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Developing the System of Attracting Talented Young People to the Engineering Educational and Career Paths: The Russian Problem Field and Empirical Research on School Graduates' Expectations

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Abstract
A decline in the popularity of engineering education is one of the most urgent challenges for the educational community in many countries of the world, including the Russian Federation. In the formation process of capitalist relations in the Russian Federation in the 1990s – early 2000s, the system of higher education was focused on the preparation of specialists in the field of economics, management and law, which were needed for the new economy.
With the saturation of the labour market and the development of industrial modernization processes in the late 2000s, the demand for highly skilled engineers in industries began to revive, at the same time, over the past, the popularity of engineering career paths among young people decreased significantly. The present work describes the preliminary results of the study on the perception of educational and career paths by graduates of Russian schools, who took the elective unified state exam in physics (USEP) in 2015. The goal of the study was to identify the main features of the target audience, applicants who pass the USEP, as a category of pupils who are most likely prone to choosing an engineering career path. Within the framework of the study, a questionnaire survey of 2030 applicants from 78 regions of the Russian Federation, who pass the USEP, was conducted. The results of the study reflected a fairly high level of understanding of the choice of engineering education and career path among applicants, the presence of significant differences between the total set of research targets and a group of winners and runner-ups of subject-oriented academic competitions (medallists) allowed determining promising areas of work aimed at attracting students to the engineering education and career paths.

Keywords: Engineering career path, education path, higher education, engineering education, reindustrialization, industry modernization, import substitution, career guidance, higher education marketing, unified state exam in physics

Introduction

The attractiveness of engineering education and engineering as a potential sphere of employment among graduates of higher education institutions (HEI) in a post-industrial society is a topical subject of scientific discourse.
The growing importance of engineering education as a specific object of research since the mid-2000s is characterized by the appearance of academic works aimed at the development of methodological and methodical basis of engineering competencies (Haghighi, 2005; Heywood, 2005; Johri, 2010).
The broad outline to problem of the studies is the crisis of the whole STEM education (science, technology, engineering, and mathematics), which is not only a key factor of national security in the 21st century, but is also the basis for the adaptation of citizens to radical technological changes (Miller, 2004). Moreover, engagement in science and engineering becomes a factor of social stability (National Research Council, 2011).
In the report of Unesco (Unesco, 2010), which reflected important development problems of engineering education, the special role of higher engineering education development in the context of economic recession, during the formation of human resources for the future of innovation growth, was noted. The report also noted that, despite the volume growth in the training of engineers on a global scale (primarily by such drivers as China and India), in many developed countries there is lack of interest to engineering education among young

people. In particular, for the last ten years, the number of graduates, who studied in the engineering areas of training, reduced in Norway, the Netherlands, Japan and South Korea.
Problems of attracting young people to engineering educational paths are observed in other developed countries. These facts are reflected both in the academic literature and in the media. For example, according to British experts, the shortage of specialists with technical education in the UK amounts to 50%, the authors emphasize that the industry faces huge problems of raising the average age of engineers and decline in innovative activity of specialists (Richardson, 2012).
In the USA the shortage of engineers is considered as a problem of national competitiveness (Bischke, 2012).
According to experts, members of the US President's Council on Jobs and Competitiveness, a situation where India and China collectively train almost 12 times more engineers than the United States, is very unfavourable. According to the data given in the article, in 2009 the number of graduates – bachelors in programming in the United States amounted to about 38000 people, this figure is lower than the same figure 25 years ago. While, in fact, a number of graduates in the areas related to design, art, cinematography and photography doubled in the same period.
In addition to the stagnation or decline in interest to the engineering education, a significant problem is the lack of subject-oriented competencies for high school graduates, as well as mistakes in the choice of a career path. So, for example, the expulsion rate of engineers-electro technicians in Germany amounts to 50% (Blau, 2011).
In the Russian Federation, the average score of the USEP, which opens a possibility to enter HEI for engineering areas of training is lower than the average score in the social sciences elective state exam, which allows entering the economic and managerial training programmes. According to the calculations that we carried out based on the state statistics, the average score in the USEP for 2011-2015 is 5.8 points lower than the average score in the social sciences state exam for these 5 years.
At the same time, the share of those who prefer to pass physics as an optional subject in the framework of USE (Unified State examination) is about 22% – 161 000 school graduates passed the USEP in 2015 (Rosobrnadzor, 2015).
Thus, the decline in the popularity of engineering professions, the problems of recruiting motivated and competent school graduates for universities led the researchers to look for new methods and technologies of teaching physics and career guidance, improving the image of technical education based on a deeper understanding of queries and motivation of young people as the subjects who choose educational and career paths. An extensive corpus of work is dedicated to the solution of such problems, in particular (Saunders, 2015; Marušić & Sliško, 2014; Akarsu & Kariper, 2013; Wells et al., 2007).
In this paper we will present the results of the study on the category of school graduates that is maximally close to choosing the engineering education and career path in the Russian Federation. The main purpose of the work was to investigate the features and context of choosing the USEP as an optional exam for USE, which opens up a possibility to enter higher education institutions for an engineering degree. Thus, we propose determining the general characteristics of the contingent, which will be the basis of an engineering talent pool in the next 5-7 years in order to get insights for more focused research on potential influence points on the decisions concerning the choice of engineering development paths. The results of the conducted study may be valuable both for authorities, developing measures to popularize engineering education, and for universities and industrial enterprises, interested in forming a long-term loyalty to their brands and the formation of a highly skilled talent pool.

Background

The historical background of the engineering education development in the Soviet Union/Russia

The development of effective large-scale engineering education was one of the most important goals of the Soviet government in the industrialization period of the 1930s-1950s (Baldin, 2006). At that time, throughout the country a multi-level network of specialized training centres was formed, which provided the actively developing industry with personnel of the required qualification level. Success of the Soviet Engineering Education confirmed during the Second World War, when in a short period of time large-scale production facilities were deployed, mass production and continuous improvement of a wide range of industrial equipment and arms were provided. By the 1960s the combination of a practice-oriented education in the production and technical schools (analogue of technical colleges) and fundamental academic training in technical universities allowed meeting the needs in personnel for high-tech manufacturing enterprises, design bureaus and research institutes, ensuring the implementation of large-scale projects in the field of rocketry, aviation, nuclear energy. In the 1970s-1980s, the technological backwardness of the Soviet Union in the field of microelectronics and automation started to affect the quality of engineering education (Kutirev, 2005).
In the 1990s, after the collapse of the Soviet Union, the demand for engineers declined dramatically. From 1992 to 2002, the volume of manufacturing production fell by almost 50% (Federal State Statistic service, 2015). Most machine building industries were under the conditions of a systemic crisis. Under these circumstances, getting engineering education has ceased to serve as a social elevator, ensure employment and a competitive salary. New economic conditions led to a significant outflow of talented engineers abroad. Even according to the data of the Global Competitiveness Report 2014-2015 (Global Competitiveness Report, 2014). Russia managed to take only the 103rd place out of 144 countries in its ability to retain talented people and the 92nd place in the ability to attract talented people from abroad.
At the same time, higher education institutions, including technical ones, began to actively develop areas of training, which are in demand in the market economy, in particular economic, managerial, legal areas of training (Boldov, 2002). Many technical higher education institutions reoriented to meet the needs of the new economy and lost its focus on specific industries.

The current context of the development of engineering educational and career paths in the Russian Federation

Restoration and development of the industry (Figure 1.) (Federal State Statistic service, 2015), which began in the 2000s, set a new goal for the education system: to revitalize engineering education, form new relationships with business and build integrated chains of personnel training with different qualification levels.

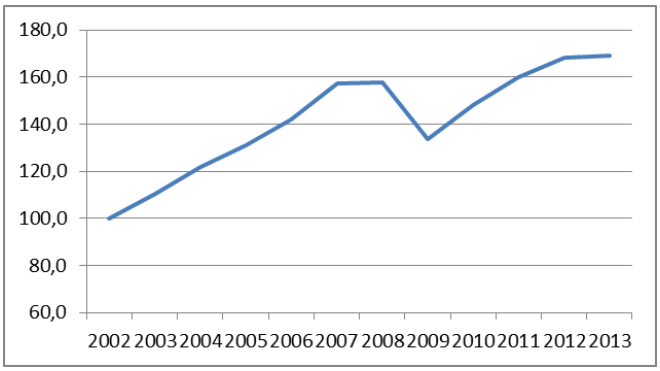

Fig. 1. The growth rate of the production index in the manufacturing industry (2002-2013)

It should be noted that the growth of industrial production was accompanied by an increase in its efficiency. According to the Ministry of Labour of Russia (Federal State Statistic service, 2014), from 2000 to 2012, the labour productivity in Russia steadily increased (for example, in 2003-2012 the growth in the manufacturing industry amounted to 67%). Enterprises also reached a sufficiently effective ratio "salary/productivity". According to the Global Competitiveness Report 2014–2015 (Schwab, 2014), Russia took the 24th place from 144 countries by the "pay related to worker productivity" indicator.

The introduction of the import substitution policy and integrated approach to the management of technological capital in leading industrial enterprises became an important catalyst for the development of the relations between HEI and industry in the sphere of engineering personnel training (Grigoriev, 2014). A number of initiatives of the Ministry of Education and Science of the Russian Federation allowed implementing the development of advanced engineering educational programmes with the co-financing of industrial enterprises (Order of The Ministry of education and Science of Russian Federation, 2015).

Thus, starting in 2010, there is a tendency for improvement of the situation in the field of engineering education, however the technical universities still face the problems in the sphere of global competitiveness (Verstina, 2014). At the same time, the issues of attracting talented young people to engineering educational and career paths became more relevant. These young people in the future will be able to take high positions in the high-tech industrial clusters.

The structure of higher engineering education in Russia

From 972 HEIs, 537 educational institutions carry out the training of engineers by higher education programmes, with 72% of HEIs, which are engaged in the training of engineering personnel by higher education programmes, are the federal state educational institutions. It enables public authorities to strategically develop and have a direct corrective influence on them, taking into account the interests of the state strategy.

From 18 Russian universities, listed in the TOP-800 QS ranking in 2013, 17 HEIs have engineering areas of training (specialties), 4 of which are universities of the technical orientation (BFM, 2013).

Despite the substantial structural transformation of the economy in the post-Soviet period, engineering education has kept its large-scale nature. In 2013-2014, the share of the admission quotas (AQ) (the number of people whose training in the higher education system is provided by the state budget) for engineering and technical areas of training made up 50% of the AQ total. Currently, in 537 Russian HEIs around 1.7 million students are studying for technical degrees (more than 30% from the total number of students of Russian HEIs). By 2010, the levels of admission quotas for engineering profession of 1980-1985 had been reached (Bannikova, 2013) Thus, a situation was formed, when the demand for a high number of school graduates, engaged in the engineering areas of training, changed with the demand for high-quality contingent of applicants for technical HEIs.

Under these circumstances, there is a need in the diagnosis of various characteristics of the current contingent of applicants, who are oriented to enrol for the engineering areas of training. The results of this diagnosis must provide analytical information for the decision-making on promoting and targeting career guidance activities of HEI, production enterprises and federal government institutions in the field of education.

Methodology

The current study was designed as a quantitative survey investigation with a numeric description of variables (in particular, such variables as the planned educational path, planned level of education, desired place of employment, willingness to move a location for education, etc.).

We chose school graduates, who pass USEP in 2015 as a general population for the study. The physics elective state exam is optional for school graduates, unlike the exams in mathematics and the Russian language. The choice to pass physics as a unified state exam, allows school graduates to qualify for admission to HEI for the engineering, theoretical physics and informatics areas of training. This, it is the pupil's choice of physics as a unified state exam that is a key marker of a possibility of their admission for the engineering areas of training.

For the purpose of the study, we designed a questionnaire and converted it into the electronic form. The questionnaire consists of 24 questions, including the filter question: "Are you going to pass the USEP in 2015"? The pilot testing of the questionnaire on 50 school graduates was conducted in 2014.

In order to form a sampled population, we posted information about the study in social networks groups, dedicated to the state exams in physics, mathematics, informatics (with not less than 5000 group members) on "Vkontakte", the most

popular Russian social network. This minimized the possibility of "random" respondents in the sample. Within the framework of this study, we also set enlarged quotas for filling out the questionnaires by the regions of Russia. After the quota was surpassed, the request to complete the geographically targeted questionnaire did not appear in the social network in that region.

Within the monitoring framework, we considered the formed sample conditionally heterogeneous (presence of regional differences was allowed), and calculated that in order to achieve the degree of certainty of 0.95 and with an acceptable sampling error of ±3% a sufficient number of respondents for the sample would be 1060 (with the amount of the general population being equal to 161000 people), however, for a representative analysis of certain school graduate categories, who pass the USEP, it was decided to increase the sample population. As a result of the collection of questionnaire forms in the period of March-July 2015, the questionnaires, which were completed over 85%, were filtered. Next, the sample was adjusted in proportion to the average number of school graduates who pass the physics exams by regions of the Russian Federation. As a result, the sample population amounted to 2030 respondents.

For the analysis of the collected data, we used the "data analysis", a statistical add-on package in MS Excel and the SPSS, statistics package programme.

Results

Providers of applicants and influence groups

To determine which sources of applicants, who pass USEP, HEI and industrial enterprises should be primarily oriented at in the organization of career guidance, promotion of engineering education and its brands, we analysed the places where the respondents received secondary education.

The data suggests that about 42% of applicants who pass the USEP in 2015 are educated either at specialized schools or in special classes. At the same time, 66% of specialized schools (classes), where the applicants, who pass the physics exam, study, have a subject-oriented (physics and mathematics) orientation.

During the study, we tested the hypothesis that among winners and runner-ups of academic competitions, the share of those, who study in physical and mathematical schools/classes in the total sample would be bigger. This hypothesis confirmed, winners and runner-ups of subject-oriented academic competitions from specialized schools/classes study in physics and mathematics schools-classes in 73% of cases.

The findings led to the conclusion that **specialized schools (classes) with the physical and mathematical bias should be regarded as the providers of 30% of talented students – winners and runner-ups of subject-oriented academic competitions who pass the exam in physics.** Moreover, it is possible to suggest that at least a third of those, who pass the physics state exam, choose physics as a subject of the unified elective state exam indirectly, at the moment they choose to study in a specialized school (6-8 years) or at the moment they choose to study in a subject-oriented class (10-12 years).

The second area of diagnostics in the framework of this logic block was the influence groups determination, which could influence the choice of their future educational path.

The majority of respondents – 70% are inclined to believe that their choice of training area is independent. At the same time, winners and runner-ups of subject-oriented academic competitions consider themselves a little more independent in the context of professional self-determination than all those who pass the USE in physics (the difference between the estimates is 6.2%). The first most important influence group, which has an impact on the applicants' choice of training area are parents and other relatives (24% of respondents say that the choice of a training area was determined by parents or other relatives). Friends and school teachers, in accordance with the respondents' opinion, determine their choices rarely (3.1% and 2.7%, respectively).

Motivation to learn and pass the USE in physics

To understand the motivation of applicants, who pass the USEP in 2015, we asked a question with a multiple choice about their favourite school subjects. The results showed that the majority of applicants have strong inner motivation to study physics, mathematics and informatics (Figure 2).

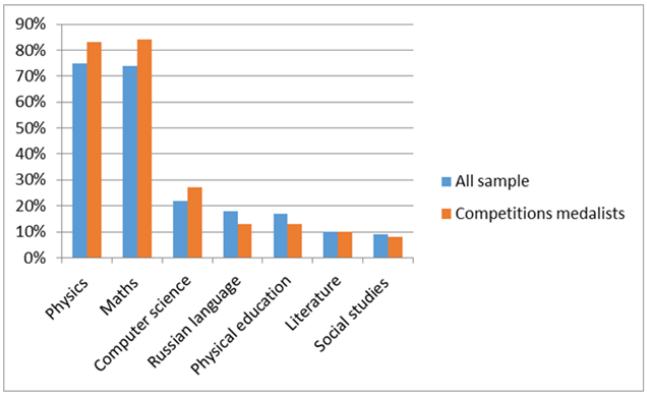

Fig. 2. Favourite school subjects of graduates, passing USEP (%)

It should b**e** noted that **such subjects as the Russian language and literature were referred to as favourite subjects by a significant part of respondents as well.** Presence of such preferences is especially relevant due to the increased importance of soft skills in the work of engineers, as well as for educational rotation and international scientific and technical information exchange. At the same time, winners and runner-ups of subject-oriented academic competitions demonstrate a more focused interest in profile subjects and prefer humanities more rarely.

Planned educational paths

Given the priority of providing an engineering development path of those who pass USE, it should be mentioned that **only 50% who chose this subject for the USE plan to study in engineering areas of training** (*Figure 3*).

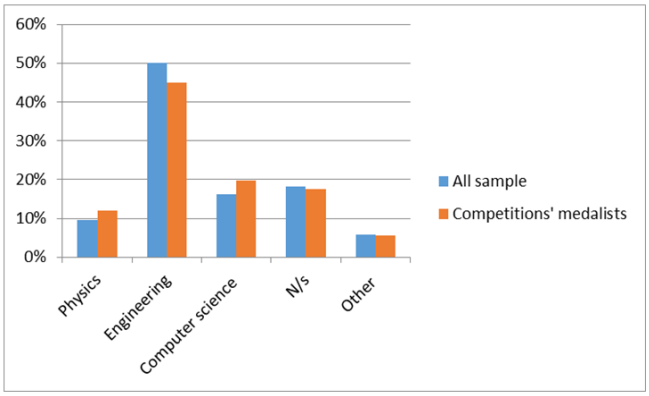

Fig.3 The expected area of specialization for school graduates,passing the USEP (%)

It is important that **among talented young people who take part in subject-oriented academic competitions, a number of those, who intend to study in engineering areas of training is lower than the average (45%).** It is noteworthy that winners and runner-ups of subject-oriented academic competitions have shown greater interest in such areas of training as "physics" (on physical faculties of HEI) and "informatics and computer science" (a total of 32% compared to 26% in the sample as a whole). At the same time, the share of those who haven't chosen a potential area of training among academic competitions winners and among all applicants who pass USEP is almost identical (about 18%). Thus, the hypothesis that winners and runner-ups of academic competitions picture the profile of their higher education more clearly is not supported by our study.

To understand respondents' current attitudes to expected volume and depth of acquired knowledge in the higher education system, we asked them about the desired level of higher education.

The results of the monitoring (*Figure 4*) indicate that about 80% of applicants have a formed request to the planned level of higher education.

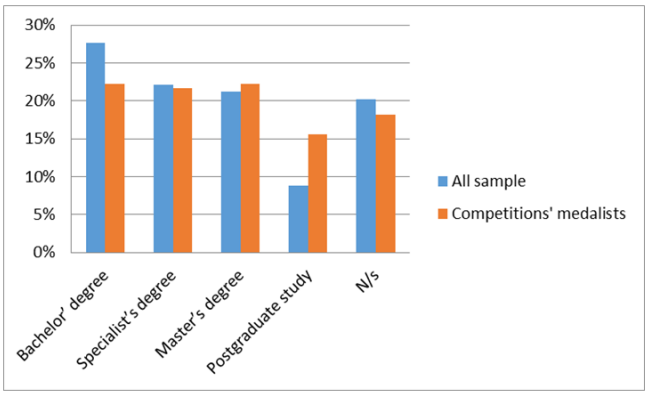

Fig.4 Level of higher education that school graduates, passing the USEP, are planning to get (%)

At the same time there are differences in the approach to building an educational path among those who pass USEP as a whole and subject-oriented academic competitions winners. Thus, significantly fewer winners and runner-ups of academic competitions, who have chosen the education level, are planning to complete their studies with a Bachelor's degree, while winners and runner-ups of academic competitions are more oriented on post-graduate studies. We attributed the relative equality of the share of respondents who plan to obtain a specialist's degree (traditional one-level system of obtaining five-year higher education with a specialization, which was wide-spread in the USSR and Russia before joining the Bologna system) and a Master's degree, to the important features that require further verification. It can be assumed that the applicants do not see significant differences between these forms of training in terms of further career advancement.

Overall, the results generally support the hypothesis that the most talented high school graduates are eager to get an in-depth development of their competencies in the subject area of interest.

Attitude to academic mobility

The issue of academic mobility within the country is important for Russia, also due to the fact that for the last 10 years nearly 40 leading universities of the research type with a modern research infrastructure have been formed. The territorial distribution of these universities by the Russian regions presupposes an increase in academic mobility to fill the needs in personnel of the regional skilled labour markets.

For diagnostic purposes, the current attitudes of the target audience of applicants who passed the USEP, the following problem was taken into account in the questionnaire (*Figure 5).*

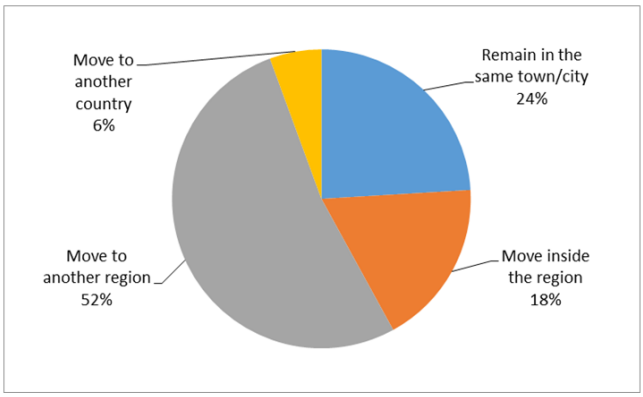

Fig. 5 The willingness to leave the home town to enter the desired HEI (%)

The analysis showed that applicants demonstrate a significant potential for academic mobility. 76% of respondents are ready to leave their home town in order to obtain higher education

Some groups of school graduates, particularly those living in the cities with a population of less than 250 thousand people demonstrated a much greater desire to leave their home town

to obtain higher education – and only about 5% of this category of respondents indicated that HEI must be located in the city of their residence (including, due to a probable lack of worthy HEI or HEI as such in their city).
High inter-regional mobility is worth mentioning – 52% of applicants consider moving to another region acceptable in order to obtain higher education. A significantly smaller number of applicants allow for the possibility of studying abroad (6%). It is important to note that among the competition winners the share of whose admitting the possibility of studying abroad is superior to the average indices and amounts to 8.6%.

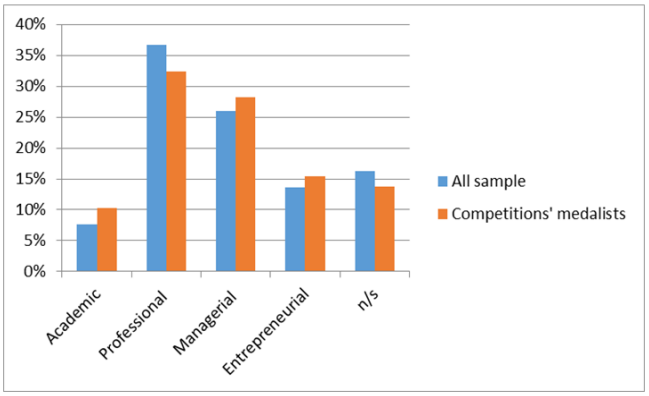

Fig. 6 The planned career paths of graduates, passing the USEP (%)

Planned career paths
Despite a significant percentage of respondents who have not yet thought about an image of the "perfect employer", it can be concluded that the most attractive employer for applicants, who pass the USEP is a state company (33%). Private companies are on the second place by popularity (21%). 19% of respondents are planning to establish their own business, while 4% of students plan to work in the freelancing mode. The rest of respondents did not think about the typology of potential employers.
In addition, the majority of applicants (about 40%) who pass the USEP, have not thought about the size of a business in which they would be comfortable working with. At the same time, the rest of the respondents showed interest in employment in large companies (37%). Only about 23% of the respondents are interested in being employed in small and medium-sized businesses. The study also found that winners and runner-ups of academic competitions, who prefer to work in small businesses, are significantly more interested in working in state-owned companies than the sampled population as a whole (38% compared with 23% of the sample as a whole). This phenomenon requires further research. We can assume that this is due to the desire of talented young people to work in small innovative companies that receive investment support from the state in return for a stake in the business.
In accordance with the results of the analysis, 63% of applicants plan to build a professional (37%) or professional-managerial (26%), career (*Figure 6*). However, a significant number of respondents (14%) intends to become an entrepreneur, 8% of applicants are planning to build an academic career. As expected, winners and runner-ups of academic competition show a greater desire to develop in the academic (10%) and entrepreneurial (15%) paths than the respondents in general, that is consistent with their educational paths, oriented on getting a master's degree or a PhD.

Attitude to career guidance activity
Since the beginning of the 2010s first, educational organizations and then industrial enterprises came to the realization of the need in long-term career guidance for applicants and pupils. This activity was primarily focused on promoting brands of certain HEI. At the same time, major corporations started to run career guidance events on a large scale, which are designed to attract pupils both to an employer brand, and to a certain engineering vocation (e.g. energy supply engineer, petroleum technician, mechanic engineer, rocket engineer, etc.) The most common formats of career guidance that are worth mentioning, are open lessons, master classes, excursions to production facilities, various contests and intellectual competitions. In order to initially assess the impact and perception of the target audience of career guidance activities held by HEI and industrial corporations, respondents were asked a direct question about their assessment of the effectiveness of career guidance activities *(Figure 7)*.

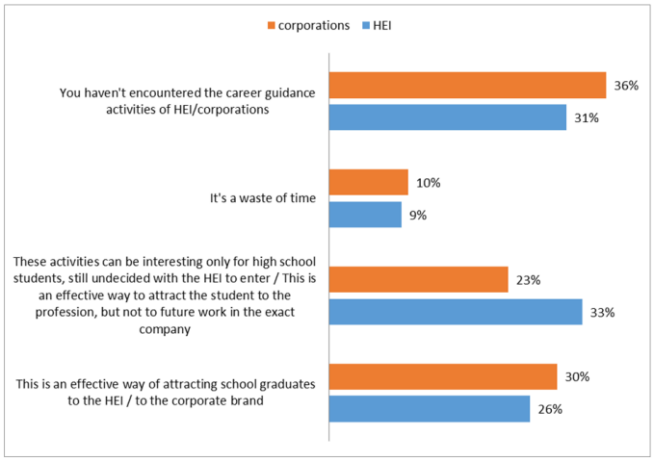

Fig.7 Evaluation of career guidance activities of HEI and enterprises from school graduates, passing the USEP (%)

According to the obtained data, about one third of those, passing the USEP, haven't encountered the career guidance

activities of HEI and industrial corporations, which indicates significant reserves for increasing the coverage and effectiveness of these measures.

At the same time, a significant number of school graduates who pass the USEP believe that the activity of HEI (26%) and corporations (30%) is an effective tool for attracting pupils. The fact that 23% of respondents consider career guidance effective only for those who have not decided on a HEI, indirectly confirms the hypothesis that a significant share of pupils selects an appropriate HEI in advance. Finally, about one third of respondents believes that the activity of corporations enable applicants to determine a future profession, but are not a tool for forming loyalty to a particular enterprise.

Discussion and Conclusion

The conducted study opens up a wide scope for further work and generates a whole range of research niches. Detailed elaboration of analytical blocks in our work and comparison of the questionnaire results with the data on the activity of HEI and corporations in the field of career guidance allows drawing out a comprehensive picture of the problem under consideration and developing effective mechanisms for decision-making.

Generally, the results presented in this article reflect the positive prerequisites for successful development of engineering education in Russia. It should be noted that the number of those who pass the USEP is enough to meet the needs of the industry in engineering staff with various levels of training. The choice of the USEP is perceived by the majority of applicants as their own and deliberate. At the same time a substantial share of gifted students, especially winners and runner-ups of subject-oriented academic competitions of various levels (approximately one quarter of the sample), show a willingness to learn for a long time (master and post-graduate programmes), in order to continue building namely professional engineering career paths. At the same time, we came to the conclusion that engineering training areas enter into serious competition with such training areas as computer science and physics, which nowadays "pull" over a substantial part of the talented applicants. Career guidance technologies should work proactively to ensure that highly motivated talented personnel will have studied engineering at HEI by the moment when there will be increase in the competitiveness of engineers' salaries and overproduction of personnel with IT-education, which is expected at the Russian labour market in the next 3-5 years. Therefore, a planning horizon for the career guidance activity should last at least 4 years, covering pupils of the 7-8th grades.

The results, obtained in the course of the study, confirmed the lack of current career guidance activity of HEI and corporations, as well as indicated the need to focus on specialized physical and mathematical schools and classes, which are "providers" of a significant part of students, who pass USEP.

A significant problem that was partially brought up in the study and which requires more serious analysis, is the limited geographical mobility of certain categories of applicants. Primarily, it concerns large cities, where applicants demonstrate minimal readiness to move to other regions for education. Such a situation may hinder the development of both regional educational centres and industrial enterprises in the regions, from which there will be an outflow of talented young people, but there will be no inflow of qualified personnel by the model "from the centre to the periphery". Undoubtedly, one of our future studies should be devoted to the study of this phenomenon and the search of mechanisms to overcome it. Despite the fact that we tested the presented data for statistical significance (H0 hypothesis rejected), we consider it necessary to hold a similar monitoring in a year in order to check the dynamics and make minor adjustments in the design of research, primarily related to the specifics of the chosen method of respondents recruitment.

In conclusion, we would like to emphasize that the problems of engineering education are of global nature. The mass automation and the transition to smart production blur the line between engineering and IT. On the one hand, engineering education becomes multidisciplinary and modular, focused on the development of applied competencies in demand, on the other hand, it requires bigger fundamental basis, which prevents the conversion of engineers into technical operators who do not understand the structure of complex systems. Mastering a set of complex competencies and expanding the frontiers of learning for the whole working life require special skills and motivation to work. Thus, the education system not only in Russia, but also all over the world, faces a need to ensure the functioning of the interconnected systems of recruitment, selection and involvement of talented young people in engineering creativity. Such approach also sets a task for future researchers of this problem to analyse the communicative effectiveness of different mechanisms of influence on the target audience, pupils of the 7-10th grades, by universities and interested industrial corporations.

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