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STRUCTURE, CRITERIA, AND INDICATORS OF SCIENCE AND RESEARCH COMPETENCE OF FUTURE ENGINEERS

The issue of development of research skills of future engineering professionals during their training is relevant due to the necessity to perform research tasks in the field of industrial production. The article analyzes current trends and specific features of the professional training of future engineering specialists in Ukrainian higher technical educational institutions from the perspective of implementing a competence-based approach. It investigates the issue of formation of science and research competence of future engineers as an integral component of a technical specialist's professional competence. Science and research activity is considered the foundation and a necessary condition for the effective professional training of future engineers.

The goals, tasks, aspects, and principles of formation of science and research competence of future engineers are characterised. The article identifies factors influencing the development of science and research competence in future engineers, including the level of professional education, individual abilities for research, experience in conducting research activities, motivation for continuous self-education and self-development, a creative attitude toward professional activity, and the ability to act in non-standard situations. The article states the criteria, indicators, and levels of science and research competence development of future engineers at higher technical educational institutions.

The effectiveness of the developed conditions for training future engineers in formation of their research competence is proved. These conditions include: fostering motivation for research work; providing relevant knowledge of research methodology; involving engineering students in university scientific communities (research schools, clubs, problem laboratories); and gaining experience in conducting research activities.

Key words: *professional training, higher technical educational institutions, future engineers, competence-based approach, professional competence, scientific research, research activity, science and research competence.*

(*статтю подано мовою оригіналу*)

Globalization processes, which are a characteristic trend in the development of the modern information society, define education as one of the key factors of productivity [14]. The current socio-economic challenges that Ukraine is facing, along with the need of post-war reconstruction and modernization of industrial production, highlighted the issue of training highly qualified, competent, and competitive engineering professionals [17]. Society requires a responsible, nationally conscious, socially active citizen and patriot of their country, a capable leader, and a competent, competitive technical specialist who is able to work effectively in a team according to European and global standards [4]. The contemporary professional activity of an engineering specialist involves organizing production processes based on the implementation of new technologies and machines. These factors demand both the knowledge of the operational specifics of such equipment and the ability to ensure the effective performance of a team working with new mechanisms and tools.

Considering the dynamic nature of contemporary socio-economic transformations affecting professional functioning, the task of higher technical education in Ukraine is to prepare future engineering professionals for effective engagement in the current socio-civilizational environment. This involves developing their personal capacity to adapt to rapidly changing social, economic, technological, professional, and informational conditions. The competence-based approach has become the leading trend of modern education, as its implementation ensures the formation of essential personal qualities of future engineers, such as creative thinking, initiative in making organizational and technical decisions, social engagement, and professional mobility [1].

The relevance of research of formation of science and research skills is caused by the necessity for future engineers to conduct scientific research aimed at improving existing technical solutions as well as developing new ones. Despite the increasing intensity of studies devoted to the theoretical and methodological foundations of engineering education, the issue of formation of science and research competence during the training of future engineers of higher technical educational institutions requires further investigation. **The hypothesis of this study** is based on the assumption that the effectiveness of the process of formation of science and research competence will be positively influenced by the following conditions: the development of motivation for research activities; the acquisition of knowledge concerning the methodology of organizing scientific research; the active involvement of future engineers in the research process; and the accumulation of practical experience in conducting scientific investigation.

Analysis of key research. Researchers of contemporary technologies of engineering education Shumilova, Poyasok, and Butsyk concluded that for professional activity to be effective, an engineer should be able to design and construct, as well as apply tools of industrial, managerial, practical, design, technological, and research activities [5; 18; 23]. The scholars emphasize that an engineer should be able to conduct scientific activity, acting as a researcher, and implementing their own ideas in practice. According to the findings of Obukhova and Hryniova, engineering professionals serve as organizers of production processes, and thus should be able to manage the teamwork and apply normative, reference, scientific-technical, and production-related information to facilitate the integration of

scientific and technological advancements into modern industry [7; 16]. Therefore, essential professional skills for engineers include the development of scientific and technical documentation, implementation of technological projects, and improvement of production efficiency through the application of scientific achievements.

The analysis of the works by Maryani and Kuzmenko indicates that a competent professional in the technical field should meet the following requirements: possess a high level of engineering education, have strong moral convictions, demonstrate the ability to collaborate effectively in a team, and be capable of making responsible decisions [11; 13]. A future engineer should be able to work with modern technologies and apply knowledge that meets the demands of the contemporary information society. The personality of a future engineer should be active, dynamic, innovative, creative, and oriented toward competence development [21].

A competent specialist in the technical field is characterized by their readiness to solve tasks in future professional activitiy, using innovations to achieve goals based on their own awareness in the field of industrial production [12; 19; 20]. Competence is the possession of the necessary knowledge and skills required for a specialist in a particular area of professional activity; awareness, knowledge, intellectual breadth, and general professional preparedness; a synthesis of cognitive, practical, and personal experience [9, 24]. Modern researchers define professional competence as a set of skills of engineering specialists to structure scientific and practical knowledge in order to better solve research tasks in future professional activity [2; 3; 8].

The competence-based approach as a conceptual guideline and strategic direction for the development of the higher education system in Ukraine, creates opportunities for future engineers to define important life goals on a personal and value level and achieve them by applying their individual traits and the competence base for successful professional functioning throughout their lives. Modern engineering education should provide a unity of knowledge, competences, and values, oriented not only towards successful self-realization in the present, but also towards high adaptability to future changes. Therefore, in the process of preparing future engineers, there should be a deep awareness and personal importance of the value of professional self-improvement through continuous science and research activity (SRA).

The conducted analysis demonstrates the relevance of research activity for engineering students based on the competence-based approach. The results obtained allow to consider research activity of future engineers as an integral component of training of a competent specialist. It ensures the integration of scientific, educational, and industrial activities in the process of professional training of future specialists.

The aim of the article is to establish the objectives, tasks, aspects, and factors influencing the development of research competence as an important component of professional competence for future engineers. This is based on the analysis of the results of contemporary research and the experience of organizing research activities at Admiral Makarov National University of Shipbuilding. Additionally, the article aims to develop criteria, indicators, and levels for assessing the formation of research competence in future engineers.

Presentation of the main material. At the first stage of the research, which involved studying research on the topic and analyzing the practical experience of training specialists in the engineering field at higher technical institutions in Ukraine, the following patterns and characteristic features of the training process were identified. They were taken into account during the development of the experimental methodology of formation of science and research competence of future engineers. The implementation of the competence-based approach is a priority task in the field of technical specialist training in Ukraine.

Modern education in Ukraine, in its competence-based dimension, prepares young people for a conscious choice of profession, allowing them to build their own life strategy. An analysis of current labor market trends has shown a demand for specialists with developed creative, flexible, and versatile thinking styles [6; 15]. Therefore, the main task of modern engineering education is to prepare innovation-oriented specialists capable of further self-development and self-improvement.

The implementation of a competence-oriented approach in the training of future engineers focuses on the ability of technical specialists to creatively apply acquired knowledge and experience in production processes. Therefore, an important feature of the training of students in higher technical educational institutions is the ability of future engineers to self-organize and reflect. The research revealed that for the preparation of future engineers to be effective, it should be based on values. This requires an axiological direction in the educational process. The importance of considering an axiological approach is also emphasized by scholars Kumar and Shetelia [22; 15]. The principle of a value-oriented attitude of the future engineer towards the knowledge acquired is the foundation of their professional self-realization. Competence-oriented training of future engineers should be based on the moral values of humanism, democracy, human dignity, patriotism, social activity, responsibility, and national consciousness.

A competent specialist in the technical field must possess a high level of engineering education, strong moral convictions, entrepreneurial energy, the ability to effectively collaborate in a team, and the skills to make responsible decisions consciously [9; 10; 24]. A future engineer should be distinguished by mobility, dynamism, constructiveness, and the ability to develop a flexible, highly adaptive, and innovation-oriented personal and competence-based sphere.

The professional competence of a graduate of a higher technical educational institution is today an important indicator of their readiness for future professional activity in the field of industrial production and an active role in society. Successful mastery of professional competencies by engineering specialists and a high level of self-organization in their future professional activities are ensured by the unity of fundamental and specific

training. This means a combination of theoretical knowledge, practical skills, significant personal qualities, and life experience.

Simultaneously, the competence-based approach implies the transformation of professional competencies acquired during the training of future engineers into active professional and creative participation in social activities. Therefore, it is important not only to teach the future technical specialist to operate knowledge and technologies but also to prepare them for new roles in modern society; to teach them to adapt to the current labor market demands, handle and manage information, actively engage, and continue learning throughout life.

Thus, the ability to conduct scientific activities and organize research work forms the foundation for high-quality preparation of future engineering specialists in higher technical educational institutions.

We consider **science and research competence** as an integrated quality of the future engineer's personality, manifested in the readiness and ability to carry out purposeful scientific and research activities in the industrial production sector based on acquired knowledge, skills, and experience in organizing such activities; personal and professionally important qualities of the future specialist in the technical field; and a value-oriented attitude towards the engineering profession, colleagues, work results, and the country's natural resources.

The formation of science and research competence involves the development of scientific culture by engaging students in fundamental industry research and fostering skills to implement innovative engineering technologies. The goal of developing scientific and research competence is to enhance the ability of future engineers to address professional research tasks in the process of organizing production processes and conducting scientific research aimed at improving existing and developing new production tools.

The study revealed that the formation of science and research competence of future engineers is influenced by the following characteristics: the level of professional education; individual abilities for scientific research; experience in conducting research activities; motivation for continuous self-education and self-development; a creative attitude towards professional activities; and the skills to act in non-standard situations.

The study also demonstrated that the process of formation of science and research competence of future engineering specialists has the following **aspects**: the goal aspect, the motivational aspect, the cognitive aspect, the activity aspect, and the reflection aspect. The goal aspect directs the scientific research activity of the future engineer, outlining their achievements at a certain stage of work. The motivational aspect stimulates the research activity of students. It is important to engage them, explain the role, form an attitude towards scientific work, and prove the necessity of scientific activity for an engineer. The cognitive aspect provides students of engineering specialties with knowledge about the methods and forms of scientific research work. The activity aspect ensures the inclusion of students in the scientific work of the university, participation in events (conferences, symposia), writing reports, articles, and participating in scientific work contests, etc. The reflection aspect involves development of students' ability to analyze and evaluate their scientific achievements, formation of the habit to participate in scientific work in professional activity.

The leading effective **methods** of formation of science and research competence include: focusing the university's activities on developing research skills; forming the experience of scientific work for future engineers; encouraging students to solve scientific problems by involving them in university research associations (schools, clubs, laboratories, etc.); presenting the results of scientific research activities through presentations at scientific seminars, round tables, conferences, symposiums; publishing the results of research work in collections of scientific papers.

Our efforts were focused on developing the scientific worldview of future specialists in the technical field; expanding their scientific knowledge, theoretical preparedness for scientific research activities; mastering the methodology and methods of scientific research; promoting creative thinking, and developing the individual abilities of engineering students to solve both typical and non-standard situations in industrial production. The important **principles** we followed, which ensured the effectiveness of shaping scientific and research competence, include: a creative attitude towards the engineering profession; professional orientation of research activities; and the personal activity of individuals in this process.

The proposed methodology demonstrated its effectiveness in shaping the practical skills of future engineers to summarise the results of their research work. In the course of the experimental work, future engineers participated in preparing reports, presentations, and discussions at the scientific and practical conference "Innovations in Shipbuilding," which is held annually at the Admiral Makarov National University of Shipbuilding. According to the conclusions of both teachers and students, this work contributed to gaining practical experience in publicly discussing the results of scientific research activities (Table 1).

Diagnostics of the level of science and research competence of future engineers requires the development of criteria and corresponding indicators. Based on the research of theoretical foundations and practical experience in training engineering specialists, we identified the following criteria for the science and research competence of future engineers: motivational-value, cognitive, and activity-practical.

The motivational-value criterion includes the motives for activity and the value orientations of the future engineer's personality. The indicators for the formation of the motivational-value criterion are: the manifestation of interest and the desire for research activities; positive emotional experiences of scientific work; the stability and strength of motivational structures regarding conscious engagement in research activities; independence in determining research strategies and choosing tasks; responsibility in research activities; the formation of moral

Table 1

Structure of Scientific-Research Competence of Future Engineers

Components of science and research competence	Characteristics of the components of science and research competence
Essence	An integrated quality of the future engineer’s personality, manifested in the readiness and ability to carry out purposeful science and research activities in the field of industrial production based on acquired knowledge, skills, and experience in organizing such activities; personal and professionally significant qualities of the individual; value-oriented attitude towards the engineering profession, colleagues, work results, and the country’s natural resources
Goal	The formation of the ability to perform professional research tasks during the organization of the production process and the conduct of scientific research aimed at improving existing and developing new means of production
Objectives	The development of a scientific worldview; expansion of scientific knowledge and theoretical preparedness for conducting research activities; mastering the methodology and methods of scientific research; formation of creative thinking, development of individual abilities of future engineers to solve both typical and non-standard situations in the field of industrial production
Ways of realisation	The formation of research experience by involving future engineers in the activities of university scientific associations: schools, clubs, laboratories; presentations at scientific seminars, round tables, conferences, symposiums; publication of research results in collections of scientific works
Principles	A creative attitude towards the engineering profession; a professional focus on research activities; the individual’s active involvement in this process
Key characteristics	The level of professional education; individual abilities for scientific research; experience in conducting research activities; motivated desire for continuous self-education and self-development; a creative attitude towards professional activities; skills to act in non-standard situations
Aspects	Goal (guides the science and research activities of the future engineer, outlines their achievements at a certain stage of work); motivational (stimulates the research activities of students); cognitive (provides knowledge about methods and forms of scientific and research work); activity (ensures the inclusion of students in the scientific work of the university); reflective (involves the development of students’ ability to analyze and evaluate their own scientific achievements; habits of engaging in scientific work in professional activities; self-improvement)
Forms	The course “Fundamentals of Scientific Research”, special courses, special seminars; activities of student scientific associations (clubs, problem groups, student laboratories); participation in scientific events (conferences, symposiums); writing reports, articles; participation in scientific work competitions; collaboration with international scientific centers and foundations
Result	Formation of motivation for science and research activity (SRA), acquisition of knowledge of research methods by involving students in fundamental industry research; developing skills and experience in implementing innovative technologies in engineering science

values, ideals, and the culture of organizing scientific work; the sense of satisfaction from conducting science and research activity.

The cognitive criterion involves the presence of theoretical knowledge of future engineers regarding the organization and methodology of conducting scientific research. The indicators for the formation of the cognitive criterion are: knowledge of types and classes of engineering research tasks; knowledge of methods for collecting and systematizing scientific information; knowledge of research tasks and methods in the field of engineering production and the conditions for their application; knowledge of methods for processing the results of scientific research.

The activity-practical criterion involves the skills and experience in organizing and conducting scientific research in the field of engineering. The indicators for the formation of the activity-practical criterion are: the ability and skills in planning, organizing, and controlling research activities (setting research tasks, formulating the methodological framework of the research, applying appropriate methods for data collection, processing, analysis, and presentation of research results).

According to the formulated criteria and their indicators, we justified the following three **levels** of formation of science and research competence of future engineers: *primary, sufficient, and creative. The primary level* is characterized by the absence or unstable manifestation of interest in research activities, readiness, and the desire to overcome difficulties in scientific work; a low level of knowledge of the methodology for organizing research activities; and the lack of experience in purposefully conducting scientific research.

The sufficient level is characterized by the manifestation of interest in scientific activities among future engineers, but this interest is not systematic and is not constant. Knowledge of the theory and practice of scientific research is present, but it is not deep or strong. The future engineer’s personal activity in conducting scientific research is not consistent, and therefore, practical skills in this type of activity are not perfected.

The creative level is characterized by a constant and stable manifestation of interest and the need to engage in research activities; the development, depth, and strength of knowledge in the methodology of organizing scientific research; inventive skills, abilities, and the creation of new developments in the field of engineering.

Conclusions. The research of formation of the science and research competence of future engineers is highly relevant due to the necessity of scientific solution of production problems in the field of industrial manufacturing. Therefore, the ability to conduct scientific activity and organize research work is the foundation for the high quality of training future engineering professionals in higher technical educational institutions. Recent observations have shown that the main tasks of modernizing the training of future engineers according to the prospective requirements of knowledge-intensive production can be solved by forming skills, abilities, and experience in innovative research activities for specialists in the technical field.

The science and research competence is considered an integral component of general professional competence and forms the foundation for training future engineers in higher technical educational institutions. The development of science and research competence ensures the growth of a scientific worldview, individual research, creative, and inventive abilities of highly qualified, competent specialists in the technical field.

The effectiveness of this process is ensured by developing motives for research work, acquiring knowledge of the methodology of scientific research, and fostering the future engineer's active involvement in the process through participation in university research associations (schools, clubs, laboratories). This, in turn, contributes to gaining experience in conducting scientific research. Involving students from other fields will provide a broader perspective on the issue of studying the impact of the proposed forms and methods of organizing research activities on the development of science and research competence. It would also be interesting to explore how student research activities affect their knowledge in various subjects and their motivation for learning.

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Романчук Н. О., Майборода О. В. Структура, критерії та показники науково-дослідницької компетентності майбутніх інженерів

Проблема формування навичок науково-дослідницької діяльності майбутніх інженерних фахівців в процесі їх підготовки є актуальною через необхідність виконання дослідницьких завдань у галузі промислового виробництва. У статті аналізуються сучасні тенденції та характерні особливості професійної підготовки майбутніх інженерних фахівців у закладах вищої технічної освіти України з точки зору реалізації компетентнісного підходу. Досліджується проблема

формування науково-дослідницької компетентності майбутніх інженерів як складової загальної професійної компетентності фахівця технічної галузі. Науково-дослідницька діяльність майбутніх інженерів розглядається як основа та необхідна умова їх ефективної професійної підготовки.

Характеризуються мета, завдання, аспекти та принципи формування науково-дослідницької компетентності майбутніх інженерів. Дослідженням виявлено фактори, які впливають на формування науково-дослідницької компетентності майбутніх інженерів: рівень професійної освіти; індивідуальні здібності до наукових досліджень; досвід здійснення дослідницької діяльності; мотивація до неперервної самоосвіти, саморозвитку; творче ставлення до професійної діяльності; навички діяти у нетипових, нестандартних ситуаціях. Обґрунтовуються критерії, показники та рівні сформованості науково-дослідницької компетентності майбутніх інженерів в закладах вищої технічної освіти.

Доводиться ефективність розроблених умов підготовки майбутніх інженерів на формування їх науково-дослідницької компетентності. Цими умовами є: формування мотивів до дослідницької роботи; озброєння відповідними знаннями методології наукових досліджень; залучення студентів інженерних спеціальностей до роботи університетських наукових об'єднань (наукові школи, гуртки, проблемні лабораторії); набуття досвіду здійснення науково-дослідницької діяльності.

Ключові слова: *професійна підготовка, вищі технічні заклади освіти, майбутні інженери, компетентнісний підхід, професійна компетентність, наукові дослідження, дослідницька діяльність, науково-дослідницька компетентність.*

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ПРОБЛЕМНО-ОРІЄНТОВАНЕ НАВЧАННЯ ЯК ОДИН З ФАКТОРІВ ОПТИМІЗАЦІЇ МАТЕМАТИЧНОЇ ПІДГОТОВКИ СТУДЕНТІВ У ТЕХНІЧНОМУ УНІВЕРСИТЕТІ

Стаття присвячена деяким аспектам використання методів проблемного навчання при вивченні вищої математики в університеті. У технічному університеті саме математика є одним із ключових предметів, основою для успішного вивчення багатьох інших навчальних дисциплін, формуючи у студента певну культуру мислення. Таким чином, від якості навчання математики залежить ефективність всього освітнього процесу.

На даний момент класична модель навчання не дозволяє повною мірою включитися студентам до навчального процесу. Все більшого поширення набувають відносно нові освітні моделі. До них належить і проблемно-орієнтоване навчання.

Відзначається, що суттєва роль у впровадженні проблемного навчання на заняттях з вищої математики відводиться проблемному домашньому завданню. Наведено способи створення проблемних ситуацій на заняттях з вищої математики в технічному університеті. Запропоновані приклади задач з курсу вищої математики, в яких використовуються елементи проблемного навчання та показані шляхи реалізації проблемних ситуацій. Використання проблемно-орієнтованого підходу наближує студентів до реальної професійної діяльності, допомагає студентам розкритися та розвинути особисті якості та одночасно з цим розвиває навички комунікації.

У статті подано результати опитування студентів Київського політехнічного інституту імені Ігоря Сікорського, які дозволили зробити висновок, що застосування впродовж двох років елементів проблемного навчання на заняттях з вищої математики сприяє підвищенню інтересів студентів до вивчення вищої математики за рахунок активізації їх навчально-пізнавальної діяльності, встановлення зв'язку між математикою і майбутньою професійною діяльністю. Теоретичне дослідження та практична апробація використання проблемної технології підтвердили факт позитивного впливу проблемного завдання на заняттях з математики у технічному університеті.

Ключові слова: *проблемно-орієнтоване навчання, освіта, математика, студенти, мотивація, професійна спрямованість, пізнавальна діяльність, проблемна задача.*

Актуальним напрямом інноваційного розв'язку освіти є STEM-орієнтований підхід до навчання, у якому академічні терміни супроводжуються прикладами із реального життя. В Концепції розвитку природничо-математичної освіти (STEM-освіти) підкреслюється, що розвиток національної економіки, зокрема інформаційних технологій, ставить перед вищою освітою завдання щодо генерування нових ідей і знань, створення нових технологій, розв'язання проблем, що можливо досягнути шляхом впровадження проблемного навчання, створення на заняттях проблемних ситуацій для самостійного здобуття необхідних знань у процесі їх вирішення.

Основними завданнями STEM-освіти є впровадження новітніх педагогічних підходів до викладання та оцінювання, практики міжпредметного навчання, використання технологій проблемного навчання; оволодіння засобами пізнавальної та практичної діяльності; визначення пріоритетною особистісну орієнтацію освіти, розвиток особистості, яка прагне до здобуття освіти упродовж життя; визначення істотної ролі математики в інтегративному підході реалізації природничо-математичної освіти.