INNOVATIVE TECHNOLOGIES OF BUILDING TECHNICAL UNIVERSITY STUDENTS PREPAREDNESS FOR DESIGN AND DEVELOPMENT ACTIVITIES

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Abstract *— The need for innovation in research and development training of engineers is related to the raising requirements to design knowledge and experience of a professional. The paper defines the concept of "preparedness to research and development activity" as the final target of a specialist's professional training at a technical university, and formulates the problems to be solved for the achievement of this aim at different stages of training. The main stress in this case is made on the organization of the study information environment, adequately modeling the professional sphere of activity of new generation specialists – developers of hi-tech technologies, having excellent command of the methods of mathematical analysis and optimization of technological processes and equipment. Also, the following factors are of great importance: continuity and succession in research and development training of students; development of rational methods of choosing the contents and structuring of study material; combination of progressive teaching methods and techniques at each stage of training; the choice of evaluation criteria and phased quality control of student's preparedness to research and development activity. The innovative techniques have been implemented at Tambov State Technical University in the training of certified specialists and masters majoring in "Energy- and Resource-Saving Processes in Chemical Technology, Oil Chemistry and Biotechnology", "Technological Machines and Equipment", and "Food Engineering".*

Key words — training, design, technique.

ENGINEERS' AND MASTERS' TRAINING FOR DESIGN ACTIVITY PROLEM STATE ANALYSIS

The increased attention to the problems of design activity is related to its growing importance for social and economic development of the society. According to the statistics [1], design stage determines more than 70% of the quality and reliability of technological, economic and social systems being implemented. Thus, the design culture of a specialist is nowadays a key element of professional activity and the level of preparedness to solving research and development tasks becomes one of the most important qualification characteristics of a technical university graduate, which can secure him/her a competitive place at the job market.

While evaluating the quality of technical university graduates' training for design activity, it has been noted that there is a mismatch between the qualification requirements to an ideal specialist set by the State Educational Standard and a real graduate's meeting these requirements. In our opinion, it is connected with the defects in forming a social demand for a specialist and chiefly with the way this demand is satisfied by specific universities, chairs and professors. To solve these problems it is necessary to improve structure, content and process organization of a specialist's training for design activity, as well as the development of his/her professional and personal qualities needed for it.

Lately the engineering pedagogics has seen a great number of new techniques of radical, combinatorial and modifying type being introduced, which aim at the improvement of both certain elements of the study process and the system of engineering education on the whole. Among these there should be mentioned the program of specialists' training on the basis of computer engineering [2], the problem algorithm system of active teaching of students [3], computer-oriented technology of specialists' training [4], and the system of engineering psychological support of creative forms of research and development activity [5], which, to our mind, can be easily adapted to the available resources and infrastructure of a particular technical university and may be successfully implemented for the improvement of quality of engineers' and master's students' training for design activity.

The analysis of the state of the problem of specialists' training for design activity in technical universities of Russia allows concluding the following:

- modern design activity is the most complex form of a specialist's professional activity, which combines scientific research, industrial technology and organizational management;
- formation of preparedness to the design of complex technical systems must be based on the integration of cognitive, research and engineering innovative practices in the study process;

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- to design technical systems, at any rate the knowledge of profession's subject matter, professional terminology, methodology of engineering design, and the command of research and development automation means is necessary;
- a competitive specialist must have a mature and systemic creative engineering thinking, high motivation for design and developed skills for self-studying and learning about related fields;
- the problem of the formation of preparedness to design activity is topical and demands conducting complex research based on the achievements of modern engineering psychology, ergonomics, heuristics, didactics of professional education, technical sciences, and information and pedagogical technologies.

TECHNOLOGY OF ORGANIZATION OF STUDENTS' TRAINING FOR RESEARCH AND DEVELOPMENT ACTIVITY

Optimization of structural content and organizational process of a specialist's training for design activity was aimed at filling "the gaps" in qualification characteristics that were not reflected in the federal component of the State Educational Standard, and at considering regional peculiarities and higher requirements to the level of technical university graduates' training. This was achieved through identifying typical research and development problems, their transformation into professional training tasks, and the choice of suitable forms of study process organization and training methods.

The development of a model of specialists' training was based on principles stated in source [6]. Modeling of the process of undergraduate and master mechanical engineering students' training for design activity was carried out at three levels: conceptual level, which considered the logic of mastering a profession; technological level, which took into account the strategy of teaching the basics of technical objects design; and methodological level, at which the components and peculiarities of training system organization were considered.

The developed model of organization of training for design activity is aimed at students' developing systemic engineering thinking, their mastering the methodology of design of complex technical objects, and developing their personal creative potential. The didactic conditions necessary for the effective realization of the model in study process are formulated in source [7].

What distinguishes the proposed technique from others is the approximation of structures of training and professional activity, phased introduction of students to solving typical research and development tasks, development of special engineering skills and knowledge of students and the building of professionally significant personality traits.

By the training for design activity we mean a systemic organization of study aimed at forming a future specialist's preparedness to innovative activities in the sphere of complex technical objects design taking into account technological and material parameters and ergonomic, economic, ecological and social psychological requirements to design results.

By preparedness to design activity a system of knowledge, skills and specialist's professionally significant traits is understood, which would allow to perform effectively all types of design procedures; the correspondence of actual structure of preparedness on the whole and of its main components to the requirements of the State Educational Standard is meant by the level of preparedness.

The structure of preparedness includes motivational, cognitive and operational components.

Motivational component involves the following motives:

- understanding the purpose of a profession and the necessity of continuous self-training and self-study;
- interest in the process and result of solving design tasks;
- creative approach to technical objects design;
- professional self-fulfillment and self-evaluation;
- professional cooperation;
- responsibility for the design results.

Cognitive component of preparedness consists in the system of knowledge

- on the objects of engineering design;
- on the modern methods and means of technical systems design;
- on the ways of organizing design activity on the whole and its separate procedures;
- on the patterns of mental and communicative processes.

Operational component of preparedness includes the activity oriented at

- learning about the subject matter of the chosen profession;
- mastering professional terminology, methods and means of simulation and optimization of the designed technical objects;
- organizing and efficient realizing of design tasks solving process;
- evaluating the results of design activity.

We distinguish four levels in the system of training for research and development activity at a technical university: preparatory level, elementary level, and professional orientation and professional adaptation levels. They correspond to the preparedness

- to use fundamental knowledge to solve research and development tasks;
- to design parts and general technical items (assemply parts, typical machines and mechanisms);
- to design simple technical systems (separate technological operations and special technological equipment);

- to design complex technical systems (production lines and industrial objects).

Thus, each level of the technology of organization of research and development training includes phases, goals, structure and content of study process, disciplines that form preparedness to research and developments activity, methods, means and forms of organization of cognitive activities, and results of training and development of motivational and operational spheres of personality. Professional orientation of training at each level and continuity of phases allow to develop the necessary for a technical university graduate level of preparedness to present-day types of design activity.

COMPUTER SUPPORT OF THE PROCESS OF SPECIALISTS' TRAINING FOR TECHNICAL SYSTEMS DESIGN

Analysis of technical and didactic facilities of modern information and communication technologies allowed to determine those aspects of organization of students' training for design activity, in which they may be used most effectively:

- solving various types of calculation graphic tasks with the use of professional software products;
- computer simulation of technological processes and establishment of automated remote access laboratories;
- using information resources of global and local networks for operational collecting, processing, storing, updating and replicating of scientific and methodological information;
- using multimedia means for visualizing study process and providing for individual learning tracks;
- quality management of professional training through the system of teacher and student workstations.

Computer support of the study process is maintained with the help of specialized software, by means of which students choose the most suitable, close to optimal, technological and design decisions, visualize calculation objects and results, rapidly and accurately make drafts of technological equipment according to the requirements of the common design documentation system, and evaluate the efficiency of the designed projects. The acquired skills are widely used in scientific research in the sphere of technical systems design, in carrying out industrial orders, course projects in general professional and specialized disciplines, graduation projects and master's dissertations. CAD/CAM/CAE systems, supporting various aspects of engineering design, and original developments in analysis, simulation, optimization and design of technological processes and equipment are implemented in the training of mechanical engineering students.

The system of mathematical modeling, optimization and design of technical objects [8] developed by the authors is aimed at the design of environmentally safe energy- and resource-saving productions. The system's software includes the following up-to-date efficient and reliable algorithms and programs:

- simulation, calculation and analysis of flows' hydrodynamics in technological apparatus, and of static and dynamic regimes and parameters of chemical technological processes and apparatus;
- parametric optimization of regime and constructive parameters of machines and apparatus of chemical production;
- calculation of reliability and durability rates of parts and units of technological equipment;
- optimal design of certain technological machines (apparatus) and chemical productions.

The system's implementation in the training of undergraduate and master's students increases the level of motivation for learning, helps to form abilities to simulate and design technical objects, develops self-study skills of the students, transforms passive "consumers" of information into researchers, increases the significance of the studied material for their future professional life, and makes students' knowlegde control more effecitive and objective.

The remote access laboratory on the design and maintenance of chemical technological systems is available at the university; it presupposes remote control of laboratory equipment on the basis of graphic programming concept for virtual measuring systems and signals input/output system in the Lab VIEW environment. The use of this laboratory in the system of engineers' and master's students' training allows to achieve several didactic goals: to build skills for the independent carrying out of experimental research, and processing and analyzing of experimental data; to get experience in working with modern information resources to obtain initial data for simulation and optimization of technological processes and equipment; and to develop professional interests and creative activity of students through the observation of a real production process.

The multimedia textbook on The Fundamentals of Computer-Aided Design of Chemical Productions developed by the authors facilitates visualizing design procedures and simulating the target processes; it also allows to present study material at different levels basing of psychological pedagogical peculiarities of students, to stimulate the processes of creative self-fulfillment and systemic engineering thinking development by means of all-round presentation of design objects and problem situations, and to renew study material efficiently. The textbook has been evaluated in the study process and presented at several Russian and international conferences and exhibitions on educational information technologies [9].

The creation of teacher and student workstations similarly contributed to the technological level of training process and animation of cognitive activity of students. A teacher workstation includes methodological information array with the model of specialist's training for design activity, operation programs and didactic materials in various

disciplines, methodological descriptions of different types of classes, evaluation of practical significance and difficulty level of course topics from the internal interdisciplinary point of view, and each student's tests and ratings. A student workstation includes the contents of subject's modules with methodological recommendations, examples of using the information and methodological material of a certain discipline for solving research and development tasks, and tests and check questions.

Thus, the formation of the required level of specialist's preparedness to design activity is assured through the organization of professionally oriented training environment, which combines in the optimal way special engineering training with information technologies and research work of students [10].

RESULTS OF IMPLEMENTAION OF INNOVATIVE PEDAGOGICAL TECHNIQUES IN THE STUDY PROCESS

We have used various types of control to evaluate the level students' preparedness to design activity: traditional, testing and expert control. The latter, in the view of many engineering pedagogics specialists, is most preferable one for the evaluation of such a complex psychological characteristic of personality as preparedness to professional activity [6].

Supervisors and reviewers of graduation projects and master's dissertations acted as experts. In order to manage the teaching process and evaluate the efficiency of the developed technology it was necessary to differentiate the students according to their level of preparedness to design activity. We distinguished among three groups. The first group (low level of preparedness) consisted of students, which, according to the experts, showed inadequate level of formation of all three components of preparedness and their poor interaction. The second group (intermediate level of preparedness) consisted of students showing the inadequate level of formation of one of the components of preparedness, or poor interaction of either two of them. And the third group (high level of preparedness) included the students, which proved having formed all three components of preparedness and being able to integrate them in the general structure of preparedness.

The results of expert evaluation of integral level of graduates' preparedness to design activity are given in figure 1.

Besides the expert evaluation, undergraduate and master's students conducted self-assessment of their preparedness. Each of them graded his/her command of the components of preparedness by three-point scale (L, I, H), which corresponds to low, intermediate and high level of preparedness.

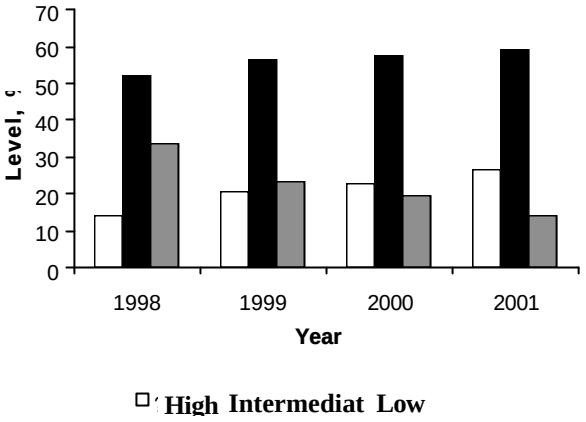

Figure 1. Dynamics of changes in the level of graduates' preparedness to design activity

Tests were used as the means of interim and final control over separate components of preparedness to design activity. Knowledge of technological processes and equipment construction, methods of engineering environment protection, of design procedures, methods of simulation, optimization and design of technical systems, and of the ways of linking and assemblage of equipment, was tested.

The practical significance of the conducted pedagogical experiment consists in the fact that analysis of individual rates of students' preparedness to design activity allows concluding what elements of the motivational, cognitive and operational components of preparedness are inadequately formed, and adjusting study process according to the data obtained.

Student's surveys showed sustainable increase of interest to solving research and development tasks, to using modern computer and communication technologies in carrying out course and graduation projects and master's dissertations, and to interdisciplinary and group projects.

Thus, the results of the conducted pedagogical experiment proved the efficiency of the developed technique of specialists' training for design activity.

CONCLUSION

The problem of the formation of preparedness of future engineers and masters in technical science to their professional activity has many aspects and peculiarities depending on particular historical period. However, solving this problem always involves resolving major contradiction between the social demand for a competitive specialist and its reflection in the State Educational Standard and study process in a specific technical university. The innovative technique of phased formation of student's preparedness to research and development activity is particularly aimed at resolving this contradiction and it has been implemented at

Tambov State Technical University in the training of certified specialists and masters majoring in “Energy- and Resource-Saving Processes in Chemical Technology, Oil Chemistry and Biotechnology”, “Technological Machines and Equipment”, and “Food Engineering”.

The arguments presented in the paper point out the necessity of innovations in the system of training for research and development activity, and speak to the fact that they positively influence graduates’ forming preparedness to the design of technical objects and other forms of engineering activity and developing professional competence of a specialist on the whole.

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