TRAINING EXPERIENCE OF ENGINEERS: COMPARATIVE EVALUATIONS OF THE ORGANIZATION AND LEARNING OUTCOMES OF BACHELORS

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Abstract

Sverdlovsk region belongs to the old industrial regions of Russia and is one of the pilot areas for the implementation of new standards of staffing for industrial growth. The Ural Federal University (UrFU), being the responsibility centre for the training of a new generation of engineering cadres, implements undergraduate educational programs based on various institutional mechanisms, including in cooperation with major industrial partners. Since 2017, the regional labor market has been actively replenished by graduates of technical baccalaureate who have been trained both within the university educational environment and in the format of social partnership between the UrFU and one of the largest enterprises in the Urals - the Ural Mining and Metallurgical Company (UMMC).

The article summarizes the results of a comparative study of the organization and results of training of engineering cadres in the traditional and network forms of practice-oriented learning. The research analysis was carried out using the methods of document analysis, case-method, data integration, student survey. The pilot status of the survey was interpreted by the authors as a research experiment, the results of which allowed to obtain the first assessment of the effectiveness of the introduction of new practices of training of engineers. The experiment involved 2 groups (traditional form – N = 28, network program - N = 32, both – class of 2017). The survey was conducted in the form of a questionnaire. The survey methodology was focused on a comparative analysis of graduates' assessments of the effectiveness of training on traditional baccalaureate (TB) and practical-technological baccalaureate (PTB), the compliance of educational programs with the requirements and demands of the labor market; identifying the specifics of professional plans and the degree of their readiness to work in the specialty. The comparative characteristic of the organization of professional training was correlated with the assessment of the importance and level of development of key competences of the modern engineer.

The results of the research experiment demonstrate the ambiguity of the identified trends. Graduates of the TB more highly evaluated the level of influence of the training program on the formation of competencies required in future professional activities, as well as the program's compliance with the requirements and demands of the market. Graduates of the PTB, adequately representing the real situation and requirements of modern production, note a higher level of satisfaction with key aspects of the organization of practice-oriented learning: the organization of work experience internship, the involvement of specialists of academic / sectoral science and production for counseling and joint management. In general, expressing overall satisfaction with the fundamentals of engineering training and the organization of work-study practicum,

representatives of both groups found it difficult to estimate the role of the educational module on forming soft skills are poorly represented what was going on. A common feature in the assessments of the role of educational modules in the formation of engineering knowledge of graduates was the predominance of mediocre grades.

The data obtained allow us to sum up the preliminary results and clarify the further program for analyzing the effectiveness of new models and professional training practices for technical specialists.

Keywords: professional training, engineers, practice-oriented learning, University-Industry collaboration, empiricism.

1 INTRODUCTION

One of the most significant problems of regional engineering education is the poor compliance of the professional competencies of graduates of technical training with the current and future needs of the engineering labor market, their qualitative deficit. The solution of the problem lies in the plane of finding effective mechanisms of interaction between technical universities and industrial enterprises. The educational practice of training engineers at the Ural Federal University corresponds to the new formats of engineering education (Rebrin, 2015, pp. 77-79, 81-83) - competence approach and methodology of designing learning outcomes based on the integration of education and production. The formation of a new generation of specialists is carried out in the conditions of a pronounced practice-oriented focus of the educational process, the creation of the corresponding educational environment by joint efforts of the university and the enterprises-partners. One of the shining examples is the interaction of UrFU with the largest enterprise of the Sverdlovsk region - the Ural Mining and Metallurgical Company (UMMC). Understanding the history of the seven-year interaction of the university with an industrial holding reveals the institutional opportunities and risks not only in the development of social partnership of subjects from education and industry, but in general, in the field of engineering training.

The partnership was initiated in 2011. On the basis of the High Engineering school of UrFU and UMMC was developed practice-oriented program of production and technological baccalaureate (PTB) in the field of "Metallurgy". The main objective of the program is to prepare junior and middle-level professional technical and engineering employees for staffing the metallurgical production of the UMMC. The program was developed taking into account international practices of preparing a new generation of engineering cadres, main trends of modern engineering education:

- ensuring the demands of modern economics based on practice-oriented learning (Degreve and others, 2013, p. 6190);
- reforming engineering education with the active participation of professional communities and specific employers (Monteagudo and others, 2011, p. 5848);
- using the methodology of learning outcomes of the Worldwide CDIO Initiative (Conceive - Design - Implement - Operate), which provides the necessary balance between the requirements of specific employers and the development prospects of existing industries and the emergence of new ones (Chuchalin and others, 2011,).

The new program also took into account the local requirements of the industrial holding - it was developed on the basis of professional standards of UMMC. In comparison with the traditional baccalaureate, the practical component was strengthened in the PTB program: duration of the production practice based on the UMMC was increased; application of project-based training technologies related to the elaboration of a specific problem node or technological chain on the instructions of manufacturer; involvement in the educational process of experienced specialists; use of active learning methods aimed at developing the necessary leadership skills and professional competencies associated with the ability to work in a team (Bannikova and others, 2013, p. 194).

An important element of the program is the transfer of part of the educational process to the sites of the enterprise. The organizational and legal form of implementing the program on the basis of the partnership between Ural Federal University and UMMC was the creation in 2012 of a basic department (a structural unit of the University that provides practical training for students on the basis of another organization carrying out activities according to the profile of the corresponding educational program). The format of the basic

departments contributes to the realization of the interests of all participants in the educational process (Dmitriev and others, 2014, p. 74), (Oleynikova, 2014, p. 105), (Boronina and others, 2016, p. 3630). Students have a new form of professional socialization, in which educational training is implemented in real production conditions. This greatly increases their chances of employment. The company prepares future cadres in accordance with their needs, saving financial and time resources for the adaptation of university graduates and their finish learning. An educational institution increases its level of competitiveness, significantly improving the material and technical base and financial support for training specialists.

The implementation of the PTB program was a powerful factor for the development of innovative forms of cooperation with industry in other areas of training technical specialists in UrFU. Along with the basic departments, forms of network interaction with enterprises in the traditional undergraduate degree appeared. The formation of practice-oriented modules in the educational program allows using not only the resources of the scientific and technological base of enterprises, but also the intellectual capital of their R & D centers, which are focused on developing innovative technologies and competitive products and feel the need for creative young professionals with non-standard thinking. The experience of cooperation between Ural Federal University and UMMC began to be actively replicated with other partner enterprises.

However, there was another, centrifugal trend in the university's social partnership with large regional employers. Thus, in 2013, the corporate Technical University of UMMC (TU UMMC) was established in Verkhnyaya Pyshma. TU UMMC is a unique project that has arisen at the junction of education and production. Today, the university has about 300 additional professional education programs. Their duration is from 16 to 300 hours. The list of training courses is updated annually by 40% in accordance with the requests of enterprises and with the aim of advanced training for the modernized production. About 8,000 employees every year receive advanced training in the TU UMMC. Every year about 12 thousand people study here - engineers and managers of all levels, workers, and students from the cities where the company operates. TU UMMC was the first private technical university in the Urals and the only private university of mining and metallurgical profile in Russia. After receiving the state accreditation of the Ministry of education and science of the Russian Federation in July 2016, TU UMMC received the right to carry out not only programs of additional professional education, but also independent training of engineers-bachelors by analogy with classical University education, and to issue state diplomas of higher education to graduates. The number of students on October 1, 2018 was already 616 people. The corporate training system, which was actively developing during the crisis of higher education in the country in the early 2000s, can become a real competitor to the classical education system in the new conditions. The acquisition of academic experience in innovative forms of cooperation with universities allows corporate forms of training to actually compete in the market of engineering work and education. An expert interview with regional employers in 2016 showed that over the past years, the demand for graduates of regional universities from employers has been minimal: "The needs for the young and inexperienced, who need to be taught, to spend money on them, will be less and less ... It is not profitable for the company to take young people and study. It is necessary to give a product, it is necessary to give the results of its activities, and not to tinker with inexperienced beginners who can't make decisions, make mistakes. The more expensive the equipment, the more expensive the cost of the error. The owner is better to prevent this mistake by hiring another" (Sholina and others, 2016, p. 180). And the matter is not only in the peculiarities of the anti-crisis personnel policy of enterprises. One of the main reasons is the unsatisfactory assessment of the presence competencies of university graduates. On average, the level of training corresponds to the expected by employers by no more than 50%. According to the informants, the graduates lack good basic training, personal responsibility, ability to work in a team, stress tolerance, self-motivation.

Professional communities of engineers and the academic environment are actively seeking answers to questions about what and how to teach engineers, rethink the content of engineering education, strive not only to keep up with rapidly changing engineering and technology, but to anticipate future industry demands for engineering competencies. How will these processes go? In close collaboration or autonomously? For whom is the current and future quality of training engineers? The history of partnership between Ural Federal University and UMMC in many respects predetermined the design of our research experiment.

2 METHODOLOGY

In the summer of 2017, UrFU carried out the second graduation of bachelors of engineering specialties, prepared in accordance with the educational standards developed by the university on the basis of professional standards of UMMC. The purpose of the research experiment is to obtain first assessments of the effectiveness of introducing new practices in the training of engineering cadres. The experiment involved 2 groups of students (the traditional form - N = 28, class of 2017; network program - N = 32, class of 2017).

In the experimental and control groups, three-quarters of the students studied on a budgetary basis, and three-quarters of both groups were male. On the programs of practice-oriented baccalaureate studied mainly residents of a small town (population less than 100 thousand people.). According to experts, the establishment of technological or polytechnic institutes is especially productive in small cities, since it helps to resolve the issue of the fixability of personnel in the workplace. Many young people will be able to get a high-quality, practice-oriented higher education in their hometown, whereas from large metropolitan areas they most often do not return after studying at university.

The survey was conducted in the form of a survey. The survey methodology was focused on a comparative analysis of graduates' assessments of the effectiveness of training on traditional / academic bachelor (TB) and PTB programs, the compliance of educational programs with the requirements and demands of the labor market; identifying the specifics of professional plans and the degree of their readiness to work in the specialty. Comparative characteristics of the organization of professional training were correlated with assessments of the significance and level of development of the key competencies of a modern engineer.

3 RESULTS

The main question of the questionnaire was focused on the evaluation of the training effectiveness of graduates in the programs of PTB and TB (table.1).

Table 1. Assessment of the influence level of the educational program on the formation of competencies required in the future professional activity of bachelor (%)

Assessment levels	PTB	TB
It helped to the full	7	19
To a large extent	57	42
To a certain degree	28	13
To a very small extent	4	23
It did not help at all	4	3
Total	100	100

When asked to assess the level of influence of the educational program on the formation of competencies required in future professional activities, graduates of PTB gave more restrained assessments. Only 7% of respondents confidently articulated an absolutely positive response. At the same time, graduates of the TB very favorably assessed the effectiveness of their educational program. The distribution of negative responses in the experimental and control groups is approximately equal (Table 2).

Table 2. Assessment of compliance of the quality of training with requirements of labor market (%)

Assessment levels	PTB	TB
Fully compliant	4	10
Rather yes than no	30	77
To a certain degree	59	10
Definitely not	**7**	**3**
Total	100	100

Somewhat surprising for researchers were the assessments of the compliance of learning outcomes with the demands of the modern labor market (Table 2). About 60% of the respondents of the experimental group (PTB) believe that the quality of training in their program only to some extent corresponds to modern market conditions, while respondents of the control group (TB) in their significant majority (87%) rate compliance very high.

Comparison of estimates of specific characteristics of the organization of professional training of bachelors, in many ways, clarified the situation (Table 3).

Table 3. Comparative characteristics of the training organization (% positive estimates)

List of statements	PTB	TB
The quality of teaching specialized disciplines	89	90
Technical base, laboratory equipment and classrooms	67	71
Organization of production practices	74	39

Involvement of specialists from academic and industrial science, production for consulting and joint leadership	52	29
Organization of educational process (schedule of classes, exams)	67	64
Learning methods and knowledge control.	70	71
The connection of acquired knowledge with real work in the profession	67	55
Work of tutor (curator) of group	49	26

* The amount exceeds 100%, since one respondent could give several answers at the same time.

At the general high estimates of teaching quality of profile disciplines, graduates of PTB have higher level of satisfaction with the organization of production practices and connection of received knowledge with real work in a profession. It is these key aspects of the organization of training, which are characteristic for the specifics of the practice-oriented program, caused the restraint of its graduates ' assessments regarding the compliance of the quality of training with the demands of the modern labor market. Rather, it is a more cautious, "adult" assessment of future engineers, well representing the real situation and requirements of modern production.

The modular structure of educational programs allowed the research group to identify the peculiarities of the respondents' opinions of the control and experimental groups about the level of influence of the disciplines modules on the formation of system knowledge about the obtained engineering profession (Table 4).

Table 4. Evaluation of the impact of educational program modules on the formation of system knowledge of the engineering profession.

Modules	PTB		TB	
	Score	Rating value	Score	Rating value
Soft skills	2,5	11	1,71	10
Software engineering	3,30	4	2,83	5
Fundamentals of engineering activities	3,70	2	3,06	3
Information technology in engineering	3,44	3	2,90	4
Mathematics for Engineers	2,67	10	2,70	6
Systems in science and technology	3.18	6	2,58	8
Fundamentals of engineering training	2,96	8	3.19	2
Control systems	3,0	7	2,65	7
Basics of business process management in enterprise	3,0	7	2.48	9
Modern machine engineering technology	3,0	7	2,65	7
Product design training	3,26	5	2,81	6
Full life cycle of technical systems	2,70	9	2,90	4
Training and Production Workshop	4,3	1	3,45	1
Grade point average	2,9		2,8	

Despite the difference between the points and rating values, graduates of both groups gave the greatest preference to the training and production workshop, and the least – to the "Soft skills" module. The core of significant modules included: "Fundamentals of engineering activities" and " Information technology in engineering." The representatives of the control group (TB) added one more module “Fundamentals of engineering training” to the core. In general, such views of students meet the needs of employers, which are now consistent with any developed educational program. This is confirmed by transcripts of interviews with the largest regional employers of 2016: “The level of basic knowledge, theoretical mechanics, strength of materials, mathematics, the fundamentals of scientific research, some basic concepts are important. The person must participate in the tests. Physics, naturally. Secondly, there are human qualities, and it already largely determine its further growth, some kind of rotation in an enterprise, if it is sociable, mobile, and able to solve problems, of course, it basically moves”; «There is need something like teamwork, work in a project team. Of course, in addition to some personal qualities, knowledge of project management, some must be case learning, portfolios. This should be taught not separately, but it should be, as a addition, such a superstructure. First of all, he should be an engineer, he should be able to know strength of materials, and the second, if he still knows how to work with a team, thus he is a successful engineer» (Sholina and others, 2016, p. 185).

Actual requirements of employers are consistent with our graduates' views about the core competencies of a modern engineer (Table 5).

Table 5. Evaluation of the key competencies of a modern engineer (% of positive estimates)

Criteria	PTB	TB
Deep sciencific, mathematics and humanities fundamental character of education	52	52
High qualification in the field of applied sciences	44	59
Interest and research skills	59	32
Communicative competencies that meet international educational and professional standards	14	26
Thinking outside the box	52	55
Skills of professional communication in English	4	23
Socially Responsible Engineering Worldview	22	19
Sustainable motivation to work on the received specialty	19	26
Wide general engineering and cultural and moral outlook	33	36

* The amount exceeds 100%, since one respondent could give several answers at the same time.

The difference in the content of educational programs is reflected in the control group. Representatives of TB in the context of the developing internalization of education and the challenges of Industry 4.0 are more aware of the importance of communication competencies that meet international educational and professional standards, including professional communication in English.

According to a nationwide survey of employers, professional training of graduates of higher education programs is estimated at 3.7 points (on a five-point scale) (Vishnevskii, 2017, p. 723). How graduates themselves evaluate the professional competencies obtained in the process, demonstrate the data in Table 6.

Table 6. Assessment of the importance and presence of professional competencies required for engineers (points)

Criteria	PTB			TB		
	Importance	Presence	Gap	Importance	Presence	Gap
Communication skills (ability to present your work, discuss your ideas	4,12	2,75	1,49	3,38	4,51	0,74
Having a comprehensive view of your industry, understanding the economic contexts of its operation	4,35	2,71	1,60	4,52	3,38	1,33
Experience in group projects	3,64	2,89	1,25	3,45	3,09	1,11
Intercultural communication ability	3,53	2,07	1,70	3,38	2.13	1,58
Ability to work independently (choice of research problem, methods, educational trajectory)	4,21	3.14	1,34	4,58	3,25	1,40
Participation in research projects	4.03	2,67	1,50	4,03	2,77	1,45
Experience of interaction with the real sector	4,03	2,78	1,45	4,70	2,87	1,63
Average	3,98	2,71	1,44	4,00	3,14	1,28

In the control group on a scale of "importance-presence" the largest gap is observed in the experience of interaction with the real sector of production. The graduates of this group have more developed communication skills (the ability to present their work, discuss their ideas), which is facilitated by considerable experience of participation in group projects, including research projects. In the experimental group there is a mirror situation. They are less confident in the ability to intercultural communication. The respondents of the experimental group of the UMMC, focused on specific production targets, don't have a comprehensive view of their industry, poorly understand the economic contexts of its functioning. In general, according to graduates' self-assessments, the level of formation of professional competencies is rather low. In the experimental group, the average score is 2.71. The representatives of the control group are more optimistic, their average score is 3.14.

Perhaps this can explain the uncertainty of all graduates in their readiness to work in the specialty (Table 7) and the desire of half of the respondents to continue their education in the master's degree and other forms of self-improvement (Table 8).

Table 7. Assessment of readiness of graduates to work in the specialty

Assessment levels	PTB	TB
Quite ready	29	23
Rather ready than not	41	58
Not sure	26	13
No, not ready	4	6
Total:	100	100

Table 8. Professional plans (%)

Criteria	PTB	TB
Work in the field related to your main specialization	37	36
Work in the field not related to your main specialization (change of employment)	4	12
Continuing education (magistracy, other specialty, advanced training)	55	52
Other	4	0
Total:	100	100

The control question of the questionnaire was aimed at identifying the stability of the choice of the engineer's profession. Respondents were asked to answer the question: "If at the time of admission to the university you knew about the future profession as well as now, would you have entered this specialty?"(Table 9).

Table 9. Assessment of readiness of graduates to work in the specialty

Assessment levels	PTB	TB
Yes, definitely	26	39
Rather yes than no	44	36
More likely no than yes	26	16
Not	4	9
Total	100	100

A high level of confirmation of a previously made choice can be assessed in two ways. On the one hand, this is an emotional justification for earlier decisions. On the other hand, the future profession is perceived by students not as a specific functional, but as a tool for shaping future status and desired lifestyle. All graduates highly appreciated the social status of the profession, it "gives the opportunity to acquire status in society, in the eyes of others", "demanded by society, socially significant", "provides an opportunity for career growth." They are unanimous in the high assessments of social resources and opportunities of the engineering profession, being aware the need for continuous training and self-education.

4 CONCLUSIONS

1. The results of a research experiment demonstrate the ambiguity of the identified trends, reflecting the specifics of academic and practice-oriented programs, their advantages and disadvantages. Graduates of TB (control group) more highly assess the level of influence of the training program on the formation of competencies required in future professional activities, as well as the compliance of the program with the requirements and demands of the market. Graduates of the PTB (experimental group), adequately representing the real situation and the requirements of modern production, translate a higher level of satisfaction with key aspects of the organization of practice-oriented training: the organization of production practices, the involvement of specialists of academic / sectoral science and production for consulting and joint leadership, the work of a tutor group.

2. Despite the revealed correspondence of the ideas of all graduates about the key competencies of a modern engineer to the actual needs of employers, the level of development of professional competencies in the self-assessments of respondents in both groups is rather low. In the aggregate, expressing general satisfaction with the fundamentals of engineering training and the organization of an industrial training workshop, representatives of both the control and experimental groups underestimate the importance of the softsills module in the educational program.

3. The stability of the initial choice of the engineering profession is correlated with the uncertainty of all graduates in their readiness to work in the specialty and the desire to continue their education.

4. The results of the pilot study need further clarification. The methodology for evaluating the effectiveness of

various forms of training of future engineers should have a multi-agent nature. For balanced conclusions it is necessary to identify the assessments of all stakeholders – employers, University administration, teaching staff. As tools for obtaining objective data can be used methodological concepts AHELO (Assessment Higher Education Learning Outcomes) (AHELO Feasibility Study Report - Volume 1, 2012, p. 78) and Quality Code for Higher Education (The Quality Assurance Agency) (UK Quality Code - Advice and Guidance Assessment, 2018, p. 4)

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