Key Components of the Educational Environment in Training Engineers of the XXI Century

R. N. Polyakov and L. A. Savin

Abstract—**The article provides a summary of the experience of training engineers in the direction of mechatronics and robotics at Oryol State University named after I.S. Turgenev, the main feature of which is the complete transition from the didactic method of teaching to project training. At the same time, the peculiarities of this process regarding the Russian education were revealed. It describes the key elements of the educational environment and the contours of their interaction. Provides statistics of successful graduate students, which prove the effectiveness of the created educational environment and teaching methods used.**

Index Terms—**Project training, innovation, educational environment, competencies.**

I. Introduction

One of the features of the current educational process is a great information flow and a significant degree of integration in the objects of designing knowledge in various engineering disciplines. In these conditions the educational environment within which a student can gain new knowledge, exchange information with colleagues and teachers, take part in the research activities of the Department in the process of creating innovative commercial products, is of great importance [1]-[3]. At the same time, the presence of such a platform as the performance of research works within the programs of the Ministry of Education and Science, Grants, economic contracts with industrial enterprises, is a serious basis of the educational, production and scientific processes.

The current stage of the development of higher engineering education is characterized by a high degree of integration and interpenetration of various fields of science and technology. Training of the highly specialized personnel leads to the difficulties in employment. Nowadays in most regions there is a situation when a significant number of graduates of engineering specialties do not practice their original profession. The training programs of specialists in mechatronics and robotics combine fine mechanics, information technology, control systems [4] and include training courses in their curriculum. Mastering the training courses leads to the synergetic effect of gaining knowledge that combines sidelines of science and technology.

Next generation technical systems require training of universal engineers with a high degree of responsibility for the results of their intellectual work as they have the functions of automated diagnosis and active management, which requires the use of artificial intelligence methods for trajectory planning and motion control. Therefore, the focus on the training of universal engineers who have profound knowledge of the technical systems design, programming of information and measuring systems, control systems design, as well as the skills of management is a vital task of the Russian education.

II. Main Topic

One of the worldwide trends in the development of engineering education is the introduction of the CDIO format which means Concieve– Design – Implement – Operate [5]. Its aim is to reduce the gap between the educational programs of universities and the real needs of enterprises, primarily in the field of training highly qualified engineers. The CDIO format has been formed in Western universities, which have their own production facilities with technological equipment of high quality and cost, which are served by the specialists of appropriate training. Also, there are supervising bodies that ensure the logistics of materials, component parts and fund projects of the graduate students.

Therefore, a simple copying of this format to the realities of the Russian education can lead to the ineffective training on new standards and the use of funds for the purchase of equipment. The CDIO training requires universities to meet the high standards of facilities - technological, experimental and laboratory equipment, maintenance of the qualified support staff and retraining of the teaching staff. There is also a necessity to turn the university classrooms into the production areas with modern equipment and power supply.

The more complex and deeper level of training universal engineers suggests a participation in research, experimental developments of scientific team of responsible/graduate department. The implementation of Research Work, Research and Development and Applied Scientific Development requires the department to have the material and technical basis, universal module equipment with modern information and measuring devices and software and hardware, reliable cooperation with industrial enterprises of the region. An exceptional condition for the implementation of such an approach is the creation of an integral learning environment in which a student interacts closely with teachers within the training courses for solving priority tasks of Russian science and technology.

Such basic postulates lead to the necessity to create an effective environment for the acquisition of competencies, which requires a significant change in the didactic format of training when the teacher is considered to be only a source of unique knowledge and to monitor the way a student masters

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the material.

The competence-based approach assumes gaining the following baseline competencies (Fig. 1). The detail description of each competence according to the goals and objectives of a particular discipline leads to the dilemma of the curse of knowledge when trying to gain a lot of knowledge a student may lose the main things and do not master the key competencies that he will need immediately after graduating the University.

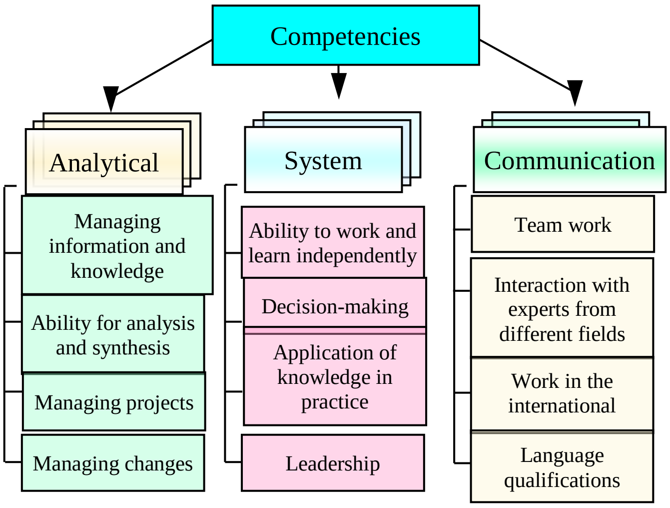

Fig. 1. Basic competencies of an engineer of the 21st century.

The training program in mechatronics and robotics has been developing for more than 10 years at the I. S. Turgenev Orel State University. During these years a unique environment for acquisition of competencies has been created, which combines the experience of the academic teaching staff, scientists, original material and technical equipment of the open architecture, a complex hierarchical module curriculum with the academic courses on initial and boundary competencies, as well as the structure of innovation and scientific activities (Fig. 2).

The excessive generality of competence formulations leads to their end-to end acquisition in a variety of disciplines without specifying the knowledge a student must gain after studying a particular subject. The difference between the new terms introduced in the basic educational program and the existing ones consists in more detailed description of knowledge and skills at the macro level and listing the type of activity, the object of analysis and to what degree the certain tasks should be solved within the general competence of the system level.

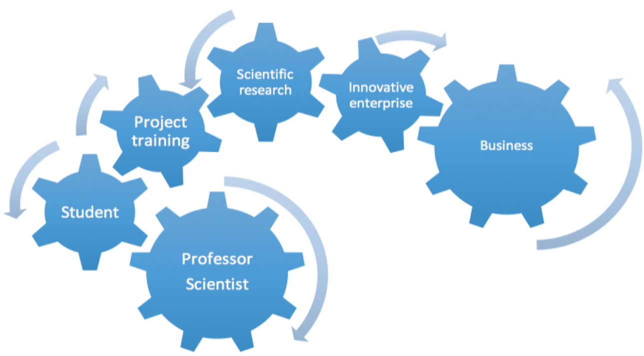

Fig. 2. The environment for acquisition of competencies at the Department of Mechatronics, Mechanics and Robotics.

The task to differentiate competences according to their complexity level and their significance for mastering next disciplines is of great importance. We propose the introduction of such concepts as initial and boundary competences, which are subject to the following rules and definitions. Initial competences are knowledge necessary for studying a particular discipline, object, phenomenon, etc. Boundary competences are newly acquired knowledge after studying a particular discipline.

To make the educational process natural it is important to coordinate the curriculum so that a student could have the necessary set of initial competences to study the next discipline. If it turns out difficult-hierarchical (avalanche) the nature of the competences that are growing and increasing each of the studied course. The initial competences of some disciplines may be the initial competences for other disciplines. The boundary competences of a certain discipline can be the initial competences for different subjects of the curriculum.

An effective curriculum should be based on the principles of project training and contain logistically reasonable schemes of coordinating the initial and boundary competences. The basic principle of the project training consists in establishing a direct connection between the educational material and students' life experience in their active cognitive and creative team-work. The project methodology as a set of search, problem methods which are creative by nature and a didactic means of enhancing cognitive activity, creativity and at the same time the formation of certain personal qualities of students in the process of creating a specific product " allows to solve a number of important problems:

- classes are practical activity of students, connected with their emotional sphere, thereby increasing motivation
- students have the opportunity to carry out creative work within a theme given, obtaining the necessary information by themselves
- the project successfully implements various forms of organization of educational activities, in which students interact with each other and with the teacher, whose role is changing: he is not a supervisor any more, he becomes an equal partner and consultant

This approach will allow to develop new methods of synergetic acquisition, understanding and application of the material of basic engineering disciplines, activate the creative approach and create a special educational environment for the selection of talented students for the next research activities of the fundamental level. For example, the discipline Details of mechatronic modules, robots and their design demands from a student the initial competence of knowledge of the laws of mechanics from the courses of Physics and Technical mechanics, knowledge of the basics of the stress-strain state of a solid from the course of Resistance of materials, the basics of integral and differential calculus from the course of Higher mathematics.

Ensuring the synergetic effect of gaining interdisciplinary knowledge and profound study of various objects requires the application that meets the following demands: three categories of equipment: scientific-experimental, laboratory, production; three fields of application: machine elements and technical mechanics, mechatronics and control systems, robotics; three levels of application: fundamental and applied science, educational process, commercial use.

A variety of subjects of the curriculum and interdisciplinarity of competences leads to the necessity to have a large number of units of material and technical equipment to provide practical and laboratory classes. Such a large number of material and technical equipment requires quite high expenses, but it sometimes is impossible in the conditions of modern Russian education. There is still a negative moment when the necessary equipment purchased does not meet the educational goals. For example, a robot-manipulator purchased allows to solve programming tasks, study its capabilities, but according to the manufacturer's warranty it is impossible “to look inside" and study its element base – the elements it consists of. At the Department of Mechatronics, Mechanics and Robotics of the I.S. Turgenev State University, an original approach has been developed, which allows to create the required material and technical equipment of the open architecture and provide a large number of competences and attract a huge team of employees and students to its creation.

Within the Project of the State Task, 30 scientific and laboratory units installations have already been and planned to be created, which allow to study the element base of machines, mechatronic modules, robots, their control systems, programming fundamentals and acquire other competences (Fig. 3). Moreover, all installations have the open architecture, not a black box structure, which allows students to acquire the competence of installing mechanical, electrical and measuring equipment, diagnostics and control of technical systems parameters not within the studying a certain training course, but learning all the disciplines of the curriculum, in which there are laboratory classes.

The educational and methodological support is based on the principle of maximum availability of all processes and studied element base not only as an instruction, but also as a guidelines with the possibility of building new measuring circuits and expanding the objects under study. Each laboratory installation can be considered not as a complete element, but as a platform for building new tools for the creative study of any mechatronic module. At the same time, the open architecture allows to use the equipment at different levels of study: education, applied science, basic research.

For example, one such test rig is designed to conduct physical experiments to determine the level of vibration of a model rotor [6] (Fig. 4).

The test rig design allows you to change the types of bearing units: rolling bearings or hydrodynamic bearings, shaft length, size and location of application of static and dynamic loads. The test rig is used when carrying out laboratory work on the discipline "Pieces of mechatronic modules, robots and their design" during the implementation of the educational program in the direction of 15.03.06 "Mechatronics and Robotics", as well as during research in the framework of the discipline "Fundamentals of Scientific Research, Organization and Planning of the Experiment" in the direction of graduate education 15.04.06 "Mechatronics and Robotics". The potential of the test rig allows you to use it not only in the educational process, but also as part of scientific research in the field of studying the dynamic characteristics of rotary support systems.

Fig. 3. Some units of educational equipment.

It should be noted that the quality of manufacture of the experimental unit assemblies and the use of a high-precision information-measuring system made it possible to conduct scientific research in the field of rotor-bearing assemblies and to obtain world-class results [7]-[9].

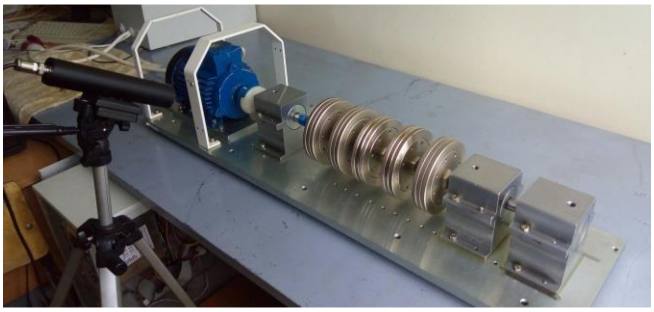

Fig. 4. Test rig for the study of rotor-bearings.

An important element of the educational environment is the electronic educational environment of the Department (Fig. 5), which aims not only to store any information for training within the curriculum, but also to encourage a student to communicate with fellow-students, teachers, employers and the University administration regularly. It allows significantly to save time for searching the necessary information, answers to questions arising within the implementation of practical training tasks, to receive an instant response to social, cultural and domestic problems. The key element of the educational environment is the student's personal account, where he/she stores all his/her works done, portfolio and other information on the training.

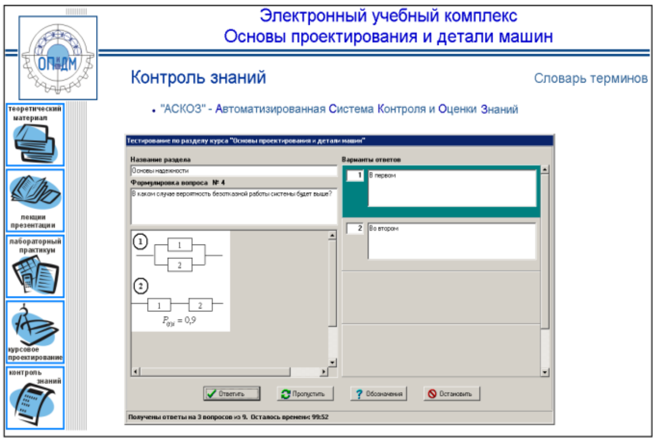

Fig. 5. Some view of the electronic educational complex (in Russian).

This, in turn, allows an employer to objectively assess the abilities of an applicant for the vacant position. The objective assessment is based on the results of the actual tasks, and not only on the information specified in the bachelor's degree. Student have constant access to the electronic educational complex, which contains all the reference and educational information on the training courses, automated system of control and evaluation of knowledge, free database of projects that are of great interest for the Department within its research and development activities. This approach can significantly reduce the load through the use of e-learning [10] approaches, distance learning, reducing logistic loads moving between buildings, etc.

The most important element of the educational environment is the teacher. The speed of scientific and technological progress in the modern world requires a radical transformation of the concept of a teacher. The training activities should be aimed at the organization and practical application of knowledge, but not only at their reproduction (replication). To train modern engineers, the teacher must be a scientist engaged in his scientific field and at the same time an academy professor, constantly improving his skills in the field of pedagogics, information systems, foreign languages and his worldview. The most effective teacher is a person who can create engineering products by himself and promote them on the market and at the same time be a research scientist who can formulate a scientific task that will be clear to students and that will not scare them. It can be achieved by developing detailed technical tasks for control works within each course trained.

End-to-end project training demands from the teacher some leadership skills and the ability to bring the development from the idea to the final implementation and make it merchantable, that is, he is to be a businessman and a good marketer. The unique team of like-minded people possessing all these qualities has been created at the Department of Mechatronics, Mechanics and Robotics, which allows to implement scientific projects of fundamental nature, experimental design works for applied purposes, to form and solve the project tasks together with students, to obtain results in the form of experimental samples of innovative technical objects and realize them in the market of educational, medical, oil and gas equipment.

Such approaches make it possible to train successful engineering personnel who due to their interdisciplinary competences work at enterprises of various profiles and at various positions. Thus, according to the internal statistics of the Department, 69 people who have graduated a specialty or bachelor's degree in Mechatronics and Robotics work at the enterprises of the electrical industry (12 people), aviation and space industry (2 people), oil and gas industry (4 people), power engineering (3 people), and 11 people work as heads at large enterprises or started their own business. 8 people continue their work at the University as researchers, have taken up a post-graduate course and teach special disciplines at the Department. Thus, the format of lifelong learning is realized in a single cluster space of the University: bachelor's degree – master's degree - postgraduate study - dissertation councils - doctoral studies-dissertation councils.

Such an approach combining modern trends in engineering education, the traditional scientific school, innovative structures of the university and interaction with industrial enterprises makes it possible to build educational programs corresponding to future professions [11], such as:

- industrial robotics designer;
- operator of medical robots;
- designer of neurointerfaces for robot control;
- architect of intelligent control systems;
- engineer of robotic systems, etc.

III. Conclusion

The unique educational environment created allows to train engineers and scientists of various specifications due to the multidisciplinarity of the acquired competences. It gives graduates greater competitiveness in the labor market, and the basis of this environment is the postulate that the paradigm of the didactic education is replaced by the idea that in the most difficult process of training engineers of the 21st century, the teacher should act not only as a source of unique knowledge, but also as a partner in the implementation of the student's life trajectory.

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