Conference Paper

The Problems of Engineering Students' Professional Identity

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Abstract

Engineering education at Ural Federal University has its traditions; one of them is the design of new programs for nascent industries and flexible adaptation to changes in the economy. It allows UrFU engineering programs not only to survive in the conditions of constant external and internal changes but also to remain highly demanded and competitive.

The article describes the problems of the professional identity of students of engineering programs, organizational models and didactic techniques that ensure professionalization in the framework of the leading educational programs of the UrFU Engineering School, which have been tested as part of pilot training for undergraduate students in the program "System Analysis and Management." The results of the survey among students and graduates of the program, which was conducted in order to understand their professional identity and awareness of the choice of an educational program for obtaining a profession, are presented.

Keywords: Learning outcomes, CDIO initiative, benchmark, modeling, Industry 4.0, student-centered learning, internships, professional identity, efficiency

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1. Introduction

The digital world in which our graduates will have to solve engineering problems has huge uncertainty both in the professions that will be in demand and in the industrial technologies that will be developed in the future. Moreover, they will have to overcome this uncertainty themselves. The academic community realizes that without preparation of students this challenge can not be resolved.

In the context of unified global information and educational space, the exchange of ideas and practical experience in engineering education is of particular importance. The global educational agenda, which has common problems and tasks for all countries, incorporates the experiences and solutions that these or those universities possess in different countries.

Communities of professional engineers, in close collaboration with universities, as part of global initiatives, programs, and projects [1-3] discuss the problems of training engineers, conduct research [4], look for answers to the questions ”What and how to teach engineers?” [5].

Multiple sections of learning outcomes were formed; taxonomies and typologies were developed: Syllabus CDIO [6], SEBoK INCOSE [7-8], and others [9].

Of interest, in our opinion, is the typology of engineers, identified by Albert Kamp, one of the leaders of the CDIO movement [10]. He identifies the following types of engineers in demand in the future:

- Researcher: How can advanced scientific knowledge help to develop and optimize innovative technologies?
- System integrator: How to combine all the elements of production into a single whole, acting in the interests of the customer’s needs?
- Innovator: How to apply knowledge and new technologies to develop new products for the consumer?
- Context Engineer: How to promote and apply knowledge and technology to develop products and processes useful to people of different cultures in different contexts?

Alone, none of them will cope with the task, only in the interaction will be found a technological solution to complex problems.

The question arises on how the indicated typology correlates with the realities of university training of engineers and the professional identity of educational programs.

2. The Problems of Engineering Students' Professional Identity

Professionalization is a continuous multi-aspect process aimed at the success and effectiveness of a person in economic activity. Today, the boundaries of traditional engineering are blurred, and the profile of the engineer is changing along with the change of technology.

The search for effective models of engineering programs has led to the need to distinguish between ”education” and ”training” [11]. Education is, first and foremost, the formation of a natural-scientific worldview, an engineering position, techniques of thought activity, mastering the general engineering languages of mathematics, programming, et cetera [12]. This is a fundamental component of educational programs.

The professional component of engineering training programs is the most dynamic and resource-intensive; it has its specifics for each industry and requires the participation of professional engineers and experts.

Universities determine their value by primary research and scholars who have an academic reputation. To what extent should a modern engineer master the techniques of research work? Is it ”education” or ”training”? [13]

Focusing on professionalization requires the allocation of specific competencies for engineering activities, on the one hand, on the other hand, environmental characteristics that allow these competencies to be formed, and on the third, personal characteristics and abilities that allow them to master these competencies. These three aspects outlined above set the problems related to the professional identity of a particular student who has chosen to engineer for himself.

The first problem is, what profile should a graduate of engineering programs have?

The Russian practice of highlighting the areas of training, which arose during the planned Soviet economy, is morally obsolete, updating educational programs by building compliance with professional standards rests on the quality of professional standards, which only affect the level of colleges and working professions. If there are indicators of the effectiveness (efficiency) of universities related to the employment of graduates in the specialty, we have, at best, compliance with staffing plans for specific industrial enterprises, formed without taking into account the dynamics of technology changes. The existing system of planning the state order for training specialists ensures an influx of personnel to enterprises, and then the enterprise itself ”brings” the graduate to the required level of qualification.

From this analysis, an important conclusion follows, confirmed by studies [14] - industry enterprises are increasingly appreciating the fundamental basis, proper general engineering training, and, most importantly, soft skills — the ability to build communication, see and formulate a problem, and find solutions. Great importance is attached to the ability to act and get results in conditions of limitations to find non-standard solutions.

The option we found for solving the indicated problem is as follows: we form a professional horizon, train a range of competencies, and, most importantly, adopt a need for training and professional development. The student understands how specific competencies fit into the profession for a particular production, workplace, technology, et cetera when he is doing an internship at a real enterprise.

The second issue is the problem of the environment in which future engineers are trained. Among the variety of environmental factors, the three most problematic can be distinguished.

1. Roles of participants in the educational process. What competencies should those who teach have?

2. Training complexes. Traditional educational laboratories formed on the principle of consolidating the knowledge gained from lectures are not practical. Will the universally forming spaces for the implementation of design technologies be able to provide the necessary efficiency?

3. How to effectively use the opportunities of open education and various contests and competitions? [15]

The third pool of problems is directly related to the personality of the student, his motivation, goal-setting, genetic data, socialization, et cetera.

The indicated problems have been translated into tasks and are being tested in the initiative of the Ural Federal University, called ”The new format of engineering education.”

A new format of engineering education, arising in response to the challenges of technological change (changes in technological platforms), includes models of engineering education at various levels, ensuring the continuity of education throughout life [16]. When developing a new format, the most considerable attention was paid to the three successful approaches to training engineers:

1. Approaches to the Russian engineering school, training on specific engineering tasks, and highlighting the crucial role of a mentor.

2. The Russian ”Phisteh,” problem-based training, research are inseparable from implementation, the search for engineering solutions in the face of uncertainty, agile-education.

3. The CDIO initiative, standards and a syllabus [6], integrating the approaches of the Russian engineering school and the experience of ”Phisteh,”

In order to test the new format of engineering education, the Higher Engineering School (HES) of the Ural Federal University was created. HES educational programs have several didactic features that provide flexibility and adaptability of preparing students for fulfilling industrial tasks.

The Learning Outcomes methodology [17-18] sets the result requirements that are understandable to all stakeholders - students, employers, teachers, et cetera. Grading training results in a universal, general professional, and professionals with different life cycles make it possible to identify the most ”dynamic” - professional, which must be validated annually. The system of formation and evaluation of learning outcomes is the didactic basis of educational programs in a new format. In order to see how learning

outcomes are formed and evaluate them, the curriculum includes convergent learning activities such as interdisciplinary research, engineering, and technical competitions, hackathons, projects, internal and external conferences during which students discuss problems, look for solutions and present their ideas and developments.

The structure of the program is formed according to a modular principle, which allows us to quickly change the content within the framework of natural science and general engineering disciplines, to replace courses that form one or another professional competency.

Of great importance in the work of a modern engineer is understanding of materials. The scientific schools and engineering competencies of the Ural Federal University in the creation and use of various materials, both natural and synthetic, are in demand in the regional industry and are dynamically developing. Among them are such materials as materials for nuclear energy and electronics, for instrument making and aviation, for robotic systems and medicine, composite materials, et cetera. New materials and technologies are created at the university as part of research and development work for the industry. This potential is reflected in the content of the educational programs of the engineering school. Understanding the characteristics and design features of materials come to students from fundamental disciplines - chemistry, physics, materials science, engineering mechanics.

Traditionally, in the Urals, metallurgy, mechanical engineering, and energy are developed. This specificity is also present in educational programs. In the traditions of the engineering school, there is an integrated approach and greening, the balance of fundamental training, and new technologies.

3. Results and Discussions

3.1. Professionalization Models

The program is an open system, included in both the Russian and world educational contexts. The program includes academic mobility in all its diversity, internships at industry enterprises, participation in various contests and competitions. The peculiarity of the program is that all these student activities are taken into account and re-read into its total labor intensity.

Another important feature - first-year students are immediately involved in various educational activities together with senior students, and there are no barriers between courses, there are events in which all students work on equal terms.

Such a program is challenging to execute, especially in typical educational situations of the class-lesson flow system, since the student-centeredness is the cornerstone of the organizational model, which implies, first of all, student activity, his motivation to achieve a result and responsibility for his choice, especially for his future profession.

It was possible to realize this model with the introduction of the role of tutor-mentor (tutoring in the traditions of British universities and mentoring in the traditions of the Russian engineering school).

This role provides student-centeredness and a mechanism that allows integrating typical educational situations into the general bulky and clumsy system of the university. The design feature of the program that provides these opportunities in the presence of a through training and production workshop with a total labor input of more than 40 credits is called SCP.

SCP is a series of competency training and interdisciplinary (convergent) activities in which these competencies can be recorded and evaluated. The internship program also includes internships at enterprises (practices). However, they are already implemented based on the principle of student-centeredness, which assumes a great responsibility of the student - the student must find the place of internship himself, and the tutor helps him formalize his choice.

Converged events include various competitions and conferences. After internships, at the beginning of the school year, a conference is held where students of different courses demonstrate the results of training and present the results of their work that they developed or acquired at industrial enterprises.

Great importance is attached to updating academic formats - research, scientific discussions and seminars, participation in various scientific conferences. Getting into the research team, in which students work not only from different courses but also from different programs of different universities, along with young scientists, students acquire a culture of academic thinking, learn the science-based reasoning of their decisions.

All the variety of open education resources is available to students, and a tutor-mentor helps to build compliance with the formal curriculum. Tutors are not only teachers but also skilled students who have already mastered specific skills and want to transfer their knowledge and skills to others. They have already confirmed their qualifications through hackathons, competitions, WorldSkills competitions.

A master class (workshop) is one of the priority forms of classroom classes, which, along with lectures, discussions, and seminars, create conditions for active learning. On the one hand, the selection in the structure of the program of a training-and-production workshop extended through all semesters and closely connected with all

courses (disciplines). On the other hand, the presence of the role of tutor-mentor creates an effective mechanism for coordinating all student activities for acquiring professional qualities (competencies) that allow you to form a professional career following your aspirations.

Upon completion of training, the graduate of the program already understands very well that his professional solvency consists of a set of specific competencies that require continuous improvement and knows in which competence centers they can be acquired.

3.2. Analysis of the survey

Analysis of the survey among students and graduates of the program, conducted in order to understand their professional identity and awareness of the choice of an educational program for obtaining an occupation, is presented below.

The above approaches of the new format of engineering education were implemented in the undergraduate program ”System Analysis and Management” of the Higher Engineering School of UrFU. In 2015, the pilot implementation of the program began - in 2019, the first cycle was completed, and graduates defended the qualification works. Throughout the entire training period, monitoring was carried out, external and internal changes were recorded, feedback from stakeholders was quickly worked out, and changes were made to the program. In the spring semester of 2019, a survey was conducted, including questionnaires and interviews with students and graduates of the program.

The following questions were asked:

- Did you have an idea or work experience by profession before entering university?
- Have your ideas about the chosen profession changed during your studies at the university?
- What factors affect the quality of training?
- Evaluate the effectiveness of teaching methods.
- What technologies and techniques are present in educational practice?
- Rate the prestige of the engineering profession in modern society.
- Is it easy to find a job in the chosen profession?
- From whom, first of all, do you expect assistance in finding employment after graduation?
- Do you currently work, and is your work related to the engineering profession?

After analyzing the information received from all students of the undergraduate program ”System Analysis and Management,” the following picture was obtained:

- More than 60% of students had no idea about the professions in which they would work after the end of the program. From the interviews it turned out that the students make the leading choice at the stage of passing the exam, if they pass physics, that is, focus on the engineering areas of preparation, and then, already during the admission campaign, they will sort out specific areas of preparation based on the goal of going to a budget place.
- 50% believe that during the training, their ideas about the future profession have changed for the better, 30% said that ”something turned out to be worse than their initial expectations.” A big disappointment is the salaries of engineering workers, especially in large enterprises.
- Of particular interest is the opinion of students about factors affecting the quality of training.
- More than 60% of students consider that ”the possibility of combining study with work without compromising the development of the educational program” and ”the possibility of learning according to an individual curriculum (trajectory) are important.”
- Students consider the use of e-learning (60% of respondents), academic mobility (75%), the involvement of employing partners (more than 80%), network forms (70%) and technical base, equipped with modern equipment (80%) ”very important.”
- When evaluating the effectiveness of training, internships at enterprises, design training, and laboratory work received the maximum score. Lectures, seminars, master classes, business games, on-line training have an average score. Independent work received an above-average score. Interestingly, only 5% of the respondents received a low score for a particular method. According to students, the usual practice in the educational program is design technologies, on-line courses, and e-learning.
- The prestige of the engineering profession is now considered above average in the future - high.
- To the question ”Is it easy to find work in the chosen profession?” half of the respondents answered in the affirmative.

4. Conclusion

A new format of engineering education that emerged in response to the challenges of dynamically changing technologies of the digital economy has a target model consisting of a range of competencies, which are integrated depending on the particular profession of a particular workplace.

The dominant feature in the training of a modern engineer is the formation of modeling, designing and prototyping skills, owning digital tools, understanding contexts, and feeling integrity. Develop engineering solutions using the full range of possible technologies, which are based on information. Design thinking and the vision of a holistic image included in contexts, the ability to convey it through visualization techniques, understanding the limitations (social, environmental, economic, et cetera)

The professional identity model of the new format of engineering education is based on a student-centered approach. Not teaching but learning. Motivation and initiative, the ability to make informed choices, make decisions, and bear responsibility for them. Furthermore, to do this during the training period learns from his mistakes, disassemble real cases and experiment, accustom himself to research and science-based solutions, not for the development of sciences, but the practice of engineering.

Network forms allow integrating into the ”learning” educational activities that a student has attracted from various centers of competence, whether it is another university or the enterprise where he has been trained.

Experience shows that only student activity and a student-centered approach can fully earn a network. Students understand well what they do not know and what efforts they need to eliminate competency deficits in the case of a specific professional activity.

They also consider professional worth to consist of a set of specific competencies that require continuous improvement.

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