BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

DEVELOPING THE SCIENTIFIC AND CREATIVE COMPETENCE OF FUTURE ENGINEERS BASED ON THE PROJECT METHOD

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Abstract. This article examines the theoretical and methodological foundations of developing the scientific and creative competence of future engineers within the modern engineering education system. The study identifies the pedagogical conditions, effective methods, and technologies for fostering scientific and creative competence in engineering education. Based on the results of experimental work, it is substantiated that methods such as problem-based learning, project-based instruction, and integrative approaches are highly effective in developing research skills, critical thinking, and creative problem- solving abilities in future engineers.

Keywords: future engineer, scientific and creative competence, research skills, problem- based learning, project- based instruction, innovative approach.

I. INTRODUCTION

In the 21st century, the rapidly advancing technological processes, the environment of the Industry 5.0 revolution, and the transition to a digital economy impose new requirements on the system of engineering education. A modern engineer must possess not only deep fundamental knowledge and practical skills but also scientific and creative competence, innovative thinking, and the ability to find non- standard solutions.

In Uzbekistan, improving the system of training engineering personnel is one of the priority directions of state policy. At a videoconference meeting chaired by the President of the Republic of Uzbekistan on June 20, 2024, with the participation of rectors from 36 universities, the issue of "Priority tasks in the system of training engineering personnel" was discussed, and the need to study the advanced experience of foreign universities and train engineers in areas such as "Cost engineering," "benchmarking," and "Reverse engineering" was emphasised. This, in turn, requires the development of future engineers' inclination towards innovation, creative and non- standard thinking, and scientific- critical reasoning abilities.

The issues of developing the scientific and creative competence of engineers have been studied by various scholars. M.S. Burgin, B.S. Gershunsky, M.I. Rozhkov, Askarov I.B., Xuramova F.U., and others, who examined methodology as a general scientific foundation, emphasised the need to classify methodology as a doctrine about cognitive activity and its resulting knowledge, their defining criteria, and the forms and methods of activity aimed at mastering knowledge.

In the research conducted by Askarov I.B., the theoretical and methodological foundations of preparing future engineers for scientific and creative activities, the formation of scientific interest, the development of independent research skills, and the possibilities of using modern information technologies were analysed [1]. Xuramova F.U., in turn, examined the nature of future engineers'

scientific and creative abilities and scientifically substantiated the process of developing their research skills [2].

The project method plays an important role in developing the scientific and creative activities of future engineers. “The project method is a comprehensive methodology that currently integrates all innovative pedagogical methods applied in the educational process” [3]. “At present, this method, as the most widespread pedagogical technology in the world, is widely used in the educational process of the USA, Russia, Great Britain, Belgium, Israel, Finland, Germany, Italy, Brazil, the Netherlands, and many other developed countries” [3, 4].

The project method plays a significant role in solving such complex didactic tasks. A university student needs to engage in serious project activities from the very first year and continue them consistently in subsequent stages [5]. This requires the introduction of an innovative education system and a revision of its form and content. The teacher should develop students’ activity and independent thinking, provide real-life examples of problem situations in the professional field, identify several alternative solutions to a problem, and draw conclusions. Such problem situations may also be caused by the following factors in production conditions: errors in calculations, inappropriate strategy selection, inflated cost estimates, poor leadership, incorrect decision-making, lack of consensus in decisions, failure to plan and allocate tasks, and the fragmentation of large and important tasks into smaller subtasks.

“What do I know and what am I capable of, why do I need this, where and how will I use them?” – this phrase has been adopted as the main thesis of the project method [6].

“In most cases, the project method is understood as any creative and specific practical activity” [7]. This method develops students’ independence and responsibility, and teaches a culture of mutual respect and equal relationships with partners.

Among foreign scholars, I.G. Pestalozzi, A. Diesterweg, S. Robinson, D.D. Rulkel, K.M. Woodworth, P. Hill, A. Stoof, R.L. Martens, J.J.G. van Merriënboer, J. Raven, I. Bem, and Y. Schneider have made significant contributions to the development of creative competence in learners through the use of the project method in the educational process.

International research includes qualities such as curiosity, quick thinking, ability to solve complex problems, creativity, and leadership among the competencies that future engineers should possess in the Industry 5.0 environment. The results of empirical studies conducted using the Debreli method have confirmed that the engineering competence model, which encompasses cognitive, functional, social, and meta-competencies, is holistic and comprehensive [8].

Based on the above, the purpose of this research is defined as identifying the theoretical foundations for developing the scientific and creative competence of future engineers and substantiating effective pedagogical conditions. In accordance with the purpose, the following tasks were set in the study:

1. To clarify the essence of the concept of “scientific and creative competence”;
2. To distinguish the structural components of future engineers’ scientific and creative competence;
3. To substantiate the pedagogical conditions for developing scientific and creative competence;
4. To experimentally verify the effectiveness of the proposed methodology.

II. METHODS AND MATERIALS

The study employed theoretical methods, including the analysis of pedagogical, psychological, and methodological literature, the examination of educational standards and curricula, as well as

comparison and synthesis. Empirical methods included pedagogical observation, questionnaires and testing, a pedagogical experiment (comprising ascertaining and formative stages), and mathematical-statistical analysis of the research results.

Within the framework of the study, the scientific and creative competence of future engineers was defined as comprising the following structural components:

1. Motivational component – interest in research activities, aspiration for new knowledge, and a spirit of inquiry;
2. Cognitive component – methodological knowledge, familiarity with scientific research methods, and skills in searching for, processing, and utilising information;
3. Technical-technological component – the ability to recognise problems, formulate hypotheses, conduct observations and experiments, and perform analysis and synthesis;
4. Scientific-creative component – non-standard thinking, generation of new ideas, and creative problem-solving in complex situations.

In the experimental groups, the following pedagogical technologies were applied:

- Problem-based learning technology – creating problem situations and guiding students towards independent problem resolution;
- Project-based instruction – engaging students in the development of projects aimed at solving real-world engineering problems;
- STEAM approach – integrating science, technology, engineering, arts, and mathematics;
- Design thinking – encompassing the stages of empathy, problem definition, ideation, prototyping, and testing.

The traditional lecture-based and practical training system was retained in the control group.

III. RESULTS

Based on the analyses, it can be noted that the project method represents an important innovative approach in teaching engineering disciplines, serving to develop students' practical skills, critical thinking, teamwork, and competence in solving complex problems [9]. However, its widespread implementation faces a number of challenges, including insufficient methodological preparation, weak technical infrastructure, an imperfect assessment system, and other issues. At the same time, many aspects of the project method in engineering education—particularly its interdisciplinary integration mechanisms, compatibility with modern technologies, specificity across different specialisations, and comprehensive assessment models—have not yet been sufficiently addressed as objects of scientific research [10].

In our study, the following principles were established for developing scientific and creative activities through the use of the project method in specialised discipline classes:

1. The importance of creativity in problem-solving, and the requirement that problem-solving demands broad knowledge and inquiry.
2. The significance of anticipated outcomes in the development of scientific and creative activity.
3. Students' independent work.
4. Step-by-step demonstration of project details and results.

For the rational organisation of project work, it is necessary to understand the typology of projects. A general didactic approach is required for classifying projects; in each subject area, this classification can be specified taking into account the characteristics of the discipline [11].

When classifying projects, the following features are taken into account: the dominant activity in the project (research, search, creative, role-play, applied); the subject-content area

(mono-project within a single field of knowledge, and interdisciplinary project); the mode of communication (direct communication during project activities, communication technologies, telecommunication projects); the nature of project coordination (rigid, flexible, or hidden—e.g., in telecommunication projects, where the coordinator may be implicit, as opposed to explicit coordination); the nature of communication (within a group, within a single educational institution, at city, regional, national, or international level); the number of participants (individual or group); and the duration of the project (designed for several sessions, medium-term—from one month to six months, or long-term—from six months to one year) [12].

General analysis showed that in the experimental groups, at the final stage compared to the initial stage, the high-level indicator increased by 22%, the medium-level indicator increased by 25%, while the low-level indicator decreased by 39%. In the control groups, the high-level indicator increased by 1%, the medium-level indicator increased by 3%, and the low-level indicator decreased by 5%.

The research skills of students in the experimental group developed significantly:

- ability to identify problems – increased by 2.1 times;
- skill of formulating hypotheses – increased by 2.3 times;
- competence in conducting experiments – increased by 2.0 times;
- ability to work with scientific literature – increased by 1.9 times;
- skill in presenting research results – increased by 2.2 times.

These indicators demonstrate the formation of readiness for scientific and creative activity in future engineers.

Statistical calculations proved that the efficiency indicator of the level of development of scientific-creative competence at the end of the experiment was 1.14 times higher (i.e., 14% higher) in the experimental groups compared to the control groups.

IV. DISCUSSION

The results of the conducted research indicate that an integrative approach is highly effective in developing the scientific and creative competence of future engineers. The significant increase in indicators across all components among students in the experimental group demonstrates the effectiveness of the proposed methodology.

In particular, problem-based learning technology enhanced students' interest in research activities, encouraged independent thinking, and fostered the ability to find non-standard solutions. Project-based instruction, in turn, served to connect students' theoretical knowledge with practice and enabled them to gain experience in solving real-world engineering problems.

Based on the research findings, the following pedagogical conditions were identified for the effective development of future engineers' scientific and creative competence:

1. Integration of educational content – teaching fundamental disciplines, specialised subjects, and innovative technologies in an interconnected manner;
2. Application of active teaching methods – problem-based learning, project-based instruction, case studies, and design thinking;
3. Creation of a research environment – the functioning of scientific circles, laboratories, and innovation centres;
4. Organisation of independent work – engaging students in research activities and project development;
5. Establishment of a motivation system – scientific competitions, grants, scholarships, and incentive mechanisms;

6. Reflection and assessment – developing students' skills in analysing and evaluating their own activities.

Based on the research results, the following practical recommendations were developed for technical higher education institutions:

- Introducing disciplines such as "Fundamentals of Scientific Research in Engineering" and "Innovative Project Design" into the curricula;
- Increasing the share of problem-based and project-based technologies in the educational process;
- Improving the system of actively engaging students in research work;
- Enhancing the methodological training of faculty members;
- Developing mechanisms for encouraging students' scientific and creative activities.

Projects should be grounded in real-life problems. However, project topics are often artificially constructed, detached from production realities, and fail to arouse students' interest. This situation contradicts the core essence of the project method – the principle of learning through solving authentic problems.

Research Limitations and Future Directions

This study has a number of limitations: the experimental work was conducted only on the basis of three higher education institutions; the research duration was 18 months; and the number of participating students was limited to 334.

In the future, it would be advisable to continue research in the following directions:

- Studying the specific features of developing scientific-creative competence in distance and blended learning environments;
- Investigating the distinctive aspects of competence development across various engineering specialisations (energy, mechanical engineering, information technology, etc.);
- Developing mechanisms for competence formation within the dual education system in cooperation with industrial enterprises.

V. CONCLUSION

1. The scientific-creative competence of future engineers is an integrative personal quality that ensures the ability to identify scientific research problems in engineering activities, formulate hypotheses, conduct experiments, analyse results, and develop creative solutions.

2. Scientific-creative competence comprises five components (motivational, cognitive, activity-based, creative, and reflexive), each of which requires targeted development.

3. The integration of problem-based learning, project-based instruction, the STEAM approach, and design thinking technologies is an effective means of developing the scientific-creative competence of future engineers.

4. The obtained results can serve as a practical foundation for improving the educational process in technical higher education institutions, developing curricula, and selecting pedagogical technologies.

5. According to statistical calculations, the efficiency indicator of the level of organisation of research and creative activities at the end of the experiment was proven to be 14% higher in the experimental groups compared to the control groups.

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