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Article

Experimental Results of Forming the Research Competence of Future Engineers on the Basis of Dual Education

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Abstract: This article analyzes the results of experimental work carried out to develop the research activity of future engineers based on the principles of dual education. The study was conducted with the participation of students enrolled in the *Energy Engineering* and *Electrical Engineering* programs at a technical higher education institution. During the experimental process, a dual education model based on the integration of educational activities between higher education institutions and industrial enterprises was implemented. The study was based on a mixed-methods research design that integrated quantitative and qualitative analysis methods. Students' readiness for research activity was assessed according to motivational, cognitive, practical, and creative criteria. The results of the experimental study demonstrated that the educational process organized on the basis of dual education is effective in increasing students' interest in scientific inquiry, linking theoretical knowledge with practical application, and developing independent research skills. The results of statistical analysis ($p < 0.05$) confirmed the reliability of the positive changes observed in the experimental group.

Keywords: dual education, research activity, engineering education, experimental study, professional competencies, integration of higher education institutions and industry.

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1. Introduction

Around In the context of globalization and rapid technological development, the requirements for training engineering specialists are undergoing fundamental changes. The accelerated advancement of digitalization, automation, and industrial technologies demands that graduates of higher education institutions possess not only strong theoretical knowledge and practical skills, but also the ability to identify real industrial problems, analyze them on a scientific basis, and develop innovative solutions. Therefore, the formation of students' research activity in engineering education is regarded as one of the key pedagogical tasks.

In this process, the dual education system based on the integration of education and industry plays a particularly important role. The dual education model enables students to acquire theoretical training at higher education institutions while carrying out practical activities in industrial enterprises, thereby contributing to the development of their professional adaptation and research competencies. Such an approach creates conditions for students to encounter real technological problems during their studies and to actively participate in solving them.

In recent years, both international and domestic studies have recognized the dual education system as an effective model of engineering education. In particular, the experiences of Germany, Austria, and Switzerland consider dual education to be an

important mechanism for training highly qualified engineering specialists in line with labor market demands. These studies emphasize the close integration of theory and practice, as well as the increased motivation of students toward professional and scientific activities, as the main advantages of dual education.

At the same time, an analysis of existing scientific literature shows that although dual education is widely applied in engineering education, the issue of developing methodological support specifically aimed at forming the research activity of future engineers and substantiating its effectiveness through experimental testing has not been sufficiently studied. This determines the relevance of the present research.

The purpose of this article is to analyze the experimental results of the methodology developed for forming the research activity of future engineers based on the principles of dual education and to provide a scientific justification of its pedagogical effectiveness.

At the same time, an analysis of existing scientific literature indicates that although dual education is widely implemented in engineering education, the development of methodological support specifically aimed at forming the research activity of future engineers and the substantiation of its effectiveness through experimental testing remain insufficiently explored. This determines the relevance of the present study.

The purpose of this article is to analyze the experimental results of the methodology developed to form the research activity of future engineers based on the principles of dual education and to provide a scientific justification for its pedagogical effectiveness.

In pedagogical science, the issue of orienting students toward research activity has been formed as an independent field of scientific inquiry. In the studies of Zimnyaya, Biggs, and Jonassen, research activity is interpreted as a complex pedagogical process that develops an individual's cognitive activity, independent thinking, and ability to solve problem situations [1]. According to this approach, research competencies are not limited solely to the acquisition of theoretical knowledge, but also include their application in practical contexts and the development of innovative solutions.

In the scientific works of Slastenin and Godnik, innovative pedagogical activity is considered an important factor in improving the quality of the educational process [2]. According to their view, innovative activity encompasses the stages of generating new pedagogical ideas, implementing them in practice, and adapting them to the educational process. This approach serves as a theoretical basis for the effective organization of research activity under conditions of dual education.

In the studies of Vilenskiy and Prince, the priority of practical-oriented and active teaching methods in engineering education is emphasized [3]. The authors substantiate that students' experience in working with real technical objects and processes increases their interest in scientific inquiry and contributes to the development of research skills [4]. This, in turn, further expands the methodological potential of the dual education model.

In Kolb's experiential learning theory, it is emphasized that the educational process occurs directly through activity and reflection [5]. This approach provides a scientific rationale for developing students' professional and research competencies in the context of dual education by engaging them in the industrial environment.

The significance of competency-based and student-centered approaches in engineering education has been widely highlighted in both domestic and international sources. These approaches aim to develop students not as passive recipients of ready-made knowledge, but as active subjects who independently seek, analyze, and apply knowledge in practice. In particular, the role of project-based learning, problem-based teaching, and case-study technologies in fostering research activity has been substantiated in numerous scientific studies.

An analysis of the literature shows that, although the integration of dual education and research activity has been widely addressed, the development of a methodology specifically aimed at forming the research activity of future engineers in technical higher

education institutions and its experimental validation remains insufficiently studied. This determines the scientific novelty and relevance of the present research.

2. Materials and Methods

This study is based on pedagogical experimental work aimed at determining the effectiveness of forming the research activity of future engineers based on the principles of dual education. The research methodology was developed through the integration of competency-based, systematic, activity-oriented, and student-centered approaches.

Research Setting and Participants

The study was conducted at the Department of *Energy and Environmental Engineering* of the Yangiyer Branch of the Tashkent Institute of Chemical Technology. The experimental work involved 2nd- and 3rd-year students enrolled in engineering programs. Participants were divided into an experimental group and a control group, with the educational process in both groups organized in a comparative manner in terms of content and forms of instruction.

Research Stages

The study was conducted in three main stages:

1. **Diagnostic Stage** – determining students' readiness for research activity and establishing baseline indicators for motivational, cognitive, and practical components. During this stage, questionnaires, tests, interviews, and observation methods were employed.

2. **Formative Stage** – implementing the methodology developed on the basis of dual education in the experimental group. This stage included:

- organizing educational activities in collaboration between higher education institutions and industrial enterprises;
- research assignments based on real industrial problems;
- project work, problem-based learning, and case-study methods;
- integrating elements of independent scientific inquiry into the educational process.

In the control group, the educational process was conducted using traditional teaching methods.

3. **Control and Analysis Stage** – at the end of the experiment, changes in students' research activity were identified and analyzed. During this stage, the initial and final results were compared.

Research Methods

The following methods were employed during the study: **Theoretical methods:** analysis, comparison, and generalization of pedagogical and psychological literature; **Empirical methods:** observation, questionnaires, tests, interviews, and analysis of students' practical and research work **Pedagogical experiment:** formative and control experimental work; **Mathematical-statistical methods:** statistical analysis ($p < 0.05$) was applied to determine the reliability of the obtained results. **Assessment Criteria** The level of students' research activity was evaluated based on the following criteria: **Motivational criterion** – interest in scientific inquiry, and aspiration toward professional and research activities;**Cognitive criterion** – level of knowledge in scientific theories and research methods; **Practical criterion** – ability to independently complete research tasks and analyze results; **Creative criterion** – capacity for innovative approaches to problems and generation of new ideas.

Students' performance for each criterion was assessed at high, medium, and low levels. The developed methodology is based on the key principles of dual education,

including the integration of theory and practice, collaboration between higher education institutions and industry, active student participation, and instruction based on real-world problems. The methodology is aimed at systematically and progressively developing students' research activity, ensuring a coherent connection between the curriculum and the content of industrial practice.

3. Results

The results of the pedagogical experimental work demonstrated that the educational process organized on the basis of dual education principles had a positive impact on the formation of research activity among future engineers [6]. Analyses conducted in the experimental and control groups revealed significant differences in the levels of development of students' motivational, cognitive, practical, and creative components.At the initial stage of the experimental work, students in both groups showed almost identical levels of readiness for research activity. According to the results of the initial diagnostic assessment, most students demonstrated medium or low motivation for research activity, and their engagement in scientific inquiry was predominantly limited to linking theoretical lessons. By the end of the formative stage, significant positive changes were observed in the experimental group. In particular, regarding the motivational component, students' interest in scientific inquiry increased, and they began to perceive research activity as an essential part of their future professional work [7]. Tasks organized based on real problems in industrial enterprises encouraged students to engage in active thinking and make independent decisions.

The results for the cognitive component showed that the experimental group demonstrated greater systematization and depth of theoretical knowledge. Students exhibited the ability to connect scientific concepts with real industrial processes, analyze cause-and-effect relationships of problems, and draw evidence-based conclusions. In the control group, knowledge remained predominantly reproductive, and the ability to apply it in practical situations was limited.Regarding the practical component, high results were observed in the experimental group. Project work, problem-based tasks, and lessons incorporating research elements, organized on the basis of dual education, taught students to conduct independent experiments, collect data, and perform analyses [8]. As a result, students in the experimental group demonstrated high activity and initiative in performing practical research tasks.The analysis of the creative component indicated that students in the experimental group were inclined to propose innovative and unconventional approaches to industrial problems. Open-ended tasks and problem-based situations stimulated their creative thinking and provided a basis for generating new technical and technological ideas. In the control group, the indicators of creative activity remained almost unchanged.

To determine the reliability of the obtained results, a mathematical and statistical analysis was conducted [9]. The results of the Student's *t*-test indicated that the changes observed in the experimental group were statistically significant ($p < 0.05$). This confirms the effectiveness of the methodology developed on the basis of dual education from a scientific perspective.

Overall, the research findings demonstrate that the educational process organized under dual education conditions exhibits higher pedagogical effectiveness in forming the research activity of future engineers compared to traditional teaching methods [10]. It was found that close cooperation between higher education institutions and industrial enterprises contributes to the comprehensive development of students' scientific, practical, and creative competencies.

The high indicators recorded for the motivational component in the experimental group (72%) can be explained by an increased interest in scientific inquiry and a deeper understanding of the significance of research activity in professional practice. These findings are consistent with the key advantages of dual education highlighted in

international studies (Euler, Deissinger) [11], [12]. In particular, experiences from Germany and Switzerland indicate that engaging students in real industrial processes enhances their intrinsic motivation, a conclusion that is also supported by the results of the present study.The results for the cognitive component (75%) once again demonstrate the didactic significance of integrating theory and practice in engineering education. Students showed a systematic and conscious acquisition of scientific concepts, which is consistent with the active and experiential learning concepts substantiated by Vilenskiy and Biggs & Tang [13]. The highest increase was observed in the practical component (78%), confirming the effectiveness of project-based learning, problem-based instruction, and case-study technologies under dual education conditions. During the research process, students demonstrated the acquisition of skills in analyzing real technical problems, conducting experiments, and drawing scientifically grounded conclusions based on data. This finding is logically aligned with the experiential and problem-oriented learning approaches developed by Kolb and Jonassen [14].

The substantial increase in the results for the creative component (70%) demonstrates the innovative potential of the dual education environment. Students distinguished themselves by proposing unconventional and creative approaches to problems arising in industrial processes. While previous studies have emphasized that creative thinking develops through problem-based situations and open-ended tasks, the present study provides practical confirmation of these theoretical assumptions.The results of statistical analysis ($p < 0.05$) indicate that the changes observed in the experimental group were not random and ensure the reliability of the methodology developed on the basis of dual education. The absence of significant positive changes in the control group suggests that traditional teaching methods are insufficient for adequately preparing students for research activity.

At the same time, the study has certain limitations. In particular, the experiment was conducted within a single higher education institution, which to some extent limits the generalizability of the findings. Future research should therefore be carried out across different regions and engineering disciplines, as well as incorporate digital and distance components of dual education [15]. Overall, the discussion results indicate that a methodology based on dual education principles enables effective orientation of students toward research activity in engineering education and contributes to improving educational quality by strengthening the integration between higher education institutions and industrial enterprises.

4. Conclusion

This study was aimed at providing a scientific and pedagogical justification for the process of forming the research activity of future engineers based on the principles of dual education and at determining its effectiveness through experimental testing. The results obtained during the study confirmed that the dual education model possesses significant pedagogical potential in preparing students for professional and scientific activity in engineering education.The findings of the experimental work demonstrated that an educational process organized under dual education conditions directly connects students with real industrial problems, significantly increasing their interest in research activity and enhancing their intrinsic motivation. The close integration of theory and practice contributed to students' deep acquisition of scientific concepts, the development of independent problem analysis skills, and the ability to generate innovative solutions.The methodology developed on the basis of the research results ensured the comprehensive development of motivational, cognitive, practical, and creative components, thereby positively influencing the formation of future engineers' research competencies. The results of statistical analysis ($p < 0.05$) confirmed the reliability of the positive changes recorded in the experimental group and provided scientific evidence of the pedagogical effectiveness of the proposed methodology.In addition, the study revealed that traditional

teaching methods are insufficient for adequately preparing students for research activity, thus substantiating the priority of dual education–based approaches in engineering education. It was also established that strengthening close cooperation between higher education institutions and industrial enterprises is a crucial condition for improving the quality of engineering workforce training.The results of this study have practical significance for improving curricula aimed at developing research activity based on dual education in technical higher education institutions, developing methodological guidelines, and introducing innovative educational technologies into the pedagogical process. Future research should expand the scope of the study across various engineering disciplines and regions, as well as explore digital and distance components of dual education.

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