New approaches to training engineers for the oil and gas industry

Regina F. Karachurina*, *Denis* A. Gulin, *Irina* V. Burenina, and *Sofiya* F. Sayfullina

Ufa State Petroleum Technological University, Ufa, Russian Federation

Abstract. The article presents an analysis of trends in the development of education, analyzes new challenges in the oil and gas industry and educational activities, as well as existing problems in training engineering personnel, and examines benchmarks - advanced engineering schools in Russia and the world. The strategic direction is presented and the main aspects of training the engineering personnel of the future are considered. The basic principles of training engineering personnel in the fuel and energy complex are presented, and possible trajectories for the development of educational programs are presented. The characteristics of the competency model of engineers of the future are determined, including professional skills, soft and digital competencies for three categories of specialists in the oil and gas industry: a research engineer with project-based learning skills; an advanced technology engineer; an industrial and applied engineer.

1 Introduction

Training of engineering personnel in universities is now on the verge of significant changes, which are inevitable due to industry trends, updating the goals of the country's socio-economic development, large-scale digitalization and other challenges.

The planned breakthrough in scientific and educational activities, outlined both by the Ministry of Science and Higher Education and other departments, should lead to the popularization of engineering and scientific activities, the industry, the emergence of new educational programs at various levels, centers for design creativity, spaces for prototyping and technological experiments, ongoing activities of student scientific societies and other activities.

Developed engineering educational programs, in addition to complying with the scientific agenda, should be in demand abroad, and as a result, attract more foreign students not only from the traditional Eurasian site, but also from other European, Latin and North American countries.

Another trend in the industry is the introduction of massive open online courses (MOOCs) into the curricula of educational programs, which, with the proper level of quality preparation, can solve several important problems: reduce the classroom load on teachers, freeing up time for contact work with students as part of coursework, research and graduate

* Corresponding author: karachurinar@mail.ru

works, as well as increase the volume of additional educational programs being implemented, including through networking with partner universities.

A new point - an opportunity for growth - is the digital turn in engineering. The emergence of new engineering software systems requires familiarization with them in the process of training through the inclusion of digital modules in disciplines, hence the need to improve the qualifications of scientific and pedagogical workers and constantly rethink the content of curricula and work programs of disciplines. The correspondence of the semantic content of programs with real production trends will make graduates competitive in the labor market.

Indeed, the implementation of all the above measures can lead to the emergence of an engineer elite. Moreover, the first steps have already been taken through the creation of engineering schools.

2 Analysis of the functioning features of advanced engineering schools in Russia and the world

The development of engineering schools in the world has been known since the mid-19th century, each of which began with a small scientific team. Let us consider the features of organizing and conducting educational activities of engineering schools in Russia and the world.

1. MIT School of Engineering [1]:

- year of foundation of the engineering school 1931;
- the school's educational programs are inextricably linked with existing scientific centers and laboratories;
- implementation of programs in cooperation with high-tech global companies;
- organizing events to support student entrepreneurship on a competitive basis for the right to work with a mentor, use prototyping tools, take advantage of business planning consultations and popularize research activities through the media. Finalists receive $100,000 to launch their company;
- MIT Sandbox: a startup competition for one-on-one mentorship, financial support, and entrepreneurial training to create a supportive environment where students can explore an idea, take risks, and change direction based on their knowledge and experience;
- StartMIT - a two-week boot camp of seminars, master classes and trainings, immersing students in entrepreneurship;
- translational fellows program (financing and bringing developments to the technology market).

2. Harvard John A. Paulson School of Engineering and Applied Sciences [2]:

- year the school was founded 1847;
- teaching staff are provided with the opportunity to use a team infrastructure for incubation, development and adaptation of new ideas and approaches to teaching, including taking into account the assessment of the quality of teaching;
- connection of educational programs with various multidisciplinary and innovative educational and research institutes, centers, such as Harvard Business School and the Harvard Innovation Laboratory;
- developing tools to facilitate connections between researchers and trainees across the university, promoting collaboration and stimulating innovation and groundbreaking discoveries;
- guidance and funding of trainees and researchers.

3. Stanford Engineering Institute [3]:

- year of foundation 1891;

- leadership of interdisciplinary innovative research activities by teachers;
- combination of a high level of higher technical education with creative abilities, cultural awareness, entrepreneurial skills;
- the goal is to transfer technologies developed within the university to Silicon Valley and beyond;
- scientific research of the school is carried out through its departments, institutes, centers, laboratories and faculty programs.

4. Yale School of Engineering and Applied Sciences [4]:
- year of foundation of the school – 1852.
- study of non-engineering subjects in classes taught by renowned teachers and together with liberal arts majors who focus on social, political, economic and other humanities areas;
- creation of separate departments for each area of training;
- the student chooses a field of science in which he has a special interest. The student's advisor is determined from a laboratory or center specializing in the chosen field of science;
- interdisciplinary association of researchers in communities;
- availability of research center resources for use by students in their research projects;
- teachers of the School of Engineering and Applied Sciences are heads of research centers.

5. Higher School of System Engineering of the Moscow Institute of Physics and Technology [5]:
- form of organization and management – graduating interfaculty department;
- preparation of masters in the field of “High-tech technologies and economics of innovation”;
- the main goal is to train technology leaders;
- combination in the educational process of fundamental sciences with international schools of systems engineering;
- mandatory study of project management competencies and management of knowledge-intensive projects;
- scientific and pedagogical staff of the school - experienced teachers, experts and practitioners, mostly invited;
- modular training of undergraduates with a combination of work and production.

6. Institute of Advanced Technologies “School X”, Don State Technical University [6]:
- selection and enrollment in educational programs based on the results of the freshmen project week
- project activities within teams;
- choice of additional areas of study not in the main specialization;
- combination of engineering design and foreign language;
- free access to the university’s laboratory facilities for research activities;
- grant support for students to implement ideas.

7. SAS School of Advanced Studies, Tyumen State University [7]:
- the main difference from the above schools is non-engineering educational programs;
- school is a tool for creating a new generation of teachers;
- an internal benchmark for other departments and faculties of the university, which is a platform for the development and implementation of new education formats;
- advanced campus and infrastructure;

- new technologies for hiring scientific and pedagogical workers;
- multidisciplinary research teams without a leader;
- a single educational space for all areas of training.

8. Russian University of Transport [8]:
- use of global technological expertise;
- response to demand for new engineering competencies from the industry;
- advanced training programs in breakthrough areas;
- cyber-physical training factories for training digital engineers;
- competency profile of advanced training engineer.

The analyzed schools, at their core, are educational spaces with common distinctive features of the organization of educational and research activities of students:
- mandatory development of teamwork and project management competencies;
- attracting the best scientific and pedagogical workers to guide students and teach;
- internal competitions and grants to support research;
- interdisciplinary research;
- mandatory modules and competencies in the field of project-based learning and technological entrepreneurship;
- multilingualism or in-depth study of foreign languages;
- study of additional specialization (both engineering and non-engineering competencies);
- communication with production representatives, high-tech partners;
- scientific internships;
- free use of university scientific equipment.

The only differences lie in the principles of working with industrial partners, intra-university competitions and grants for financial support of student research, and the format of organizing the work of scientific and pedagogical workers.

3 A study of the opportunities and threats facing engineering education in Russia

The driver for the emergence of advanced engineering schools in Russia will be grant support for universities, designated by the Ministry of Science and Higher Education. The draft competition documentation takes into account all the above-mentioned features of the functioning of engineering schools, including the need for interaction with the high-tech partner of the State Corporation. The main goal of creating advanced engineering schools is to improve engineering education and conduct breakthrough research and development. Moreover, the orientation of schools will be aimed at both higher education (mainly master's degrees) and additional professional education. Indicators of achievement are new programs, retraining of scientific and pedagogical personnel, internships, commercialization of the results of intellectual activity and company spin-offs.

Achieving the indicated results in engineering education will go through problems that have existed for several years.

First of all, the outflow of talent, which is presented in the form of a negative migration movement of young people in most regions of the country with the exception of traditional subjects: Moscow, St. Petersburg and the Republic of Tatarstan, as well as the decreasing attractiveness of Russian engineering education among applicants from the CIS countries - more and more young people are striving to obtain higher education in universities in Western European countries rather than in Russia. For example, youth migration in the Republic of Bashkortostan, for 2016-2020. There is a pronounced outflow to other regions of Russia; the same indicators are presented in 65 out of 85 regions [9].

Talented youth do not see for themselves a constructive development trajectory both in the learning process and in their professional work activities. Only a small percentage of existing engineering educational programs are subject to technological examination and professional accreditation, hence the low percentage of graduates being employed "in their specialty" and a decrease in interest to continue master's studies and the shortage of personnel for the digital economy in engineering. Based on research data from the Higher School of Economics, only 53% of university graduates in 2019 work in a profession that is in no way related to their education, including 40% in engineering education [10].

Secondly, an obstacle to achieving the presented results will be the existing model of interaction between universities and high-tech industrial partners. Thus, companies representing the fuel and energy complex conduct a large amount of R&D at their subordinate research institutes, which successfully carry out their tasks. Competitions are traditionally organized for third-party organizations to carry out work, however, the topics presented are often secondary. Another side of the "university-partner" relationship is internships or practical training. The new format of interaction requires students to have greater freedom in production, work with corporate documentation and, in addition, interaction not only during the training weeks of internships. In this case, much depends on the management team of the partners.

Thirdly, digital competencies, which, as already mentioned, are the main component of modern engineering educational programs. The digitalization of production at the production sites of one high-tech partner is represented by great fragmentation: from complete absence to complete automation at various specific facilities. Also, approaches to the interpretation of digital competencies differ.

Nine "end-to-end" technologies of the "Digital Economy of the Russian Federation" program "Digital Economy of the Russian Federation" program, order of the Government of the Russian Federation 1632-r, July 27, 2017 [11]:

1. big data;
2. neurotechnology and artificial intelligence;
3. distributed registry systems;
4. quantum technologies;
5. new production technologies;
6. industrial Internet;
7. robotics and sensor components;
8. wireless communication technologies;
9. virtual and augmented reality technologies

In order for an engineer to be able to design the entire life cycle of a product, it is necessary to qualitatively rebuild engineering training, using the possibilities of interdisciplinary integration of such sciences as computer science and mathematics. At the same time, it is necessary to develop criteria for assessing the level of development of digital competencies in "end-to-end" technologies and related research and development. In addition, the examination of the criteria should also be comparable with the requests of industrial partners in the context of end-to-end technologies.

Digital competencies are directly dependent on digital technologies. The design of new digital technologies when preparing an advanced technology engineer should be carried out in stages:

- identifying the basic principles of new digital technologies
- formulation of the concept of new digital technology
- computational and experimental proof of concept
- layout and/or component tested in laboratory conditions
- the layout and/or component must be tested under realistic conditions

– technology demonstration using digital engineer competencies on a model or prototype.

The introduction of digital competencies into the profile of an advanced technology engineer makes it possible to further scale the use of new digital competencies in engineering.

4 Soft skills in the competency profile of the engineer of the future

Another important component in the training of engineering personnel, which has become increasingly important in recent years, is its soft skills.

Reports and studies from various agencies were analyzed that address competencies that are classified as soft skills, Table 1.

Table 1. Soft skills in engineer training.

LinkedIn research, 2020 [12]	SWECOM model [13]	Reserach published by Altium, 2021 [14]
creativity; ability to persuade; ability to interact; skills to adapt to change; emotional intellect; time management	behavioral skills; cognitive skills; subject-specific competencies (e.g. health science, communications)	communication skills; self-motivation; leadership skills; responsibility; teamwork; problem solving skills; determination; ability to work under pressure and tight deadlines; flexibility; problem solving skills

According to a study conducted by LinkedIn, in 2020, emotional intelligence should be highlighted as a new skill in the competencies of an engineer, which implies the ability to perceive, evaluate and respond to one's own emotions and the emotions of others.

According to the SWECOM model, the main emphasis in the engineer's competencies is on a set of cognitive skills, the presence of which allows the specialist to approach problem solving using various methods, such as reasoning, analytical methods and prioritizing information to solve problems, use skills in creating models and abstractions that support analysis and problem solving (brainstorming, prototyping, modeling and simulation).

The behavioral attributes and skills in the SWECOM model are demonstrated by the ability to productively apply knowledge, cognitive skills, and technical skills. Behavioral skills of an engineer include initiative, enthusiasm, willingness to take on challenging tasks, work ethic, reliability, leadership, communication skills and team building skills.

Behavioral attributes and skills, as well as cognitive skills, are not determined by competency level; however, increasing competency in cognitive skills and behavioral attributes and skills becomes increasingly important as levels of technical competence, scope of responsibility, and breadth of interactions increase.

Currently, due to the increasing role of teamwork, an engineer must have, in addition to basic core competencies, universal competencies in the areas of "Soft", "Digital", "Creative", "Cultural". Since it is almost impossible to make a successful and profitable product without team building, for example, Facebook, iPhone, Google are products of team work. At the same time, it is very difficult to be a team player without interpersonal communication skills (the ability to communicate with colleagues, to express one's opinion in a reasoned manner). Cooperation in an international environment also dictates the need to apply the principles of intercultural communication and business correspondence. Proper time planning, setting

effective goals, managing your emotions and a conscious approach to work are also the main components of an engineer's profile.

For career growth, it is necessary to develop leadership qualities, developed emotional intelligence, and conflict management skills. Currently, modern companies have their own competency matrix. It reflects the required set of technical skills for specific positions and allows you to understand which position the employee is suitable for.

5 Defining the characteristics of the engineers of the future

Summarizing the results of the research, we can imagine the following challenges for engineering education: advanced personalized learning, improved virtual reality, engineering analysis from function to structure, interdisciplinarity, development, implementation and testing of new design technologies in digital engineering. The consequence is that there are three areas of need for the engineering workforce of the future:

1. A research engineer with project-based learning skills is a specialist who is able to independently conduct research and lead a project implementation team, as well as promote the results of intellectual activity on the technology market.
2. An advanced technology engineer is a specialist characterized by a competency-based approach to solving interdisciplinary problems, including within the framework of digital professions.
3. A production and application engineer is a specialist with in-depth knowledge of the industry, including blue-collar professions. Able to evaluate the effectiveness of applying certain approaches to the implementation of industry projects.

Characteristics of engineers by area are shown in Table 2.

Table 2. Characteristics of engineers of the future by area.

	2025	**2030**
Research engineer with project-based learning skills	1. The ability to independently search for a problem 2. Ability to set research goals and objectives 3. Conducting research at the intersection of subject areas 4. Competencies in business modeling	1. Organization of team work for research 2. Selling and promoting research results 3. Organization of the work of SIE
Advanced technology engineer	1. Multiple subject areas 2. Hardsoftskills – ratio 70|30 3. Willingness to work in cross-functional teams 4. Ability to respond to global challenges, 5. Readiness for commercialization 6. Digital twins as the core of engineering training	1. Multi-scope 2.Hard | softskills – ratio 50|50 3. Replacing a specialty with a digital passport 4. Willingness to work on knowledge generation

Manufacturing and applications engineer	1. Multiple subject areas 2. Diploma of VO+SPO 3.Hard | IT – ratio 70|30 4. Economic and financial literacy	1. Multiple subject areas 2.Hard | IT - ratio 50|50 3. Project management competencies

The competency model of the engineer of the future can be combined into the following areas:

1. Systems thinking - the ability to analyze, make decisions and learn from a practical approach to engineering.
2. Life cycle coverage – the ability to manage the processes of development, implementation, operation and disposal of a technological product;
3. Design and modeling - the ability to produce and create technological products using both professional technical competencies and digital technologies.
4. Management – the competencies of communication, communication, interaction both within the team and with the environment, the ability to control and correct the actions of the team in order to perform an engineering task in a high-quality and timely manner.

6 Conclusion

Education should become a research and development tool that will generate new business interest in innovative projects.

Management of educational activities must pass through the strategic and tactical levels of management, the first of which is of greatest interest, which includes the following divisions: a directorate with two centers of competence, a center for online educational technologies, a promotion and marketing center, and a recruiting and scouting center.

The main functions of the Directorate include coordination and administrative support of the educational process through the staff of educational program managers, international accreditation of educational programs, implementation of corporate groups and customized training with foreign industry partners, including additional educational programs, youth policy events to support and attract talented youth. Administration of the educational process takes place through the Educational Office with two centers in the following areas:

- Eurasian center for training world-class engineering competencies;
- Eurasian center of digital competencies.

The Center for Online Educational Technologies manages and promotes the platform of massive open online courses, develops and administers online courses, implements online continuing education programs and online master's programs through functioning studios.

The main functions of the Center for Promotion and Marketing are analysis of labor markets and development trends in industrial sectors for the discovery of new educational products, interaction with partner organizations, and promotion of existing programs.

The objectives of the Recruiting and Scouting Center are to conduct winter and summer schools, promote Ufa State Petroleum Technological University (USPTU) educational programs among foreign students and graduate students in the international educational services market, organize online admissions, and work with USPTU graduate ambassadors.

At the tactical level of management, student self-government, a language training center for university scientific and pedagogical workers, and other auxiliary functions are implemented.

The engineering school of the future in training personnel for the fuel and energy complex is an engineering greenfield, focused on the work of student project groups to solve

interdisciplinary problems of a corporate partner without a pronounced emphasis on a specific area of engineering with implemented modules of digital competencies, soft skills, multilingualism and technological entrepreneurship.

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