its alternatives (e.g. highly specific assessment in assessment centres) are not always feasible or eligible.

A special attention was paid to studying STI personnel's competencies; in particular, a set of skills-related indicators applied in course of the European Reflex project[2] was tested. The main objective of the study was to measure the level of graduates' skills and determine how far the competencies they obtained matched the employers' requirements. In the course of the project, professionals were surveyed in 13 countries in 2005, 5 years after their graduation from universities. As in our survey, both doctorate holders and people without this academic degree were included in the samples [1, 2].

An important methodological issue addressed in course of the REFLEX project was the application of an assessment procedure in a mass survey. Specific features of a large scale survey led researchers to the conclusion that without self-assessment procedures, collecting reliable data would be impossible. Accordingly, comparing the available and required competencies took the form of identical scales, where respondents answered the questions: «How would you assess your knowledge and skills level in the following areas?» and «What level of these knowledge and skills is required at your job?» for each of the 19 skills reflecting professional knowledge, functional flexibility, ability to mobilise available resources, readiness to innovate, international experience and mobility. The Reflex methodology places its accent upon assessing general or «soft» skills. This reflects in part employers' needs for their employees to have good social, communication and management skills, and be willing and able to develop them throughout their careers. Such requirements have been highlighted in numerous studies. In contrast, specialised professional (or «hard») skills are not analysed in detail. In a large-sample questionnaire-based survey, it is difficult to address the huge range of highly specific skills associated with a broad diversity of professional backgrounds of respondents. For example, even within a specific professional group, there will be considerable variations in the sorts of equipment being employed to carry out almost similar tasks, and these types of equipment experience rapid generational changes in some areas especially where they involve new Information Technologies. Thus the surveys ask about the use of professional skills in the respondent's own field, without any detailed specification of what that field is or how the knowledge is precisely configured.

The Russian survey used similar self-assessment procedures to assess engineers' competencies regarding (a) their actual skill levels, and (b) the levels required at their workplace. The actual skills set used in the survey was somewhat modified, taking into account specific features of Russian engineers' work environment.

The list of competencies used in the survey included the following:

- Use of professional knowledge:
  - mastery of own field or discipline;
  - knowledge of other fields or disciplines;
  - analytical thinking;

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[1] The study was implemented in the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) in 2011.

[2] http://www.fdewb.unimaas.nl/roa/reflex/

- ability to rapidly acquire new knowledge;

- Teamwork skills:
  - willingness to question own and others' ideas;
  - ability to mobilize the capacities of others;
  - ability to come up with new ideas and solutions;
  - alertness of new opportunities;
- Management skills:
  - ability to coordinate business activities;
  - ability to use time efficiently;
  - ability to negotiate effectively;
  - ability to find a customer / sell a product or a service;
- Personal effectiveness:
  - ability to work productively with others;
  - ability to perform well under pressure;
  - ability to make ideas clear to others;
  - ability to assert authority;
- Communication skills:
  - ability to use computers and the internet;
  - ability to present results of your work to an audience (meeting, workshop, etc.);
  - ability to write reports and other documents;
  - ability to write and speak in a foreign language.

III. Results and Discussions

A. The value of diplomas, scientific degrees, experience

Following the traditional approach, to assess skills of highly qualified personnel, graduates of engineering schools and universities, the level of education or years of schooling have often been used as a proxy. The analysis of data concerns how the surveyed engineers' first job after graduation relates to their profession according to the respective diploma. This reveals that the majority of them (62%) worked «exactly according to their professional qualifications» and only 10% found jobs which had nothing to do with their formal specialism. The closest match between the first job and formal qualifications is observed for doctorate holders and research engineers, which is probably explained by their early immersion into the professional area, participation in research projects during their student years, and combining postgraduate studies with work.

This hypothesis is confirmed by the respondents' answers to the question about their professional activities during their university studies. Doctorate holders participated in their university's research projects twice as often as the average for the sample, and much more frequently had (part-time) jobs in their professional field. This group also stands out in terms of engagement in R&D work at their university. At the same time other groups of the surveyed engineers show much lower activity in terms of learning their chosen profession at university. The least active of all were the future industrial engineers: for them, the most typical form of extra work during university years was part-time jobs, both inside and outside their professional area.

Despite the fact that the share of engineers who work in line with their formal qualifications is quite high, less than a third of the surveyed were fully satisfied with the knowledge they possessed. Note that research engineers are the most dissatisfied in the sample (77%), while engineers employed by industrial companies are more happy than others (33% are quite satisfied). Also the share of engineers who feel an acute shortage of knowledge and the need for further education or another form of professional upgrading, is rather small – between 6-9%.

An important indicator for the willingness to upgrade and participate in life-long education and training is the investment of one's own money into further education. According to the survey, only one third of the respondents (on average for the sample) ever invested their own funds into their professional advancement. The most common form of upgrading was short-term training courses and workshops in their main or related professional area (every third respondent engineer took part in such events).

At the same time the survey results showed that further education (and not just short courses or workshops, but even postgraduate studies) often had no effect on the surveyed engineers' positions. In approximately one quarter of the cases, further education had not affected the respondents' careers. Fewer respondents still reported that after upgrading they were able to find a more interesting job: for those who completed postgraduate studies the relevant figure was just 5%, and for those who received second higher education, 12%. The same goes for pay (at least, according to the respondents' reported feelings): upgrading had a positive effect over their compensation in only 6-9% of the cases. The most effective forms of upgrading in terms of getting a pay rise was acquiring an MBA degree, and learning to use specialised software packages. The most common positive effect of further education was strengthening one's job security, at the same job in the same organisation.

B. Engineering education and application of acquired skills

Analysis of the collected data revealed that the surveyed engineers generally rated their knowledge and skill levels quite high in practically all areas. One may suppose that the respondents had a tendency to exaggerate their self-assessment, since (with rare exceptions) their self-assigned ratings didn't go below three on the scale of one to five. On the other hand, being accepted for the posts that these people actually occupy necessarily involves possession of a high level of the skills. Furthermore, cases of engineers' rating their skill level above the required at the job were rare (tab. 1).

Thus the assessment shows that on average, the level of skills, knowledge and abilities required by employers is regularly seen to be somewhat higher than the level of competencies the engineers actually had. Industrial engineers are expected to possess competencies needed to efficiently perform their work, including theoretical knowledge and professional engineering skills.

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TABLE I. LISTS OF MOST RELEVANT COMPETENCIES AS RATED BY INDUSTRIAL ENGINEERS

Rating	Actual competencies	Required competencies
1	Ability to work productively with others	Ability to use time efficiently
2	Ability to rapidly acquire new knowledge	Ability to work productively with others
3	Ability to make ideas clear to others	Ability to make ideas clear to others
4	Ability to use computers and the Internet	Knowledge of other fields or disciplines
5	Ability to write reports, memos or documents	Mastery of own field or discipline
6	Ability to use time efficiently	Ability to rapidly acquire new knowledge
7	Analytical Skills	Ability to negotiate effectively

The biggest gaps between what is needed and what skills are actually possessed were found to relate to organizational and management skills, the first of which being an ability to find customers, sell products/services. The surveyed engineers assessed their proficiency with this skill as low, with research engineers showing the worst assessments. On the other hand it should be noted that researchers were more critical about their skills and abilities than all other surveyed engineers, however these are self-assessments rather than independent judgments, and it may be that the lower ratings reflect the nature of research work, rendering self-assessments judgments were more critical by default; this remains to be investigated by other means.

C. *Competency space: primary structuring factors*

Surveying a large number of workers, employed at various industries and performing various functions, produces complex results in terms of the numerous skills considered. Therefore techniques for analysing empirical data are particularly important. These can reveal significant correlations between various kinds of skills, and identify, on the one hand, major characteristics which differentiate among sample participants, and on the other, allow us to examine the actual structure of the skill set under consideration. One such technique is multidimensional scaling of competencies.

Multidimensional scaling of competencies made for the whole sample of the surveyed engineers, allows us to build a competency space which reflects the structures of actual and of required competencies. This method (unlike measuring average values) allows to reveal latent connections between various types of competencies, and identify, on the one hand, the most important characteristics which differentiate the sample of engineers, and on the other, analyse the actual structure of the skill set being assessed here.

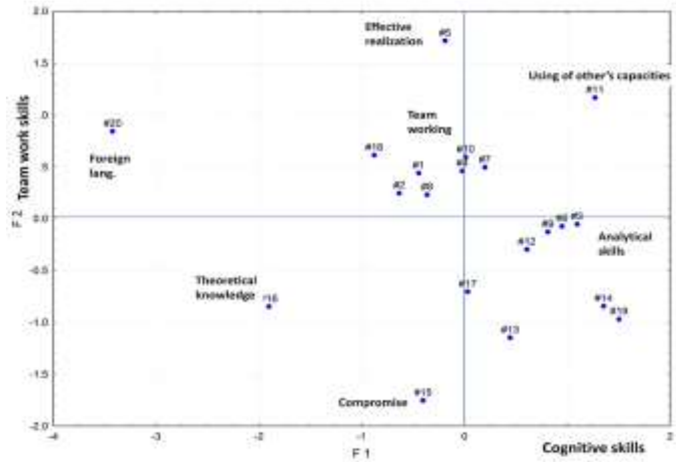

Figure 1. Actual competency space of the surveyed engineers

First, actual competences are considered (fig. 1). The set of knowledge, abilities and skills the surveyed engineers possess is represented as a space structured along two axes, which can be labelled «cognitive skills» and «team work skills». Axis F1 (cognitive skills) differentiates engineers depending on the level of their analytical skills, computer and Internet skills, ability to clearly present their ideas, and foreign language skills. Note that the ability to discuss professional topics in foreign languages is an important differentiating factor, far removed from all other cognitive skills in the competency space and forming a kind of negative pole – which demonstrates not just the importance of this competence but its low level among the surveyed engineers.

Axis F2 (team work skills) differentiates engineers depending on their ability to find compromise solutions, and on the other hand, depending on their abilities to mobilise and use other people's (subordinates') potential, and efficiently implement their plans.

Now, turning to required competences (fig. 2), the skills that the engineers believe are called for at their jobs are structured differently than skills they actually have.

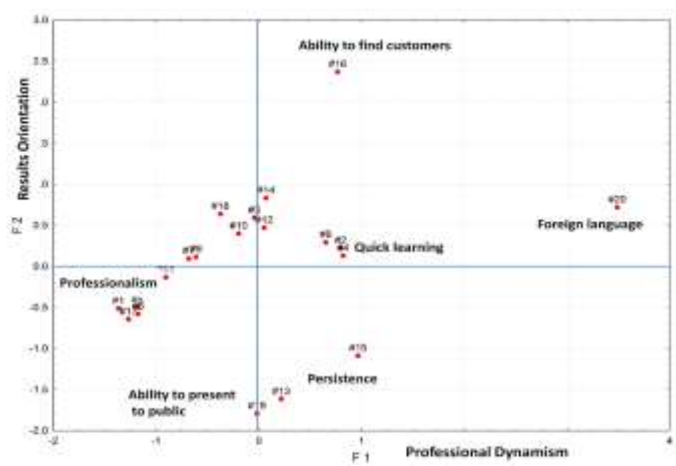

Figure 2. Required competency space of the surveyed engineers

The two structuring axes are F1 (which we call «professional dynamism») and F2, which can be defined as «results orientation».

The professional dynamism axis allows differentiating engineers depending on the level of their professional engineering skills, their ability to critically asses their own and other people's ideas, efficiently implement plans, and discuss professional topics in foreign languages. Note that the accent here is placed on practical application of engineering knowledge and skills, while theoretical knowledge in the specialism area is not a differentiating factor. The «results orientation» axis allows to rate engineers depending on their ability to sell their ideas/products/ services; ability to present their results to an audience; and ability to insist on their position. Again, practical aspects of the above skills and abilities, and their active application are the important factors here.

Thus results of multidimensional scaling of actual and required skill levels of the surveyed engineers form «competency classes» different from the theoretical grouping in five groups: professional, organisational, management, communication and personal efficiency. The data analyses suggest that the group of competencies includes the following subgroups: «professional dynamism», «results orientation», «team work skills», and «cognitive skills». As for skills required by employers, there is a clear stress on the active application of skills necessary for the efficient achievement of results, while engineers themselves demonstrate a latent inclination to «use what they already have». Skills mostly in demand are the ability to find customers and sell products/services, and professional communication with foreign partners or consumers – qualities directly related to innovation culture. The most important of actually available skills are the ability to find compromise solutions, use other people's potential, and one's own analytical ability.

These results are very much in line with the ones obtained by Russian [3, 4, 6, 19, 20] and international researchers analysing professional competencies and skills in demand in the labour market [2, 11, 14]. Specifically, according to surveys of employers, the following skills are currently more in demand than others:

- the ability to efficiently operate in a competitive environment, under stress factors, etc.;
- business communication skills, in particular cooperation and team work;
- the ability to work with various information sources (finding, processing, storing, reproducing information);
- the ability to operate and make responsible decisions in unusual and uncertain situations;
- willingness for continuous learning, training and professional upgrading;
- critical thinking and self-organisation ability.

Our survey of engineers' competencies did not involve such polling of employers, and was based only on engineers' self-assessments; however, in future, during the next round of highly skilled professionals' monitoring, we do intend to collect employers' opinions – which would help to have a deeper understanding of which skills are in demand in the innovation economy.

IV. Conclusion

The study has shown a number of deficits in the perception of innovation skills and the respective demand for these. For a large proportion of university graduates, the qualifications acquired at university or related higher education institute are not sufficient for efficient work in the engineering profession in the current economic situation. To become successful and demanded, they turn to various sources of further knowledge and skills. A third of all participants in additional training found that their main objective was to acquire new knowledge in their existing professional area. It could be shown that technical competencies and specific engineering skills, alone Russian engineers and doctorates poses are not sufficient in the modern labour market but employers expect engineers to actively promote the products they create, including at foreign markets. Insufficient university training in a number of fields including the development of social, management and communication skills leads to an objective and understandable gap between the perceived and the required levels of such competencies. Russian engineers and researchers are expected to have management skills and be more innovative than their European colleagues. Moreover there is an increasing high demand for professional dynamism, orientation towards results, and team work skills

This observation is confirmed by the assessment that Russian companies and research institutes frequently lack efficient managers, thus their responsibilities frequently have to be taken by engineers and researchers.

The most important trend identified during the study is that Russian doctorate holders' level of general and specific skills is lower than what's required at their jobs, while for Europeans the trend is reverse, i.e. they believe the level of their skills (practically in all categories used in the survey) is higher than what their employers need.

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