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The development of research competence among the students of technical education

El desarrollo de la competencia investigadora entre los estudiantes de educación técnica

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ABSTRACT:
The focal point of the paper is the conceptual foundations of educating technical students with the help of a competence approach which is conducive to the development of the progressive engineering personnel. A key aspect of the paper is the analysis of existing approaches to stimulate students of an engineering university to do research. There is much evidence that research work contributes to the development of engineering educative methodological foundations. In the paper, we offer a special functional model. Central to the entire paper is the content of the functional model and the conditions for its effective functioning. Extensive research has shown that the functional model develops students' creativity, their research abilities, the formation of functional research skills as universal methods of contact with the surrounding world. This paper attempts to describe the assessment criteria, which includes special determinants and indicators for describing the level of research competence of engineering university students, defining cognitive, personal, and activity components. The practical value of the paper is the implementation and verification of the effectiveness of

RESUMEN:
El objetivo del trabajo son los fundamentos conceptuales de la educación de los estudiantes técnicos con la ayuda de un enfoque de competencia que es propicio para el desarrollo del personal de ingeniería progresista. Un aspecto clave del trabajo es el análisis de los enfoques existentes para estimular a los estudiantes de una Universidad de ingeniería para que investiguen. Hay muchas pruebas de que el trabajo de investigación contribuye al desarrollo de fundamentos metodológicos educativos de ingeniería. En el papel, ofrecemos un modelo funcional especial. La central de todo el papel es el contenido del modelo funcional y las condiciones para su funcionamiento eficaz. Una extensa investigación ha demostrado que el modelo funcional desarrolla la creatividad de los estudiantes, sus habilidades de investigación, la formación de habilidades de investigación funcional como métodos universales de contacto con el mundo circundante. Este trabajo trata de describir los criterios de evaluación, que incluyen determinantes e indicadores especiales para describir el nivel de competencia de investigación de los estudiantes universitarios de ingeniería, definiendo los componentes

the main conceptual foundations and the functional model.
Keywords: research training, engineering work, research competence.

cognitivos, personales y de actividad. El valor práctico del trabajo es la implementación y verificación de la efectividad de las principales fundaciones conceptuales y el modelo funcional.
Palabras clave: formación en investigación, trabajo de ingeniería, competencia investigadora.

1. Introduction

Nowadays, there is much agreement on the issue that global development leading drivers are those countries that offer state-of-the-art breakthrough technologies and with their help form a modern technological base. The main advantage of this strategy is the basis for technological, and economic independence of the country, which serves as the driving force behind the technological transformation of the society. In today's competitive world of much importance for Russia is a competitive engineering personnel, ready for active participation in innovative engineering processes, the development of new ideas, and the solution of research production problems. The country needs engineers who think in a non-standard way and who can adopt non-standard solutions with the help of the research. It is now well-established that the engineer of the future is a researching engineer.

It has previously been observed that modern production methods, the adoption of educational and professional standards, the wide introduction of the competence approach change fundamentally the ways of educating technical students. This educational shift determines the need to search for the model of the educational process management in a technical university in such a way that the research activities of students are of primary importance. Therefore, there must be a significant revision of educational traditions, targets, and objectives, as well as innovative technologies of engineering education. A graduate of a technical university should know how to manage the tools for research and design, the roots of invention, the procedure for conducting patent research and experimental works, be familiar with scientific and technical literature on research subjects. There is a growing confidence that the formation of research competence allows educators to fully implement the Federal State Educational Standards (FSES) for Higher Education, to form a strong complex of general cultural and professional competencies, to promote the development of students' creativity, their research abilities, and the formation of functional research skills as universal means of contact with the outside world.

Several reports have shown that the analysis of training activities of intended Russian engineers shows that it does not fully correspond to modern requirements. The educational system existing in engineering universities does not create conditions sufficient for the formation of the research competence of students, the fulfillment of their creative potential, personal and professional development, and the comprehensive solution of research tasks.

Prior studies of several problems of engineering education in Russia stress the need for the development of innovative technologies, sustainable growth in the volume of industrial production, research, and development. Moreover, there is an urgent need for competitive engineering personnel ready for active participation in innovative engineering processes, the development of new ideas, the solution of research production problems, and capable of making non-standard decisions with the help of the research.

2. Methods

There are three main types of methods which we used in our study. They are as follows: 1) a theoretical method (a study approach, the analysis and the synthesis of educational, social, engineering, economic literature on the problem under analysis, the analysis of the subject of the study, the modeling of an educational process, the generalization of research results); 2) an empirical method (the study of specification documents, observations, interviews, tests, a self-assessment approach, a documentation analysis, the study of product activities, an educational project); 3) an experimental method (a teaching experiment, the methods of statistical

processing of results).

3. Results and discussion

We systematized existing approaches to the formation of the research competence of technical students. The current study also identified and developed the main objectives, relevant for the development of research activities. There is a growing body of literature which emphasizes the individual aspects of research competence development. The basic trends in this field are as follows:

- the leading role of motivation and commitment to scientific development during training time (Nenasheva, 2010; Timofeeva, 2009, etc.);

- the pivotal role of personal-oriented approaches to learning, the use of interactive technologies that promote orientation to self-education through the actualization of vital experience, the creation of success situations and the development of a student as a reflecting person of a (Grosheva, 2010; Churliaeva, 2007, etc.), the transition to project methods, IT- and the Theory of Inventive Problem Solving-technologies (TIPS-technologies) (Gubaidullin, 2011, etc.);

- the organization of students' classroom activities, as well as, independent work when performing tasks of various types (Ermakova, 2010; Timofeeva, 2009, etc.);

- the use of active methods, information technologies, modular training, interdisciplinary integration (Grosheva, 2010; Naumkin, 2009, etc.);

- the introduction of a special environment to students. This environment must stimulate the students to perceive the model of professional activities and the implementation of early professional self-determination (Ianiuk, 2010); the development of modern HR policy and promotion in universities (Churliaeva, 2007).

The discussed works showed that the researchers focus on the important aspects of preparation for research activities, they pay much attention to the content of engineering education, the technological component of training. However, we have observed a certain shortage of attention to the conceptual idea of forming research competence of students, which requires specially organized measures and has a significant potential in improving the quality of vocational education. Collectively, these studies do not consider research activity as a basis for the formation of general cultural and professional competences. They ignore the requirements of FSES for Higher Education and accordingly do not study the preparation for research activities from the standpoint of constructing innovative didactics of an engineering university. These studies do not propose the issues of changing the quality management system of education; do not touch upon the issue of university educational environment development. As a result, there is no close connection between the university and employers, their employers' participation in the process of preparing students for research.

Many of the international researchers (Bendrat, 2005; Birgit, n. d.; Brown, 2004; Mulders, 2013; etc.) share their experience of the educational process management, focused on research training in technical universities. Proceeding from their observations, we believe in Russia, it is efficient to apply the approaches, which are as follows: the application of special courses; the introduction of heuristic methods; research assignments and projects; the development of industrial design skills, aesthetic development of students; the training of ethics.

Data from several theoretical studies suggest that in modern conditions engineering activity has several typical features, i.e. the expansion of the scientific knowledge, the complication of engineering objects. Engineering becomes creative, acquires a pronounced research character, through which an engineer interacts with the world as a subject and acquires the ability to change the community around him.

The analysis of the professional standards, the structure of engineering activity, the complex of

competences has shown that the research activity obtains the leading position in all components of engineers' professional development. The described labor functions in combination with the necessary skills have a research component and determine the need to prepare engineering students for research activities.

There is much evidence that FSES for Higher Education do not always correspond to the existing realities, therefore, we have defined several provisions that should be added to the standards. They are necessary for the formation of a competitive graduate. These provisions are as follows: a mandatory compliance of FSES for Higher Education with professional standards; integration processes; the introduction of special end-to-end courses, project-oriented, end-to-end research assignments; the work with the companies, the conclusion of contracts on target preparation; the introduction of virtual labs in the educational process, the access to unique and closed processes; technologies, modern equipment (Gorshkova, 2016).

The competencies presented in the FSES for Higher Education are not sufficient to ensure the preparation of students for research. The resolution of this problem lies in the domain of expanding research activities at the expense of special competencies. There are many of them, i.e. the ability to understand the essence and significance of research activities in the overall structure of engineering activity, its importance in self-actualization in the profession, and ethical standards; a system of value orientations of research activities, directed at its implementation (Special Competence (SC)-1); the readiness to use effectively the generalized bases of research activity in carrying out interdisciplinary research (SC-2); the readiness for creativity in the engineering profession on the basis of its own reflection (SC-3) (Gorshkova, 2016).

We solve the problem of research preparation of technical students, proceeding from a competence conceptual framework, which interacts with traditional approaches (axiological, value-motivational, synergistic, integrative, activity, contextual). This concept is systemically important and introduces fundamental changes to the learning process, expressed in strengthening practical orientation and instrumental orientation of engineering education. This conceptual strategy creates optimal opportunities for students' research activities.

The concept uses a program-target system for managing the quality of education in a university. This system allows to achieve the targets which are as follows: to establish socially justified and achievable goals, namely the formation of the research competence of students in order to implement the requirements of FSES for Higher Education for the formation of a competitive graduate; to create a working group (representatives of the university, main enterprises); to develop a program of research training in which the process of forming the research competence of students plays a pivotal role, the applied technologies and methods, the possibilities of control and correction of innovations, and the phased monitoring of the results; to guarantee the necessary support: personnel, material, information, methodological, etc.

The transition to a program-target system for managing the quality of education contributes to the creation of developing educational environment of the university, which includes the following structural components: the spatial-objective component (architectural and aesthetic organization of the educational process, symbolic space (symbols and traditions of the university, etc.)); the content component (functional model as a meaningful content of the concept); organizational component: human resources, management resources, a special communication sphere, organizational conditions. Personnel resources should provide the creation of a team of like-minded people united by a common goal through coordination of the work of the structural units of the university; the increase of the professional competence of the university staff-members. The information component offers networking, the use of networking educational resources, the introduction of an electronic system "Educon" to support the educational process of, aimed at developing the infrastructure of a single educational information space.

We have proved that the creation of a developing educational environment requires:

- the organization of interaction and joint activity of all persons who become an integral part of the educational environment in the learning process;

- integrating learning and research at all levels of the educational process;

- transforming the content of education, developing a new methodological approach, and improving the existing ones; changes in the organizational and technological foundations of the educational process;

- the formation of a system of partnership with universities, scientific organizations, enterprises. We actualized "the resource model" of the basic professional education programs (PEP). These programs functioned within the network cooperation, according to which we concluded the agreements on comprehensive cooperation with basic enterprises. This allows for a purposeful distribution of graduates, involving representatives of enterprises into the process of research training; practice; visiting laboratory and practical work; internships for teachers; the monitoring of the demand for graduates at the labor market, analyzing the success of their activities, etc.;

- the expansion of the competence set of the FSES for Higher Education due to special competencies;

- the self-regulation, self-generation of students.

We actualized the content of the concept as a functional model of preparing students for research. This model forms the basis for some innovative didactics of an engineering university, which includes several components which are as follows: a target component; a motivational and informative component; operational-activity and control-productive components. The introduction of the model contributed to the formation of students' motivation for research, as a result the students developed their subjectivity as active participants in the educational process because of adopting common goals and harmonizing the interests of all subjects, creating an atmosphere of productive activity.

The development of content components included the following requirements:

- the structured content of education;

- the interdisciplinary and intrasubject integration of disciplines. This facilitated the unification of teachers of different subject blocks, the coordination of the content of educational programs, lectures, laboratory, and practical assignments;

- the coordination of the sequence and methods of solving research problems and cross-cutting research tasks. The students mastered the methods of research activity gradually and systematically, therefore, they acquired individual research experience, which mastered the awareness basis of their actions;

- the opportunities inherent in the discipline of the basic part of the curriculum. We also introduced permissible changes to the content, i.e. such special practices "the methods for solving non-standard research tasks of an engineer", "the culture of the research", "the methods of mathematical statistics in engineering research", "the creativity in the profession of an engineer", "the heuristic methods of research", etc.;

- the changes to the variable part of the curriculum. We developed several special courses which were as follows: "the fundamentals of the methodology of scientific research", "the professional self-determination", "the fundamentals of research activities of the engineer". All these subjects alongside with the basic disciplines, contributed to the transfer of emphasis on the learning process as a process of productive knowledge, actions;

- the introduction of new tasks to the practice module. We worked out the tasks jointly with representatives of enterprises and directed them at solving practical production problems with necessary methodological support;

- the renewed educational working programs, developed according to the FSES for Higher Education. We reformed the content of the competencies, introduced interdisciplinary links; designed the list of laboratories, practical, and individual work of students, their methodology with a special accent on active and interactive methods, a set of defined competences and the ratings criteria.

We introduced the methodological support of the process of preparing students for research activities, as well as many textbooks, teaching aids, assisting instructions and recommendations for laboratory, practical work, for studying disciplines, for individual work. We completed the construction of educational and methodological manuals, executed in the form of logically completed thematic sections, starting with goals, and ending with the didactic tools for checking progress and achievements, accompanied by various tasks.

We used a modular scheme for constructing the learning process, which includes studying the material of the discipline in the process of educational, research activities, rating control which includes rating indicators and journals posted in the online educational system “Educon”. This strategy contributed to teaching students the general principles of constructing concepts, conclusions, allowed to build theoretical generalizations, stimulated independence, the possibility of an individual pace of advancement in a module.

The research proves that it is impossible to offer a single level of research competence for all students because abilities, individual characteristics, the levels of preparation of students are different. We set a basic level (mandatory for all students in accordance with the requirements of FSES for Higher Education) and a “higher” level (for the students most focused on research activities). This strategy required the application of an individual approach, therefore, we appointed individual consultants to the most advanced students, and developed “individual trajectories”. Students actively participated in the work of initiative groups, i.e. a group with individual projects, as well as, in competitions and conferences.

There is much evidence that to activate the research activity of students it is necessary to form new experience from theoretical comprehension through its application. To achieve this goal, we included in the process of solving problem several forms of interactive technologies, which are as follows: various forms of discussion (dialogues, a group discussion, the analysis of situations, etc.); games (didactic games, creative games, including business (management), role-playing, organizational-activity games); training activities; interactive activities (clash of ideas, development of proposals, simulations of real engineering activities, sophistications). The current data highlight that the problematic presentation of the material at the lectures promotes the development of scientific thinking among students. Problematic presentation is also necessary for the mastering of the necessary methodological knowledge, the formation of methods of research activity.

The finding of our study is the idea that activities imitating real research and professional situations are the basis for the process of preparing for research activities. We developed special forms and means of out-of-class activities, which were as follows: on-site laboratory and practical work; the fulfillment of research assignments, projects, the working projects of initiative groups. When performing laboratory and practical assignments, students develop research skills, which is facilitated by the possibilities of a network form of interaction with representatives of basic enterprises; electronic educational resources that allow observing the processes under study, to put forward hypotheses, to collect material for research, to model objects and processes, and to find optimal solutions.

The use of the electronic educational system “Educon” contributed to the creation of electronic methodological disciplines which included the following forms: virtual laboratories and practical works, presentations, excursions, the system of tasks for in-class and extracurricular work, assessments, the ways of information search, and open educational resources, interactive communication among teachers, students during consultations and reviews.

The developed system of tasks was of much importance. For their implementation, we

developed several forms of in-class activities (laboratory and practical work), extracurricular work (on-site laboratory work, individual work), network interaction in the system “Educon”. We paid attention to the didactics of research assignments: the formulation of the problem, the assessment of the given conditions; the definition of requirements to the result; the research plan (search for ideas), the choice of research methods and the definition of actions, the verification of results, their evaluation (reflection).

One of the effective means of forming research competence is the implementation of projects. During the 1st and the 2nd years of studies we introduced the projects of the initial (basic) levels, which allowed to master the basic knowledge, to form the general cultural competence (organization and self-organization of the project activity, the technology of the project, the culture of the presentation of the results, the formulation of the results in accordance with regulatory requirements), professional and special competence.

The advanced level of projects (Student Scientific Research Work, course projects, graduate qualification work) requires the search, analysis and the systematization of information, new information, longer preparation time, and, therefore, they need at extra-curricular time. We summed up the results of creative assignments, conferences and seminars projects, roundtables together with the representatives of the base enterprises. It is important to use complex research projects, cross-cutting research assignments while writing course and graduate qualification work. The topic of the project must relate to the research activities of the departments, the demands of industrial production.

While organizing and conducting the practice tasks, which are aimed at solving real production problems, students master their research methodology. The key aspect of the model was the students’ portfolio, the complex of works, which reflects the dynamics of the students’ development through the presentation of heterogeneous results of an activity. The portfolio is an instrument of students’ self-presentation, contributing to self-organization, self-development, reflection.

Teachers were responsible for the control-effectiveness component during the formation of the research competence of the students and, if necessary, correcting it, as well as the implementation of the self-control by the student. The self-control functions usually develop step-by-step, they form conscious, strong-willed character, and research activities become more meaningful. It is of much importance to create necessary conditions for the development of students' reflection and self-control. Students need skills for analyzing and evaluating their own actions with the aim of involvement into the process of self-observation, self-knowledge, self-and mutual evaluation, and open access to rating indicators.

The effectiveness evaluation of the proposed model requires the selection of criteria, indicators of the formation of research competence of students. We have identified all the necessary components which are as follows: cognitive, personal, and active. We used these components as criteria for the formation of the research competence of engineering university students.

The cognitive component determines the degree of mastering the conceptual apparatus, the ability to use the formed theoretical base in the process of research activity.

The personal component includes the motives and values of personality, the student’s reflections during the process of research.

The activity component determines the level of research activities’ development, the possibility for the practical application of the learned methods of acting and accumulated knowledge.

Now we proceed to the description of the experimental results. The total number of people involved in the experimental work was 1520 people, 1390 of which were students and 130 were teachers. We carried out the experiment in three stages: verifying, formative, and generalizing.

At the verifying stage, we decided that the research competence of the 1st-year students was not formed enough; students with a low level of research competence dominated.

At the formative stage, we proved the educational practicability of introducing a functional

model of preparation for the research activity.

At the generalizing stage, we focused on the model effectiveness evaluation through the description of the evolving dynamics of the research competence formation, and the analysis of the obtained results.

At each stage of the experiment, we conducted the analysis of the results, designed special analytical tables and histograms, allowing to trace the dynamics of changes that occurred because of a targeted impact on the process of research training, and to evaluate the model's effectiveness.

The data of the initial and final sections showed a stable increase of the indices of all components in the experimental groups in comparison with the control groups (Table 1).

Table 1
The research competence of students, %

The level of the competence maturity	Experimental group		Control group	
	input	output	input	output
Advanced	0	3	0	1
High	0	47	0	11
Intermediate	1	40	1	33
Low	2	9	2	48
Zero	97	1	97	7
c2	172,8		79	

The effectiveness of the model is also confirmed in a comparative analysis of the results of graduates of 2016 (experimental groups) with the results of graduates of 2011 (Table 2).

Table 2
The research competence of graduates, %

Levels	personal		cognitive		activity	
	2011	2016	2011	2016	2011	2016
Advanced	1	3	1	3	1	3
High	4	45	12	50	4	49
Intermediate	16	40	36	40	36	40
Low	66	10	47	7	47	7
Zero	13	2	4	0	12	1

c2	121	69,7	100,8

The statistical analysis verified the reliability of the results through Pierson's chi-square test. Due to the realization of the functional model, the students of experimental groups showed statistically significant changes in the levels of formation of all components of research competence, these differences were statistically significant in comparison with the comparative results of control groups.

4. Conclusion

The concept of the students' research training includes the systematization, analysis, interpretation and development of existing approaches in the new educational and socio-economic conditions, taking into account the requirements of professional standards and employers' demands.

Our major finding is the content of innovative didactics of an engineering university, which we presented in the form of a functional model that ensured the development of students' creativity, their research abilities, the formation of functional research skills as universal methods of contact with the outside world.

The developed and implemented functional model of research training for engineering university students ensures achievement of the set goals in the field of engineering education.

Another important finding is our attempt to develop and describe the criterial-evaluation apparatus, including criteria and indices of determination of readiness for research activity of students of an engineering university, which unites cognitive, personal, activity-related components.

The analysis of the results of experimental work, the comparison of the experimental and control group indicators, shows the effectiveness of the developed concept which we realized through the functional model of students' research training in the context of competence-oriented engineering education.

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