



Zhytomyr Ivan Franko State University Journal.  
Pedagogical Sciences. Vol. 4 (107)

Вісник Житомирського державного  
університету імені Івана Франка.  
Педагогічні науки. Вип. 4 (107)

ISSN (Print): 2663-6387

ISSN (Online): 2664-0155

UDC 378.147.811

DOI 10.35433/pedagogy.4(107).2021.32-40

## **MATHEMATICAL COMPETENCES AS A BASIS OF PROSPECTIVE ENGINEERS TRAINING IN HIGHER TECHNICAL EDUCATIONAL INSTITUTIONS**

**N. O. Romanchuk\***

*The article analyzes theoretical and methodological basics of formation of mathematical competences as a key condition of training prospective engineers in higher technical educational institutions. The study considers the problem of prospective engineers' mathematical training implementation based on the competence approach aiming at future activity in industrial production field on the level of world standards. On the basis of the analysis of modern concepts essence, purpose, and management of prospective engineers' training in higher technical educational establishments from the perspective of the competence approach realization are reconsidered. Mathematical education is considered as a basis for the training of technical specialists. Despite the fact that the issue of professional development of higher technical educational institutions students was given considerable attention in the research of the scientific community, the problem of forming their mathematical competences remained insufficiently covered and was not the subject of a dedicated special research. The aim of the article is to study the theoretical and methodological foundations of prospective engineers' mathematical competences formation as a basis for their professional training. Theoretical research methods were used during research, namely: study and analysis of psychological-pedagogical, legal and special literature on the researched issue; analysis of state educational standards, programs, textbooks and teaching materials. The specifics of teaching mathematical disciplines in higher technical educational institutions are determined. The basic techniques and principles of realization of the competence approach in education are revived. The stages of prospective engineers' professional competence formation are characterized. The article focuses on personal values of a prospective engineering specialist in the process of professional competence formation. Procedural, technological, logical, research and methodological components of mathematical competence of technical specialists are described. The article proves on the effectiveness of prospective engineers' mathematical competences formation in order to train highly qualified specialists of technical field in higher technical educational institutions.*

**Key words:** *higher technical educational institutions, professional training, prospective engineering specialists, competence-based approach in education, professional competence, mathematical competence.*

\* Candidate of Pedagogical Sciences (PhD in Pedagogy), Docent  
(Admiral Makarov National University of Shipbuilding, Mykolaiv)  
nataliiaromanchuk11@gmail.com  
ORCID: 0000-0002-3225-6428

## **МАТЕМАТИЧНІ КОМПЕТЕНТНОСТІ ЯК ОСНОВА ПІДГОТОВКИ МАЙБУТНІХ ІНЖЕНЕРІВ У ВИЩИХ ТЕХНІЧНИХ ЗАКЛАДАХ ОСВІТИ**

**Н. О. Романчук**

*У статті досліджуються теоретико-методологічні засади формування математичних компетентностей як необхідної умови підготовки майбутніх інженерних фахівців у вищих технічних закладах освіти. Розглядається проблема реалізації математичної підготовки майбутніх інженерів на засадах компетентнісного підходу з метою їх ефективної діяльності в галузі промислового виробництва на рівні світових стандартів. На основі аналізу сучасних концепцій переосмислюються сутність, мета, зміст підготовки майбутніх фахівців інженерного профілю у вищих технічних закладах освіти з позиції реалізації компетентнісного підходу. Математична освіта розглядається як базова для підготовки фахівців технічного профілю. Незважаючи на те, що питанню підготовки студентів у вищих технічних закладах освіти приділялася значна увага у дослідженнях наукової спільноти, проблема формування їх математичних компетентностей залишалася мало вивченою і не була предметом спеціального наукового дослідження. Мета статті полягає в дослідженні теоретико-методологічних засад формування математичних компетентностей майбутніх фахівців інженерного профілю як основи їх професійної підготовки. У роботі використовуються теоретичні методи дослідження: вивчення та аналіз психолого-педагогічної, нормативної та спеціальної літератури з проблеми дослідження; аналіз державних освітніх стандартів, програм, навчальних посібників і методичних матеріалів. Визначаються особливості викладання математичних дисциплін у вищих технічних закладах освіти. Розкриваються основні підходи, принципи реалізації компетентнісного підходу в освіті. Характеризуються етапи формування професійної компетентності майбутніх фахівців інженерного профілю. Акцентується увага на особистісних цінностях майбутнього інженерного фахівця в процесі формування його професійної компетентності. Обґрунтовуються процедурна, технологічна, логічна, дослідницька та методологічна складові математичної компетентності фахівців технічної сфери. Доводиться ефективність формування математичних компетентностей майбутніх інженерів з метою підготовки висококваліфікованих фахівців технічного профілю.*

**Ключові слова:** вищі технічні заклади освіти, професійна підготовка, майбутні фахівці інженерного профілю, компетентнісний підхід в освіті, професійна компетентність, математична компетентність.

**Introduction of the issue.** The current stage of socio-economic development of Ukraine and the introduction of new technologies of industrial production require a modern rethinking of the notion, function and content of prospective engineering specialists training in higher technical educational institutions. The demand to provide state industrial objects with highly qualified engineers who are competitive and flexible to changing market conditions requires new ways to improve the quality of professional training of students in higher technical educational institutions. The relevance and importance of researching the basics of training prospective engineers in higher technical educational institutions

is proved on the example of modern development of education as a social institution that ensures the professional success of young engineers capable of creative demonstration of activity and independence in solving industrial problems, and promotes competitiveness in labour market.

The professional competence of a higher technical educational institution graduate is determined as a valuable indicator of alacrity for future professional activity and civil position [6; 12; 15]. Thus, the competence approach in education is one of the priority areas of reforming the higher technical education system in Ukraine. Its implementation ensures the realization of the humanistic education concept and

training of competent, socially and professionally mobile engineers who are fluent and ready for continuous professional development.

**Current state of the issue.** Problems of the competent approach realization in education are covered by N. Bibik, O. Uremenko, V. Lugoviy, O. Ovcharuk, O. Pometun, O. Savchenko, G. Selevko, V. Serikov, K. Khoruzhiy, A. Hutorskiy and others, who define the competence of a prospective specialist in the technical field as the ability of socially valuable activity. The competent specialist is characterized by his willingness to solve problems in future professional activity, using innovation to achieve goals, and based on awareness in industrial production.

Modern mathematical education, as noted by researchers Z. Bondarenko, Y. Galaiko, O. Yevseyeva, M. Kademiya, S. Krylashchuk, V. Klochko, T. Krylova, L. Kudryavtseva, T. Maksimova, G. Mikhalyn, V. Petruk, M. Pratsovytyi, N. Sennikova, O. Skafa, Z. Slepkan and others, occupies a special place in the state educational system, for developing the intellectual abilities of the students also improves the ability to draw analogies and logically substantiate own point of view [3; 10]. Therefore, the process of teaching mathematical disciplines in higher technical educational institutions should be organized in a way that promotes the comprehensive and harmonious development of the personality of a prospective engineer, ensuring the formation of the necessary mathematical competences.

**The outline of unresolved issues brought up in the article.** Modern researchers of professional training of prospective engineers in higher technical educational institutions S. Artyukh, O. Baranets, N. Bryukhanova, E. Zeer, O. Kovalenko, A. Nizovtsev, Y. Pazynich, N. Tymkiv and others state that an engineer is both able to set up and maintain technical devices and be a researcher and a team organizer. Today,

engineering education in Ukraine is characterized by the actualization of the competence component of prospective engineers training content on the basis of the person-centered approach implementation. However, according to the analysis of the problem of teaching mathematical disciplines as a basis for training prospective engineers in higher technical educational institutions, the formation of their mathematical competences was insufficiently covered, and therefore requires a separate study.

**Aim of research.** The formation of mathematical competences is a key condition for training qualified engineers capable of competent and effective activity in the technical field at the level of European and world standards. The aim of the article is to study theoretical and methodological issues of prospective engineers' mathematical competences formation as a basis for their training in higher technical educational institutions.

**Results and discussion.** Mathematical education is the basis for professional training of engineers in higher technical educational institutions, because in addition to actual knowledge of the subject, it provides the development of logical and abstract thinking of students, shaping their scientific worldview, ability to create mathematical models in future professional activity. Modern society requires engineers with advanced mathematical knowledge, logical thinking, and the ability to apply the mathematical competences acquired in the training process and in future professional activity.

In its communicative and subject essence, the profession of an engineer combines interdisciplinary knowledge, innovative ideas and features of the environment with their own ability to synthesize information in order to create a new subjective reality. The professionally trained engineer is expected to be able to design and construct; to use the means of production, management-practical,

constructive-technological and research activity; to organize the production process; to ensure the implementation of scientific and industrial achievements; to develop scientific and technical documentation; to use normative guidelines, scientific-technical, and production information; to develop technical and technological projects, plans, tutorials; to standardize and manage the work of production; to develop and implement measures to increase production efficiency.

The specific feature of training students of higher technical educational institutions is prospective engineers' skills of self-organization and reflection. It means that the students are expected to feel the need for acquiring learning material and understanding it, i.e. not only the knowledge transfer, but the development of technical skills as a priority characteristic of a value-oriented personality.

The ideas of general and personal development, formulated in the context of psychological and pedagogical concepts of humanistic education, are the basis of the modern understanding of the competence approach. The concepts of goal-setting and goal-orientation of the educational process underly the analysis of the competence approach categorical basis. Under such conditions, competences determine a higher, generalized level of students' skills and abilities, and education content design involves the unity of four components: knowledge, skills, creative personality and personal experience of general values [5].

Implementation of the competence approach in the process of prospective engineers training involves the formation of an individual experience in professional challenges as well as solving life situations [1]. Therefore, the competence approach involves the performance of relevant professional functions and social roles. This ensures that the competence of the technical specialist includes semantic (deep

knowledge of the subject) and procedural (mastering of work skills) components. The formation of these components involves mastering new information in order to effectively solve problems in future professional activity.

The major characteristic of the competent personality of prospective technical specialist is the development of professional activity skills by not only applying the knowledge of the subject, but increasing awareness of a needed educational material, as well as the ability to self-organization and reflection, which is specific to the implementation of the competence approach in the process of prospective engineers training in higher technical educational institutions.

The formation of professional competences of technical field specialists, including mathematical, should come along with human values, which is an essential characteristic of competence, and involves a deep personal interest in a particular activity. Under such conditions, the personality values of the prospective engineer are the basis of his/her professional competence.

Modern researchers N. Bordovska, V. Raevsky, A. Rean, A. Khutorskiy define the professional competence of a specialist as a system of skills and abilities to systematize scientific and practical knowledge in order to effectively solve professional issues. Besides, V. Fedina emphasizes that the process of professional competence formation occurs throughout the professional activity and consists of three main stages. The first stage of formation of professional intentions and orientation is carried out in the process of adaptation of prospective engineers to activities in the field of industrial production. The second stage, according to the researcher, is a mastery of special professional knowledge and skills. The third stage implies professional development of a specialist in the technical field, characterized by the

acquisition of a professional mentality and skills of high quality professional activity [13].

V. Petruk emphasizes the importance of the value attitude of a specialist's personality to the solution of professional tasks, which defines professional competence as the readiness of an individual to mobilize their own resources organized into a system of knowledge, skills, abilities and personal qualities in both typical and non-standard situations [7].

Professional competence of prospective engineering specialists declares the unity of fundamental and subject competences and provides a set of knowledge and personal qualities of students, which ensures a high level of self-organization of future professional activity [2; 4]. The readiness of a specialist to perform professional duties is determined by his/her professional competences, including mathematical, which should be formed on the basis of theoretical knowledge, practical skills, significant personal qualities and life experience.

The professionalism of a modern specialist in the technical field, according to O. Romanovsky, determines his/her competence in the field, namely: organization-managerial, design-engineering, operation-technological and researching. Among other important competences of prospective specialists in the technical field, the author includes psychological, economic and legal ones [11]. The formation of engineering skills and abilities to predict social, economic, environmental consequences of their own decisions, according to L. Tovazhnyansky, is closely connected with the need to solve complex organizational, managerial, technical and scientific issues in future professional activity in industrial production [8].

The professional competence of the prospective technical specialist, as an integrative characteristic of his business and personal qualities, reflects the level of knowledge, skills, and experience for

effective activity in industrial production. In addition, it includes the ability to analyze and forecast results and to use current information. The competence of a technical specialist includes professional knowledge, skills, experience in the industrial field, socio-communicative and personal traits ensuring independent professional activity. The professional competence of the prospective engineer includes: the formation of the ability to evaluate professional issues; creative thinking; taking the initiative in solving production problems; conscious understanding of personal responsibility for the results of work; leadership skills to manage a team.

We assume that the professional competence of prospective specialists in engineering is determined by the level of his/her professional education, experience, individual abilities, motivation for continuous self-education and self-development, and creative and responsible attitude to professional activity.

The effectiveness of professional activity of prospective specialists in the technical field is ensured by a thorough engineering education combining abstract theoretical principles and specific tasks of industrial production, which requires the formation of mathematical competences. Mathematical competence of engineering students involves their ability to apply the acquired mathematical knowledge and skills in the study of mathematical models of technical problems including logical thinking, selection, evaluation, and applying of information needed to solve professional issues.

Implementation of mathematical training of prospective engineers on the basis of the competence approach involves the focus of the educational process on the formation and development of key (basic) and subject mathematical competences. Competence approach in teaching mathematical disciplines in higher technical educational institutions is closely related

to personality-oriented and activity approaches, for active creative activity helps to acquire deep understanding of learning material and skills of its creative implementation in future professional activity.

We consider the introduction of individualization and differentiation of education relevant in the context of personality-oriented mathematical education, which contributes to the disclosure, preservation, development of individual abilities of students, inherent in each person's unique qualities; formation of cognitive interests, the pursuit of self-improvement and self-realization in future activity in the field of industrial production.

In the context of the competence approach, the ability of a higher technical educational institution student to apply mathematical knowledge in future professional activity is embodied by:

- teaching methods, tools and techniques for applying knowledge of mathematics to study mathematical models in future engineering activity;
- development of logical thinking and technical tasks analysis and finding means of their practical implementation;
- formation of mathematical competences by providing the necessary mathematical knowledge as a universal tool of engineering research.

We define mathematical competence of the prospective engineer as an integrative professional quality which is manifested in theoretical readiness and practical ability to independently, responsibly and effectively perform industrial tasks, as well as in values to the profession of an engineer. Professional and value orientations of prospective graduates of higher technical educational institutions are defined as a systemic component of the general professional culture of an engineering specialist due to his/her readiness for future professional activity in accordance with high personal values. Professional and value orientations are directly

related to the activity, act as its basis and regulator. That is why it is important in the process of mathematical training of prospective engineers to form a value attitude to the profession of engineer.

Mathematical competence, according to S. Rakov, expects engineering students to see and apply mathematical knowledge in real life and professional activities; knowledge and understanding of the content, methods of mathematical modeling of technical processes; ability to create mathematical models, to study them using mathematical methods, to interpret the obtained results, to estimate the error of calculations [9]. In the context of our study, we consider author's classification of mathematical competences: procedural, technological, logical, research and methodological.

The formation of mathematical competence of a prospective engineer is based on the combination of scientific and theoretical training (general mathematics and special branches of mathematics) and experience in applying mathematical knowledge, which is represented in solving both typical and problematic situations in professional activity in industrial production, knowledge and personal experience (life and professional). Therefore, the structure of mathematical competence reflects: the system of knowledge and skills acquired by prospective engineers in the process of scientific-theoretical and practical mathematical training to solve basic production issues; personal experience of applying the acquired competences to solve typical and non-standard tasks of professional activity related to the application of mathematical knowledge; the system of value orientations and experience of emotional and value attitude of prospective engineers to the categories of higher mathematics, to the profession, to themselves, to colleagues and society.

Basic mathematical competences include procedural competence, i.e. the skill of prospective engineers to work with formulas, solve typical

mathematical problems, and reproduce the context of problems in practice reduced to typical ones. The acquired computing techniques, usage of different types of software, estimating the error of approximate calculations, building and researching computer models determine student's technological competence.

The formation of logical mathematical competence of prospective engineers involves the development of their logical literacy and logical thinking ensured by accurate and consistent thinking, avoiding contradictions in their reasoning as well as justifying the correctness of a technical problem solution and anticipating possible logical errors in the solution process.

Mastering research competence requires prospective engineers to operate the methods of researching socially and individually significant tasks, to build analytical and algorithmic models of problems, to anticipate and empirically

test the validity of hypotheses based on methods of analogy, induction, generalization, as well as based on personal experience. The key characteristics of methodological mathematical competence are the knowledge of prospective technical field specialists of methods of mathematical problems research in future professional activity as well as the skill to modify the original technical problem and to establish links with the results already obtained, finding analogies in other disciplines.

So, the mathematical competence of prospective engineers is represented as a holistic personality characteristic, and its effective formation is ensured by the successful higher technical educational institutions students' mastering procedural, technological, logical, research and methodological mathematical competences (Table 1).

Table 1

<b>Mathematical training of prospective engineers in higher technical educational institutions</b>		
<b>The aim:</b> formational of mathematical competence as a holistic characteristic of personality of prospective specialist in the technical field		
<b>The components of mathematical competence</b>	<b>Procedural</b>	The skill to work with formulas, solve typical mathematical problems, and reproduce the context of problems in practice reduced to typical ones
	<b>Technological</b>	The acquired computing techniques, usage of different types of software, estimating the error of approximate calculations, building and researching computer models of mathematical tasks
	<b>Logical</b>	The development of logical literacy and logical thinking ensured by accurate and consistent thinking, avoiding contradictions in reasoning; justifying the correctness of a technical problem solution
	<b>Research</b>	The knowledge of the methods of researching socially and individually significant tasks, to build analytical and algorithmic models of problems, to anticipate and empirically test the validity of hypotheses
	<b>Methodological</b>	The knowledge of prospective technical field specialists of methods of mathematical problems research in future professional activity as well as the skill to modify the original technical problem and to establish links with the results already obtained, finding analogies in other disciplines
<b>The result:</b> formed mathematical competence of prospective engineers		

### **Conclusions and research perspectives.**

Thus, the need to modernize the system of higher technical education in Ukraine and to improve its quality is an important socio-cultural issue shaped by the state demand in training prospective engineers at the level of international standards and providing conditions for their personal and professional development, socialization and self-realization. Since the competence approach in education has become a socially significant phenomenon and a trend in the formation of higher education foundation and content, the development of the state system of higher technical education, according to analysis of pedagogical experience of the last decade, should be based on the competence approach.

Realization of ideas and principles of state education policy is possible due to the realization of a systematic approach to the organization of prospective technical specialists training (organization-managerial, design-engineering, operation-technological, economic-legal, research and psychological). In addition, it depends on the process of formation of relevant competences, in particular the mathematical ones, which should be based on humanistic principles.

Successful professional competences acquisition involves the formation of mathematical competences of prospective engineering specialists training in higher technical educational institutions and consequently ensures the effectiveness of professional activity of engineers in broad social, cultural, and economic contexts. The formation of mathematical competences as a basis of prospective engineers training in higher technical educational institutions provides conditions for personal and professional self-development of a highly qualified competent specialist in the technical field.

Further research can be aimed at reviewing the results of approbation of

the presented material in real conditions and substantiation as well as development of plans and programs for the amplification of professional competence of prospective engineers training in higher technical educational institutions.

### **REFERENCES (TRANSLATED & TRANSLITERATED)**

1. Bibik, N.M. (2004). Kompetentnisniy pidhid: refleksyvniy analiz zastosuvannya [Competence approach: reflective analysis of implementation]. *Competence approach in modern education: world experience and Ukrainian perspectives*. Kyiv: "K.I.S.", 47-52 [in Ukrainian].
2. Elkin, M.V. (2005). Formuvannya profesiinoi kompetentnosti maibutnoho vchytelia heohrafii zasobamy proektnoi diialnosti [Formation of professional competence of the prospective teacher of geography by means of project activity]. *Candidate's thesis*. Kyiv: Central Institute of Postgraduate Education NAES of Ukraine [in Ukrainian].
3. Kademiya, M.Yu. (2013). Innovacijni tekhnologiy u vikladanni fiziko-matematichnih disciplin. [Innovation technologies in teaching physics and mathematical disciplines]. *Modern informational technologies and innovative methods of teaching and training specialists: methodology, theory, background and issues*. Vol. 36. Kyiv-Vinnicya: "Planer LTD", 25-28 [in Ukrainian].
4. Kovalenko, L.V. (2017). Rozvytok profesiinoi kompetentnosti vchytelia ukraïnskoi movy ta literatury v systemi pisliadyplomnoi osvity: metodychnyi posibnyk [Development of professional competence of a teacher of Ukrainian language and literature in the system of postgraduate education: methodical manual]. Sumy: Niko [in Ukrainian].
5. Medentseva, I.P. (2012). *Kompetentnostnyiy podhod v obrazovanii* [Competence approach in education]. Moscow: Buki-Vedy [in Russian].

6. Ovcharuk, O. (2005). Kompetentnosti yak kluch do onovlennia zmistu osvity. Osvita v konteksti stratehichnykh zavdan rozvytku Ukrainy [Competences as a key to updating the content of education. Education in the context of strategic objectives of Ukraine's development]. *Dyrektor shkoly Ukraina: naukovo-metodychnyi zhurnal – Director of the school Ukraine: scientific and methodical magazine*, 3-4. Retrieved from <https://ru.osvita.ua/school/method/381/> [in Ukrainian].
7. Petruk, V.A. (2008). Teoretiko-metodichni zasady formuvannya bazovih profesiynih kompetentnostey u maybutnih fahivtsiv tehnicnih spetsialnostey. [Theoretical and methodological principles of formation of basis professional competences in the prospective specialists of technical specializations]. *Doctor's thesis*. Kyiv [in Ukrainian].
8. Tovazhnyanskyi, L.L. & Romanovskiy, O.G. (2002). *Problemy ta perspektyvy formuvannya natsionalnoyi nauково-technichnoyi elity [Problems and perspectives of the formation of the national scientific and technical elite]*. Kharkiv: NTU "HPI", 293 [in Ukrainian].
9. Rakov S.A. (2005). *Matematichna osvita: kompetentnisniy pidhid z vikoristanniam IKT [Mathematical education: a competency approach using information-and-communication technologies]*. Kharkiv: Fakt, 360 [in Ukrainian].
10. Rovenska, O.G. (2011). *Problemnyi pidhid u vykladanni vyschoyi matematyky dlya inzhenernykh spetsialnostey [Problem approach in teaching higher mathematics for students of engineering specialties]*. Donetsk: DonTU, 49-52 [in Ukrainian].
11. Romanovskiy, A.G. (1997). *Teoreticheskiye i metodicheskiye osnovy podgotovki inzhenera v vyshem uchebno-metodicheskom zavedenii k budushey upravlencheskoy deyatel'nosti. [Theoretical and methodological basis for training an engineer in a higher educational institution for future management activity]. Extended abstract of doctor's thesis*. Kyiv [in Russian].
12. Sysoieva, S.O. (2012). *Problemy nepererвної profesiinoi osvity: tezaurus naukovoho doslidzhennia: nauk. vydannia [Problems of continuing professional education: thesaurus of scientific research: science. edition]*. Kyiv: Vydavnychi Dim "EKMO" [in Ukrainian].
13. Fedina, V.S. (2011). *Formuvannya profesiynoyi kompetentnosti u maybutnih fahivtsiv-shidnoznavtsiv. [Formation of professional competence in prospective specialists in the Eastern field]. Candidate's thesis*. Lviv [in Ukrainian].
14. *Zakonu Ukrainy "Pro osvitu" vid 5 ver. 2017 roku № 38-39 [Of the Law of Ukraine On Education from September 5 2017, № 38-39]*. (2017, September 5). Retrieved from <https://zakon.rada.gov.ua/laws/show/2145-19#Text> [in Ukrainian].
15. Zyazyun, I.A. (2000). *Intelektualno-tvorchiy rozvitok osobistosti v umovah nepererвної osvity. [Intellectual and creative development of personality in terms of continuous education]. Continuous professional education: problems, findings, perspectives*. Kyiv: "Vipol", 11-57 [in Ukrainian].
16. Hicks, K. (2015). *Top Education Technology Trends*. Edudemic, May 13, 2015. Retrieved from <http://www.edudemic.com/education-trends-keep-tech-front-center/> [in English].

Received: November 18, 2021  
Accepted: December 09, 2021