CONSIDERING STUDENTS' RESEARCH TRAINING IN TECHNICAL HIGHER EDUCATION INSTITUTIONS ACCORDING TO THE CONTENT AND STRUCTURE OF A MODERN ENGINEER'S RESEARCH ACTIVITY

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Abstract. The earnestness of the issue under scrutiny is because of the progress to an inventive economy, the improvement of data advances, the creation and spreading of complex human-machine frameworks, of sociotechnics, which has subjectively changed the designing movement, made everything including, the main impetus behind the mechanical change of society. Around the world, there is a developing requirement for aggressive designing work force prepared for dynamic support in inventive building forms, the improvement of new thoughts, the arrangement of research generation issues – as it were, for experts who don't think traditionally and are equipped for embracing non-standard arrangements showing research conduct, since the specialist of things to come is an exploration engineer. The reason for the article is to take care of the issue of research preparing with regards to capability arranged building training based on the substance and structure of research exercises of a cutting edge engineer. In light of the systematization, investigation and improvement of existing arrangements of logical research and works in the field of designing training, proficient teaching method and the points of interest of building exercises, on administrative archives, instructive and proficient norms, the substance and structure of the examination action of an advanced architect is characterized. These arrangements are the reason for a model went for research preparing of understudies of specialized colleges. Exact strategies (perception, surveys, interviews, testing, self-appraisal, documentation examination, item investigate, academic structure) made it conceivable to decide the dimension of research ability of first-year understudies and graduates when the test on executing the model of understudy look into. The strategies for numerical measurements demonstrated the dependability of the outcomes, the examination of which demonstrated that the presentation of the model of research preparing in the instructive procedure of a specialized college adds to the advancement of the understudy's innovativeness, inspiration, cautious disposition to look into, availability for dynamic investment in creative building forms, capacity to grow new thoughts, research and generation undertakings and the appropriation of non-standard arrangements. The materials of the article are of handy incentive for the showing staff of specialized schools, in the arrangement of extra instruction for the advancement of the aptitudes of administrators and instructors of specialized colleges, and for masters in strategy, hypothesis and routine with regards to professional training.

Keywords: research activity, engineer, research training, research competence, engineering activity.

1.Introduction

Consideration of the problem of vocational training in technical universities to investigate the activity requires identifying the essence and structure of this type of activity. For this, it is necessary to consider a number of key concepts. As an initial understanding of the activity as an object of investigation, the author will adopt the conceptual model developed by A.N. Leontiev. From this position, activity is understood as "... a unit of life mediated by psychic reflection, the true function of which is that it guides the subject in the objective world" [12]. In the framework of this view on professional activity, the author takes into account the position of V.D. Shadrikova and considers "activity as a form of vigorous attitude towards reality, aimed at achieving consciously set goals related to the creation of socially significant values and the development of social experience" [18].

The study and analysis of scientific works made it possible to single out a number of provisions for revealing the essence of research activity (Table 1).

Table 1 The essence of the notion 'research activity'

Researches	Definition
Research activity – research-estimating, intellectual-creative, cognitive	
V.V. Davydov	"An activity to examine surrounding objects to obtain information that contributes to solving problems facing the subject" [6].
P.V. Seredenko	"A kind of creative intellectual activity, which through the mechanism of search activity promotes the realization of oneself in the form of research behavior" [16].
Research activity as a means of satisfying cognitive needs	
A.N. Leontiev	"An activity where the subject is the development of new knowledge" [13]
I.A. Zimnyaya, E.A. Shashenkova	"A specific human activity which is regulated by the consciousness and activity of the individual, aimed at satisfying cognitive, intellectual needs; the product of which is new knowledge, obtained in accordance with the goal and with objective laws and circumstances that determine the reality and attainability of the goal" [8].
Research activity is connected with the consideration of research behavior	
A.I. Savenkov	"A kind of intellectual creative activity generated as a result of the functioning of search activity

	mechanisms, built on the basis of research behavior. ... It includes motivating factors (search activity) of research behavior and mechanisms of its implementation" [15].
S.L. Belykh	"Activities, in contrast to research behavior, understood as a conscious process, having a goal, and representing self regulation aimed at achieving the goal" [1].
M.I. Koldina	"A kind of creative, cognitive activity aimed at independent mastering of theoretical and experimental work, modern methods of scientific research and experimental techniques" [10].

Thus, the study of various interpretations of the term 'research activity' is regarded by the author of the present study as a process of purposeful, active interaction of a person with a real or model environmental object, oriented to obtaining subjectively new and objectively new knowledge in accordance with intellectual requests of the individual.

2.Methods

Theoretical (study, analysis and synthesis of pedagogical, social, engineering, economic literature on the problem under consideration, of normative documents, educational and professional standards, analysis of the subject of research, modeling of the educational process, generalization of the research results); empirical (study of normative documents, observation, interviews, testing, self-assessment, documentation analysis, study of product activities, pedagogical design); experimental (pedagogical experiment, methods of mathematical processing of results).

3.Results and discussion

3.1.Contents of research activities of an engineer

When identifying the specifics of the research activity of an engineer, it is necessary to take into account that its result should be an innovative research product in demand in science and industry, and it is also necessary to consider the specifics of the engineering activity itself. The professional activity of an engineer is considered as labor activity, noting its purposeful nature and the unity of the three components: the subject-effective (as a process in which a person, with the help of the means of labor, carries out a planned change in the subject of labor); physiological (as a function and needs of the human body); psychological (realization of a conscious goal, manifestation of will, attention, intellect) [11].

The main characteristics of engineering activities are [14]: strengthening the creative nature of the activity; integration of engineering functions and activities; effective inter-professional communication; and orientation to the needs of the market. Modern engineering activity is characterized not only by the quantitative sophistication of engineering objects, by the increase in the number of their components and connections or by the expansion of the volume of scientific knowledge – it becomes creative, has a pronounced research character, and through it a person interacts with the world as a subject, acquiring the ability to change it.

The concept of an engineer's research activity is inextricably linked with the notion of professionalism. Questions of professionalism in the last decade have become the subject of close attention of scientists (A.V. Gneushev [4], A.A. Derkach and V.G. Zazykin [7], E.A. Klimov [9], A.K. Markov [13], S.A. Chistyakov [20], and others). Professionalism as a personality trait integrates the personal and activity aspects of the phenomenon and manifests itself in "integrated development to a very high level of constituent substructures of the psychic properties and character of the personality, its experience and orientation, and this level of development is not 'peak', not 'definite'" [7] .

In this regard, two sides of professionalism are distinguished: the state of the human motivational sphere and the state of the operational sphere (methods, means of activity, abilities, knowledge, skills, etc), that is, professionalism is defined as the unity of professionalism of the individual and professionalism of activity. Thus, a modern engineer should see their profession in the totality of its broad social ties, of its demands, content and specificity and those of its representatives; they should navigate in the sphere of professional production tasks and be ready to solve them in changing social conditions – in other words? they should be ready for research.

Taking into account the above definitions of research activity and professionalism and the specifics of engineering activity, the author determines the research activity of an engineer as a process of purposeful, active interaction of a person with a real or simulated object, aimed at obtaining new knowledge necessary for the creation of innovative technologies for the development of production and improvement of its technical and economic indicators, making creative contributions to the profession.

3.2.Structure of research activities of an engineer

In modern conditions, the structure of engineering activities and tasks that are being addressed are changing. Let us consider the structure of engineering activities using the example of FSES HE (Federal State Educational Standards for Higher Education) for the expertise area 'Oil and gas business' [17]. The structure includes: production and technological activities, organizational and management activities, experimental research activities, and project activities (Figure 1).

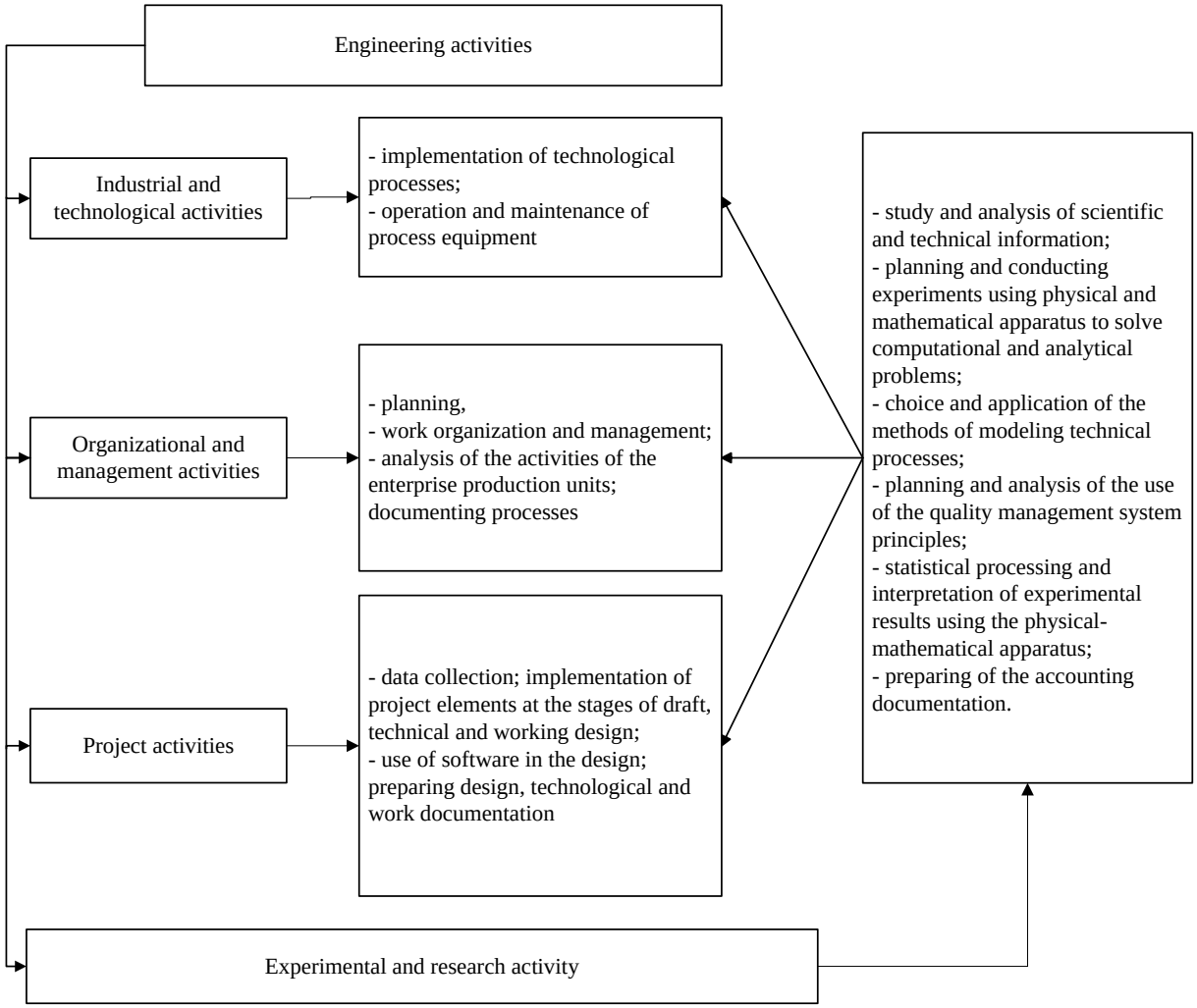

Fig.1 Structure of engineering activities

In spite of the fact that experimental and research activity is represented independently by a separate complex, it is inextricably linked with all the components of an engineer's activity and not isolated from them. Engineering studies are carried out in a relatively short while and are directed to solving specific engineering problems while specifying the available scientific knowledge, and at the same time they include: preliminary assessment of the task, estimation of the possibility to use already obtained scientific data for solving a specific problem, the scientific substantiation of the development, the preliminary evaluation of the development effectiveness, analysis of the need for missing scientific studies, etc .

The competencies considered for each type of engineering activity are inextricably linked with the competence of experimental research activities which contributes to the effective development of all the engineering activities in general. The relationship of competencies is shown in Figure 2.

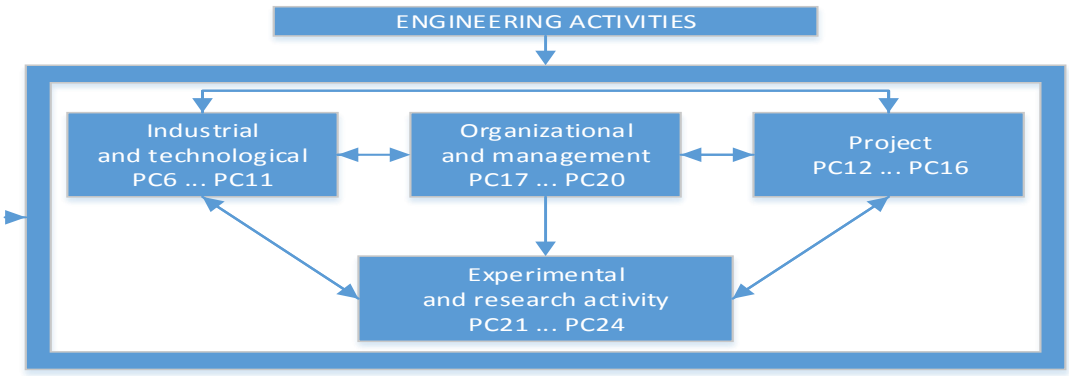

Fig. 2 Components of engineering activities

For greater visibility of the presence of the research component in each activity, consider the competence matrix of all the activities of an engineer (Table 2).

Table 2 Competence matrix

EA	ITA						OMA					PA			
	PC 6	PC 7	PC 8	PC 9	PC10	PC11	PC12	PC13	PC14	PC15	PC16	PC21	PC22	PC23	PC24
PC17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PC18	+	+	+			+	+	+	+	+	+	+	+	+	+
PC19	+	+	+			+	+	+	+	+			+	+	+
PC20	+	+	+	+	+		+	+	+	+	+	+	+	+	+

Thus, the analysis of the components of engineering activities, as well as the consideration of a set of general cultural and professional competencies, shows that the research character is manifested as leading in all the components of an engineer's activity, contributing to its effective flow. A modern engineer should be ready for designing and analyzing their activities, for acting independently in conditions of uncertainty and for possessing a desire for self-realization and development.

When identifying the structure of research activity, relying on the existing science provisions on the structure of activities, the author also took into account the components of the ideal model of the psychological system of activities proposed by V.D. Shadrikov, which is regarded as a "theoretical (or informative) generalization, and allows reducing various forms of activity to a specific theoretical construct, which reflects the components common to any activity and their connections. ...This model can be used in the analysis of a particular activity, treating it as private" [19]. As functional blocks of activity, the author distinguishes the object, the subject, the motives, the objectives, the content (actions) and the result (Figure 3).

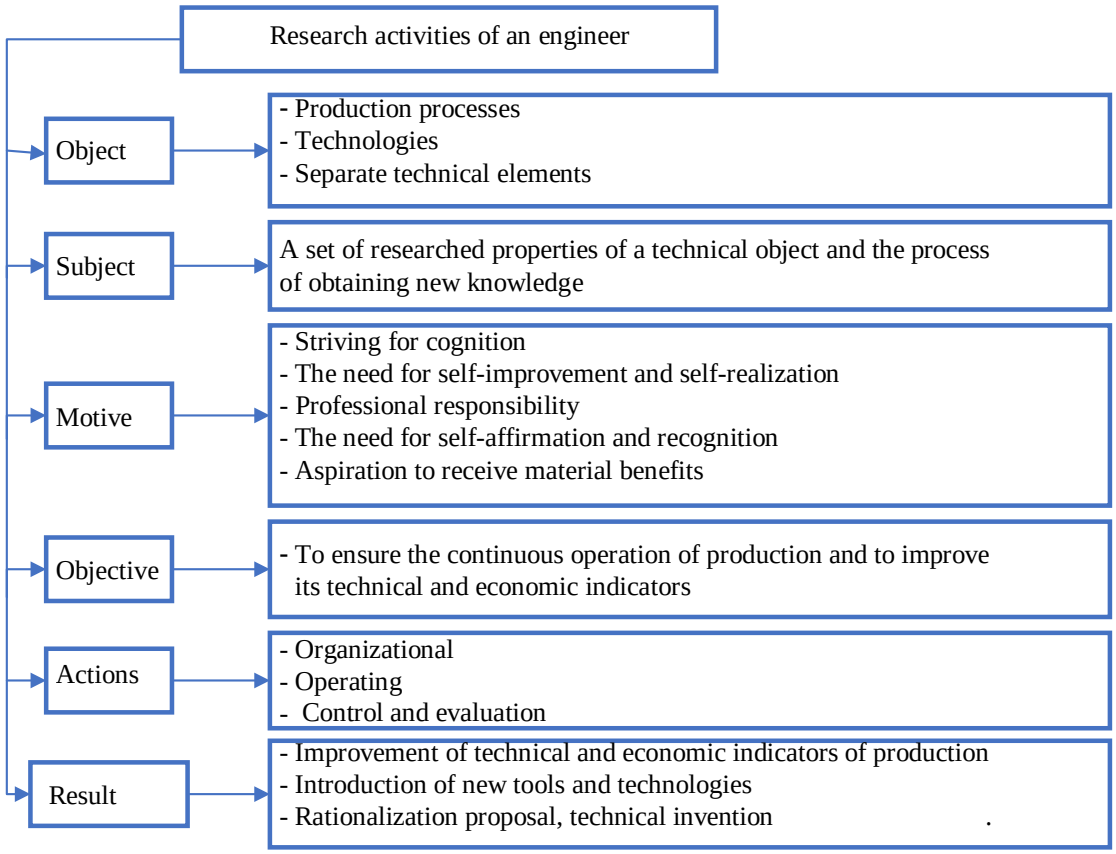

Fig. 3 Structure of research activities of an engineer

The motives are considered in terms of their significance, namely: the desire for cognition; the need for self-improvement; professional responsibility for the results of labor; the need for recognition and self-affirmation; satisfaction of material needs.

The objective is disclosed for private purposes, determined from the analysis of the content of engineering activities, namely, improving the quality of products; ensuring the uninterrupted operation of production; increasing in labor productivity and production efficiency, etc.

The research activity of an engineer comprises a number of actions: organizational, operational and control, including a certain set of operations (Table 3).

Table 3 Actions performed in the research activity of an engineer

Type of action	Contents of action	Research competences/skills
Organizational	Definition of goals and objectives of the research	active, intellectual
	Collection and processing of information, the choice of technical objects and methods of their research	active, intellectual, informational
	Search for solutions; research planning, equipment selection	active, intellectual, informational
	Definition of production conditions for research	active, intellectual
Operational	Development and implementation of the solution	active, intellectual, informational
	Information analysis, setting up real-life conditions experiments	active, intellectual
	Collection and processing of results	active, informational
Control	Verification of the practical efficiency of the solution	active, intellectual, informational, reflexive
	Verification of the economic efficiency of the solution	active, intellectual, informational
	Determination of production conditions most effective for the suggested solution	active, intellectual, informational, reflexive
	Coice of the most rational solution on the basis of the conducted research, presentation of the result	active, intellectual, informational, communicative, reflexive

Organizational actions are aimed at determining the goals and objectives of research; when revealing a deviation in the technological process or in the functioning of equipment, the engineer formulates the goal of the study, determines the object, the hypothesis, the tasks and the methods of research. Carrying out the research requires drawing up a program of actions and determining the optimal conditions for research.

Operational actions are certain operations performed to achieve the research goal which are aimed at creating a model (design or technical) based on a preliminary hypothesis, further testing the hypothesis in the laboratory, and then under production conditions.

Control actions are carried out to verify the effectiveness of the work done. Faults are eliminated, and the result is estimated.

The blocks included in the structure are interrelated and allow considering the research activity of an engineer as a process of purposeful and active interaction of a person with a real or simulated object aimed at developing new knowledge necessary for the creation of innovative technologies for developing production and improving its technical and economic indicators, making a creative contribution to the profession.

Thus, the analysis of professional standards allows stating that the allocated labor functions, in combination with the necessary skills, include a research component (direction) and determine the need for students of an engineering university to be trained for research activity.

As a result of the analysis of FSES HE expertise area 'Oil and gas business' and professional standards, taking into account the requirements of employers, the author identified the main research tasks that a graduate of a technical university should be able to solve to be successful in engineering activities:

1. to analyze information on the operation of technical devices and the flow of technological processes;
2. to carry out experimental research of objects (technical devices and technological processes), choosing optimal methods;
3. to perform processing of experimental results using mathematical statistics methods, to compile reports (description of ongoing research, preparation of data, surveys and other documentation);
4. to collect initial data and submit them for the purpose of developing object models (based on fundamental sciences achievements); to collect project documentation for improving production processes, technologies, equipment; to work on the methods of negative impacts elimination (prevention), depending on the profile of training;
5. to perform calculations on the design of processes, to assess the impact of various factors on production processes (using application software products); to assess the economic effectiveness of decisions taken;
6. to provide results in the form of design, technological and working documents; to participate in design and research decisions.

3.3.Groups of research skills

Performing research activities and solving research problems is possible due to the formation of research skills. In the scientific and pedagogical literature, there are various interpretations of the term 'research skills': the way of implementing a 'separate activity' [2]; the ability to observe, the experience acquired in solving research problems. The author considers research skills as ways to carry out research activities mastered by a person on the basis of theoretical knowledge and experience of research activities.

In this study, taking into account the previously identified main types of research tasks solved in the professional activity of an engineer, the following groups of research skills are distinguished (Figure 4):

- *active*: setting research tasks, taking into account the requirements for the results of the decision; justifying the progress of tasks solving, defining the structure of actions; planning research activities; using collected information in the planning and organization of research; choosing research methods; applying research methods; developing diagnostic tools; design, presentation of results; applying norms and ethical principles in the research process;
- *intellectual*: study of various sources for the collection of information; generalization, systematization, information analysis; observation of phenomena, processes, facts and their analysis; synthesis of new information; logical deductions from private, single cases to the general conclusion; logical deductions from the general to the particular; the ability to draw analogies; summarizing research findings;
- *informatization*: use of technical means and network resources in the process of collecting, processing information, conducting experiments, processing and providing work results;
- *reflexive*: self-analysis, self-control and mutual control of research actions; objective evaluation of the research results, self-esteem;
- *communicative:* presenting the research activities results (ability to conduct a dialogue, speak on the results of work); teamwork in the research process.

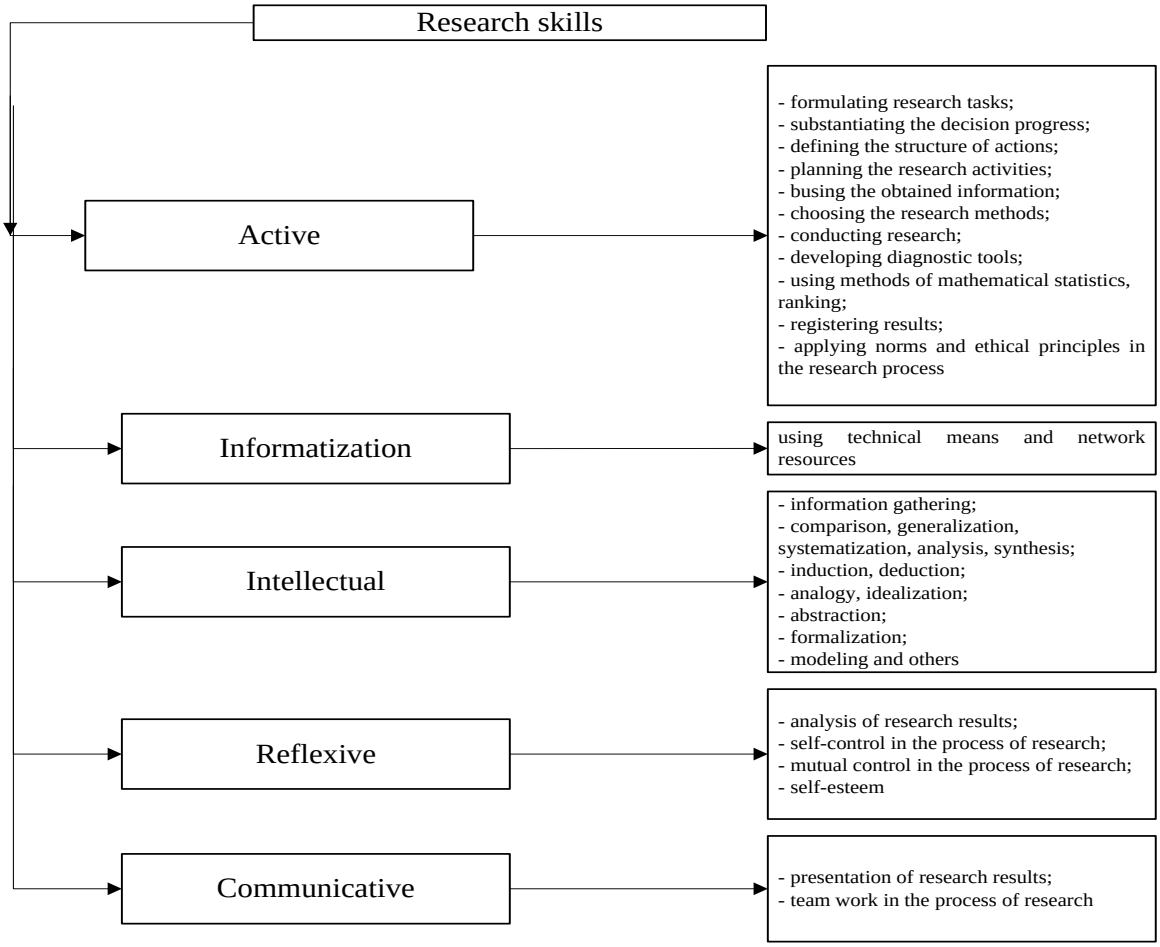

Fig. 4 Research skills

The selection of organizational, operational, control and evaluation activities and a certain number of research skills as part of the research activity gives grounds to paying special attention to the didactics of solving research problems, namely: setting the task, assessing the conditions; determining the requirements to the results of the decision; planning research, identifying the structure of research activities, choosing research methods, verifying the solution, evaluating the results.

At the same time, as the methods used in engineering research, which an engineering university student should master in the process of research preparation, the author distinguishes the following: observation, comparison, experiment, formalization, abstraction (identification, isolation, constructivization, assumption of potential admissibility), analysis and synthesis, deduction and induction, analogy, modeling, idealization, ranking, methods of mathematical statistics (least squares, correlation, regression, dispersion analysis et al.), systemic approach, axiomatic method, hypothetical method, etc.

3.4.Functions of research activity

Characterizing the research activity, it is necessary to distinguish its functions (Figure 5), contributing to the implementation of the requirements of FSES HE for the formation of general cultural and professional competences, with the goal of becoming a competitive graduate of an engineering university:

- personal development (development of emotional and volitional sphere, cognitive processes, mastering ways of self-improvement and intellectual self-development);
- scientific-methodological (formation of an integral modern scientific picture of the world, development of a scientific style of thinking, mastering the methods of scientific knowledge);
- culturological (involvement in the broad socio-cultural context of the development of science, technology, familiarization with the culture of scientific schools [29]);
- value-orientation (awareness of the value of research as one of the conditions for the successful self-realization).

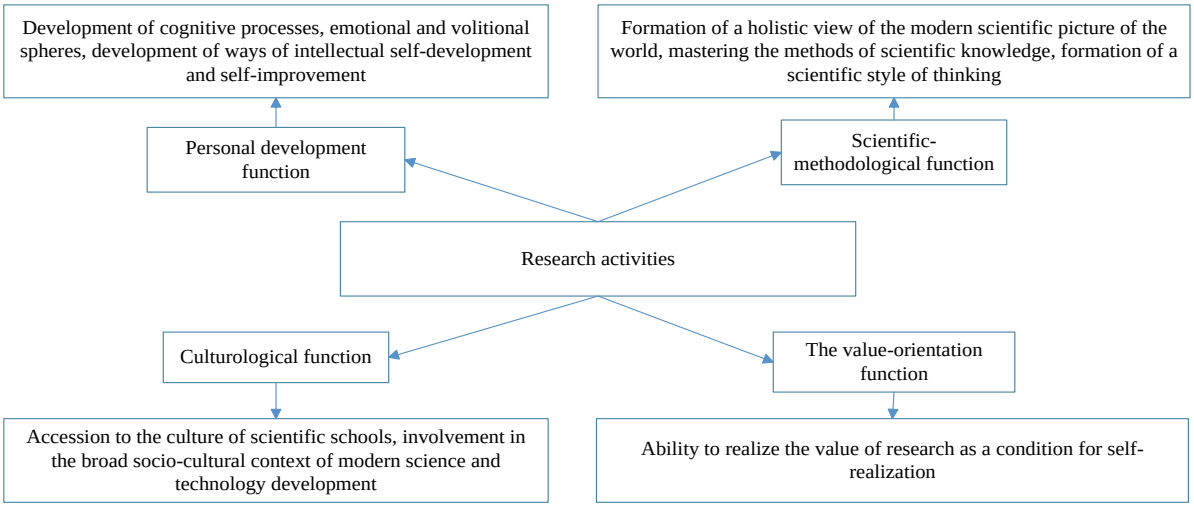

Fig.5 Functions of research activity

Having examined the content, structure, functions of the research activity of a modern engineer, it is necessary to conclude that in the process of student's research training an important value should be given to the formation of sustainable motivation; clear definition of goals; the formation of organizational, operational and control and assessment actions the fulfillment of which is possible when a complex of research skills is formed oriented towards research problem solving.

The research training of students as a factor in improving the quality of technical education is also considered by foreign researchers and teachers. Introduction of special courses to the learning process, acquaintance and use of heuristic methods, implementation of research assignments and projects, development of industrial design skills, aesthetic development of students and ethical education are presented in the following works: [21], [3], [23], [22], [27], [28], etc.

The study of foreign experience made it possible to identify a number of provisions that should be taken into account when preparing students of an engineering university for research: including in the curriculum special disciplines aimed at preparing for research activities; step-by-step acquaintance with the methods of solving research problems, use of heuristic methods, methods of generating ideas; development of industrial design skills, aesthetic development of students (creating a system of tasks and applying it in the class and extracurricular activities); implementation of group and individual research projects to attract students to research and development activities; close cooperation with production (joint development of programs, assignments, evaluation tools, participation in control activities, field visits, work, internships); replacing competition with cooperation (team research project work); free access to information resources and software (network interaction with employers, electronic support system of educational process); portfolio management, promoting the knowledge of legislation in the field of copyright, rules for its compliance) [5].

Thus, the need to introduce a learning process model oriented towards student research [25] in the educational process of a technical higher education institution is conditioned by the requirements of FSES HE, professional standards, features of modern production and society.

3.5.Results of the implementation of the research training model for technical universities students

The implementation of the research training model for technical university students was carried out in the educational process of Tyumen Industrial University (the branch in the city of Surgut), Surgut State University and Surgut State Pedagogical University. The total number of people involved in the experimental work was 1520, of which 1390 students and 130 teachers. The implementation of the model was carried out in three stages: ascertaining, forming, generalizing [24]; questionnaires, testing, ranking, analysis of works, assignments, self-assessment, observation, expert assessments, etc. were used, and the results were recorded in individual cards.

To assess the effectiveness of the model, it was necessary to select the criteria adequate to the tasks in view. The cognitive, the personal and the activity components were used as components of research competence, and also as criteria.

The cognitive component determines the degree of mastering the conceptual apparatus and the ability to use the theoretical basis formed in the process of research activity, the personal component is the motives and values of, the student's reflexivity in the process of research. The third component determines the degree of mastering the ways to perform research activities and the possibility of using the acquired ways of acting and the accumulated knowledge in practice [26].

The ascertaining stage showed that first-year students do not fully realize the research character of an engineer's activity, and their research competence is not formed (Table 4). At the same time, interest was noted in the implementation of research activities in the studying process at the university.

Table 4 Development of the research competence of first-year students,%

Levels	motivational		reflexive		cognitive		activity	
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Highest	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0
Medium	1	1	1	1	1	1	0	0
Low	2	2	2	2	9	10	4	4
Zero	97	97	97	97	90	89	96	96
χ^2	0,33		0,33		0, 038		0,28	

The results of graduates' readiness before the experiment on implementing the model of research training for students of technical colleges turned out to be low (Table 5) and reflected the results of the traditional training process at the university. We recorded the dominance of graduates with a low level of research competence, which indicates that graduates are not ready for independent research engineering tasks.

Table 5 Development of research competence of graduates before the experiment

Levels	Personality component, %				Cognitive component, %		Activity component, %	
	motivational		reflexive					
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Highest	0	0	0	0	0	0	0	0
High	4	4	4	4	12	12	4	4
Medium	16	16	16	16	37	38	32	33
Low	67	66	67	66	47	47	58	57
Zero	13	14	13	14	4	4	6	6
χ^2	0,0164		0,0164		0, 24		0, 088	

At the forming stage, a model for the research training of students (experimental groups) was introduced into the educational process of a technical university. In the control groups, the training took place according to the traditional scheme. At the end of each academic year, control samples were taken, which allowed determining the intermediate results. The results of the development of the research competence of students at the end of the experiment are presented in Table 6.

Table 6 Development of the research competence of first-year students,%

Levels	motivational		reflexive		cognitive		activity	
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
Highest	3	1	3	1	3	1	3	1
High	45	9	45	9	50	19	49	9
Medium	40	26	40	26	40	38	40	43
Low	10	54	10	54	7	40	7	44
Zero	2	10	2	10	0	2	1	3
χ^2	120		120		94,8		57	

The effectiveness of the model is also confirmed in a comparative analysis of the results of graduates before and at the end of the experiment (Table 7).

Table 7 Development of the research competence of graduates, %

Levels	Personality		Cognitive		Activity	
	before	at the end	before	at the end	before	at the end
Highest	1	3	1	3	1	3
High	4	45	12	50	4	49
Medium	16	40	36	40	36	40
Low	66	10	47	7	47	7
Zero	13	2	4	0	12	1
χ^2	121		69,7		100,8	

The reliability of the results is confirmed by a check based on statistical analysis using the criteria of mathematical statistics. Analysis of the implementation of the model oriented towards the students' research training revealed its effectiveness. Due to the implementation of this program, students of experimental groups had statistically significant changes in the levels of formation of all the components of research competence, and these differences are statistically significant in comparison with the results of control groups.

4.Conclusion. At the current development stage of technical education in Russia, the problem of preparing students of an engineering university for research is dominant, requiring a rethinking of the goals and tasks of engineering education, and the formation of conceptual bases for the educational activity of the university. The purpose of research activity training is the formation of the research competence of technical university students.

The author of the present study determined that engineering activity has a pronounced research character; through it an engineer interacts with the world as a subject and acquires the ability to change it. The analysis of general cultural and professional competences and professional standards demonstrated that in the activity of an engineer the research character is manifested as the leading one, contributing to its effective development, which is the basis for self-development and determines the need for purposeful preparation of students for research activities. Research training (as an obligatory quality of the implementation of the requirements of FSES HE) provides a value-based attitude to research; the ability to identify information failure and (at the activity level) to obtain new knowledge for solving research engineering problems; the ability to plan and conduct research, to collect and process data, and to interpret the results. As a result of the analysis of FSES HE, professional standards and employers' requirements, the main research tasks were identified that the graduate of a technical university is to be able to solve and the methods of engineering research to be mastered in the process of research training at the university; these methods were used in the implementation of a model aimed at research training.

In the process of research the author developed and implemented a functional model for preparing a student of an engineering university for research, which is the basis for innovative didactics of an engineering university and an integral part of the concept in which the target, content, motivational, operational-activity, control and regulation components are presented. The model contributed to the fact that:

- the students' motivation for research was formed, their agency was developed as of active participants in the educational process on the basis of common goals, an individual approach was implemented, an atmosphere of productive activity was created;
- the content of education was structured, interdisciplinary integration was carried out, special courses and practical tasks were included in vocational training; special forms and means of out-of-class activities were created (field laboratory and practical work, research assignments, projects, work of initiative groups, etc.);
- interactive forms and methods of mastering the content of the curriculum were chosen and rationally used, as well as information technologies, network educational resources (virtual laboratories, excursions, presentations, etc.);
- a system of tasks important for engineering activities was developed and used, purposeful training on ways of their implementation during the studies and practice period took place, complex comprehensive cross-cutting research projects were used in carrying out course and final qualification work;
- conditions for the development of reflection and self-control were created (skills of analyzing and evaluating one's own actions with the aim of attracting students to the process of self-observation, self-knowledge, self- and mutual recognition, and open access to the rating indicators were made) [25].

The results obtained in the course of the experimental work showed that the introduction of a model of research training in the educational process of a technical university contributes to the development of the student's creativity, motivation, value-based attitude to research, readiness for active participation in innovative engineering processes, the ability to develop new ideas, production tasks and the adoption of non-standard solutions.

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