



Methodological principles for ensuring high-quality training of technical specialists in higher education institutions

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■ **Abstract.** The acquisition of competencies by higher education students faces problems of deterioration of basic school knowledge, as well as the unstructured and fragmented nature of higher mathematics teaching, which hinders the assimilation of professional disciplines. The aim of the study was to improve the methodological tools for forming a comprehensive system of quality knowledge and its conscious assimilation. The main directions for creating methodological and organisational conditions for ensuring the continuity of learning and building interdisciplinary links were developed. Methodologically, the study relied on the use of methods of analysis and generalisation in the creation of visual basic material. Statistical methods were used in the systematisation and processing of the results of testing students' residual knowledge and evaluating the results of testing as small samples. Testing the knowledge of the school course in mathematics and physics of students majoring in electrical engineering revealed shortcomings in their training that must be taken into account when teaching sections of higher mathematics. The correspondence between the volume of material in the discipline and the time required to master it was analysed, which made it possible to identify basic knowledge from the entire course of higher mathematics to ensure a differentiated approach to the acquisition of professional knowledge. The specifics of distance learning were considered, which led to the creation of visual reference notes with enhanced explanatory functions. In accordance with professional competencies, a classification of material was proposed, which ensured interdisciplinary links and expanded propaedeutic opportunities. The methodological approach created made it possible to systematise the teaching material in higher mathematics, which can be used by teaching staff, applicants and other participants in the educational process, as well as in the development of curricula and the compilation of working teaching programmes

■ **Keywords:** quality of education; methodology; knowledge system; higher mathematics; electrical engineering speciality; propaedeutics

■ Introduction

The problem of high-quality training of specialists in technical specialities in higher education institutions is mainly internal in nature, characterised by imperfect methodological tools and discrepancies between

the requirements for the acquisition of professional competences by applicants and the basic knowledge of higher mathematics that provides them. The training of highly qualified specialists for the needs of the

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country's industry and business faces dynamic processes of transformation in the external and internal environments in which they operate. Such changes require all participants in the educational process to improve its effectiveness, aimed at obtaining certain competencies in the relevant fields of knowledge. Given that the Kryvyi Rih iron ore basin is a powerful mining and metallurgical complex in the region, it needs to replenish energy-intensive enterprises with high-quality electrical engineering personnel. Staff training is based on ability to set and solve problematic tasks with in-depth adaptive knowledge of higher mathematics, which determined the relevance of the research topic.

In view of the above, O. Ivanashko *et al.* (2023) revealed their vision of essential issues regarding the effectiveness of educational activities, which they consider to be the main prevailing idea that determines the sustainability of the entire education system in the country. The authors conducted a comprehensive analysis of the Ukrainian experience in providing educational services in higher education. A distinctive feature of the study was the consideration of crisis phenomena inherent in the current conditions of education. Based on the assumption that the crisis will continue in the long term, the authors propose the development of algorithms to stimulate the efficiency and effectiveness of the higher education system, which will not only provide the labour market with qualified personnel, but also guarantee the development of science regardless of unfavourable conditions. An important condition for obtaining high-quality professional training is the ability to form stable and comprehensive knowledge, which is the basis for further learning. Many scholars have devoted their work to the level of training of applicants, which is determined by testing residual and current knowledge. The authors S. Vadzyuk *et al.* (2021) noted that the main aim of such a measure was to identify gaps that prevent students from fully realising their knowledge and skills. For the teacher, it provided an opportunity to adjust the educational process and led to the improvement of the teaching system. The authors presented a proposal to divide knowledge control into initial, final and performance indicators.

The researcher S. Yutkalo (2020) proposed that testing should be considered the main form of control. The aim of testing is not only to determine the level of mastery of the material, but also to identify shortcomings in the learning process that lead to poor mastery of the necessary practical skills and abilities. It was proposed to use testing to carry out various types of assessment depending on the volume of material being tested. The author, like most educational researchers, emphasised the importance of the assessment function of testing, but also considered it as a system of training tasks and a procedure for monitoring the quality of acquired knowledge. One of the reasons for the deterioration in the quality of education is the transition of the

majority of educational institutions to distance learning. A number of teachers, O. Afanasieva *et al.* (2021), pointed out the lack of standards for distance learning in Ukraine, which makes it difficult to unify the material even within one country. Therefore, higher education institutions are forced to independently seek opportunities to apply the most suitable information and educational technologies.

Full assimilation of knowledge, especially in distance learning, is impossible without technological knowledge. L. Mesarosh (2023) emphasised that after 2020, it is impossible to imagine a future specialist without an understanding of the importance of information processes and information and communication technologies. This allows for the processing of large amounts of information, without which it is impossible to function fully in a changing world and impossible to reach a new level of quality in education. The author proposed to create mathematical knowledge competencies that define a certain set of knowledge and boil down not only to the assimilation of typical algorithms for finding solutions, but also to the understanding and ability to practically implement mathematical research methods. In substantiating the importance of interdisciplinary connections, which are an integral part of learning, A. Didyk (2019) emphasised the importance of disciplines such as higher mathematics and physics. The researcher suggested that disciplinary connections should be considered as a reflection of interdisciplinary connections, which are inseparable from scientific knowledge. The author defined the features of the course "Electrical Engineering and Electronics" as interdisciplinary potential and the creation of conditions for self-improvement and self-development.

Scientists O. Strakh & T. Lukashova (2021) drew attention to the fact that interdisciplinary connections not only perform educational and upbringing functions, but also form a comprehensive vision of the surrounding environment. This makes it possible to solve real-life problems. In addition, it creates the possibility of developing a holistic approach to mathematical objects and the algorithms used to describe them, thereby contributing to the intellectual development of students. N. Honhalo (2022) proposed the same goal using MS Excel. The combination of the components of the problem and their relevance, as well as the analysis of the work of scientists on this issue, identified a number of issues that require the creation of a conceptual system for the provision and assimilation of quality knowledge, primarily for students of technical specialities. The aim of this article was to avoid fragmentation of knowledge and supplement it with specific propaedeutic material in mathematics that is unique to these specialities.

■ Materials and Methods

The validity of the selected research methods and tools was based on general scientific research methods.

These included empirical research methods for testing residual knowledge and the use of informational and explanatory reference notes. Methods of analysis and comparison were used in researching the work of scientists on the research topic, as well as general logical methods, in particular deduction in analysing the stages of the qualitative knowledge system, and generalisation in formulating interim and general conclusions of the research. This article developed methodological approaches for testing the quality of residual knowledge and evaluating its results. The research was conducted in accordance with the Declaration of Helsinki (2013), and the confidentiality of personal information was preserved and agreed upon with the applicants. The verification of residual knowledge was carried out using the example of speciality 141 "Electric Power Engineering, Electrical Engineering and Electromechanics"

at Kryvyi Rih National University on the Google Classroom platform, with 18 students participating in the writing of the work.

Stage 1. Determination of school education knowledge that is basic for this speciality and needs to be corrected. The mathematics tasks were designed to test the level of general theoretical training, the results of which would reveal shortcomings in performing calculations; finding solutions to various types of equations and inequalities; mastering algebraic and trigonometric transformations; composing and solving meaningful problems, etc. Applicants were given a mathematics test consisting of 15 tasks of medium and lower levels of knowledge in the main sections of elementary mathematics, which was assessed on a 100-point scale. They were given 80 minutes to complete the test. An example of a mathematics task is given in Table 1.

Table 1. Example of a mathematics test to check residual knowledge

No.	Task content
1.	Calculate $\frac{(2\frac{4}{5}-1,2)\frac{1}{2}}{4,2-3\frac{2}{5}}$.
2.	When processing oil, 40% petrol is obtained. How much oil is needed to obtain 12 tonnes of petrol?
3.	Solve the system of equations $\begin{cases} 3x + 7y = -17; \\ -x + 3y = -9 \end{cases}$ and find $z = x + y$.
4.	Simplify the expression $\frac{ab+b^2-b}{a^2-ab} \cdot \frac{a-b}{a^2+ab-a} : \frac{5b}{a^2}$.
5.	The first term of a geometric progression is 5, and the common ratio is 2. Find the 5th term of the geometric progression.
6.	Solve the equation $3^{\sqrt{x}} + 3^{\sqrt{x+2}} - 90 = 0$.
7.	A cyclist travelled from one inhabited locality to another at a speed of 15 km/h. On the return journey, he cycled at 12 km/h, so the return journey took 1 hour longer. Find the distance between the inhabited localities.
8.	Solve the equation $\sqrt{x+4} = 3$.
9.	Solve the equation $\log_3(x-3) = 1 + \log_3 3$.
10.	Given $\triangle ABC$, $\angle C = 90^\circ$, $ CA = 2$, $\text{ctg} \angle B = 9$. Calculate $ BC $.
11.	Solve the equation $\text{tg} \alpha$, where $\sin \alpha = 0.6$, $0^\circ < \alpha < 90^\circ$.
12.	Solve the equation $4\cos^2 x - 4\cos x + 1 = 0$, where $0^\circ < x < 90^\circ$.
13.	Find the lateral side of an isosceles trapezium if its bases are 8 cm and 14 cm, and the area is 44 cm^2 .
14.	The base of a pyramid is an equilateral triangle with a side of $2\sqrt{3}$ cm. Two lateral faces are perpendicular to the base plane, and the third forms an angle of 60° . Find the volume of the pyramid.
15.	Find the value of x , that satisfies the inequality $\frac{x-7}{3-x} \geq 1$.

Source: compiled by the authors

Stage 2. Assessment of residual knowledge test results. When assessing the results of empirical studies, statistical methods were used to find numerical estimates for small samples and to construct confidence intervals when the mean square deviation of the general population was unknown. Since standard (point) estimates do not fully assess the qualitative state of residual knowledge, it is proposed to extend them to interval estimates. The point estimate, which determined the average score, was found using the formula:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}, \quad (1)$$

where \bar{x} – average number of points; x_i – number of points for the work of the i -th student; n – number of

students. Since the number of students is not large, corrected grades were used. The corrected standard deviation S – deviation from the average number of points;

$$S = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}. \quad (2)$$

The interval estimate of the average number of points (confidence interval) was calculated using the formula:

$$\left(\bar{x} - \frac{t_{\gamma} \cdot S}{\sqrt{n}} < a < \bar{x} + \frac{t_{\gamma} \cdot S}{\sqrt{n}}\right), \quad (3)$$

where γ – confidence probability (reliability), which determines the probability of error; $t_{\gamma}(n-1; 1-\gamma)$ – the value of the critical point according to the Student's

distribution. The methodology presented made it possible not only to identify gaps in knowledge, but also to understand the range of their assessment for the majority of students, which depends on the specified reliability.

■ Results and Discussion

Based on the above analysis of issues of interest to the educational community, a number of areas requiring further research can be identified. In doing so, it is necessary to take into account both the regional and professional specifics of training engineering specialists at each educational institution. The research conducted and its results are subject to certain stages, the essence of which lies in analysing the level of student training based on secondary education knowledge, comparing the volume of subject material and the number of hours required to master it, and selecting an appropriate form of training and ensuring that the content of the material corresponds to the professional competencies of future graduates. Practical issues that can be used to implement these stages of improving the quality of education depend on the specific technical speciality.

The importance of training engineering personnel, in particular in electrical engineering specialties, is due to the location of Kryvyi Rih National University in the Kryvyi Rih iron ore basin. The development of the basin's deposits requires an appropriate industrial base and qualified personnel for their operation. Based on this, the training of specialists capable of not only solving complex specialised tasks in the electrical engineering field is relevant (Bachelor's educational programme..., n.d.). At the same time, attention is drawn to the uncertainty of the conditions in which such specialists work and the complexity of the tasks they face. The main competencies that applicants for speciality 141 – “Electrical Power Engineering, Electrical Engineering and Electromechanics” (EEM) in the educational and professional programme of the specified speciality for the discipline of higher mathematics boil down to the formation of the ability to: analyse and think abstractly; independently search for and process information; solve practical problems using mathematical methods. The main stages of forming a comprehensive system of knowledge and its structural content are presented in the form of a diagram (Fig. 1).

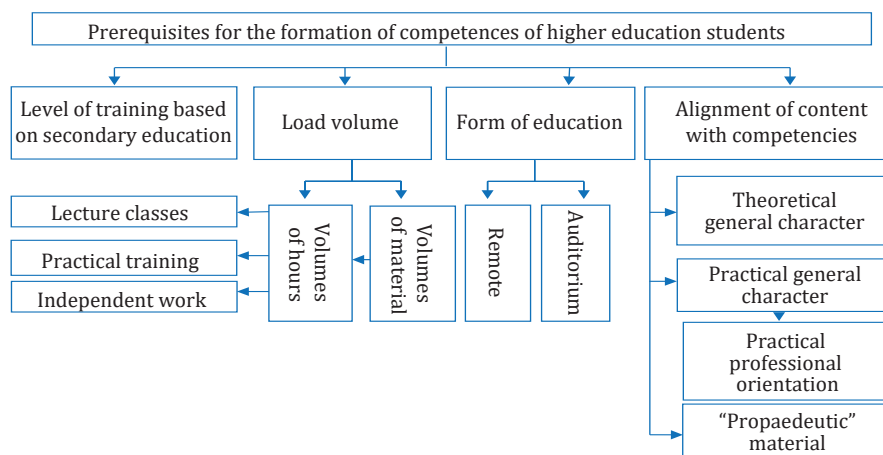


Figure 1. Scheme of forming a system of quality knowledge of future specialists

Source: compiled by the authors

The implementation of a quality education system (Fig. 1) begins with testing residual knowledge from

the school mathematics course. The results of the test for speciality 141 EEM are presented in Figure 2.

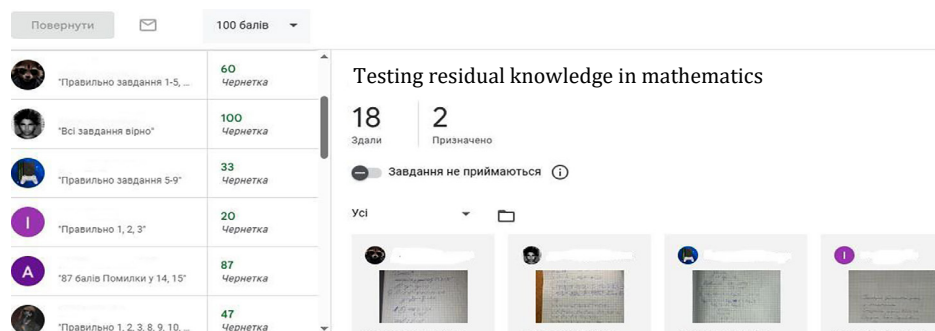


Figure 2. Form and results of the residual knowledge test on the Google Classroom platform

Source: compiled by the authors

When determining the numerical characteristics of this sample, which characterises the average number of points and the confidence interval for assessing

knowledge of the school course, methods for working with small samples were used. The results of the calculations are presented in Table 2.

Table 2. Results of calculations of the average score for residual knowledge in mathematics and physics

No.	Indicator	Results of calculations
1.	Average score	$\bar{x} = \frac{954}{18} = 53.$
2.	Corrected standard deviation	$S = \sqrt{601.53} = 24.53.$
3.	Confidence level (reliability)	$\gamma = 0.99$
4.	Critical point in the Student's distribution	$t_{\gamma}(17; 0.01) = 3.97.$
5.	Confidence interval	$a \in (30; 76)$

Source: compiled by the authors

Therefore, with a reliability of 0.99 (the margin of error is only 1%), it can be stated that the average score for the assessment of residual knowledge in mathematics for the EEM speciality falls within the interval $a \in (30; 76)$. An analysis of the research results for the sections of higher mathematics and physics for the 141 "Electrical Power Engineering, Electrical Engineering and Electromechanics" speciality is presented in Table 3.

The worst results in mathematics are related to the fact that applicants do not have developed spatial

thinking, and there is a negative impact from the absence of subjects such as drawing and descriptive geometry in the school curriculum and in higher education programmes. However, the most negative aspect is that the overall percentage of correct answers is lowest for trigonometry tasks (questions 10-12). This means that even at the secondary school level, basic knowledge of trigonometry has not been developed, which complicates the understanding of complex numbers, which are mainly used to describe processes related to electric current.

Table 3. Analysis of the results of the residual knowledge test

No.	Section of mathematics	Result		№	Section of mathematics	Result	
		number of correct answers	%			number of correct answers	%
1.	Actions with fractions	14	77.79	9.	Logarithmic equations	15	83.33
2.	Problems on percentages	15	83.33	10.	Trigonometric functions in a right triangle	7	38.89
3.	Systems of linear equations	12	66.67	11.	Basic formulas of trigonometry	10	55.56
4.	Algebraic transformations	7	38.89	12.	Trigonometric equations	3	16.67
5.	Arithmetic and geometric progression	7	38.89	13.	Planimetry	7	38.89
6.	Exponential equations	11	61.11	14.	Stereometry	4	22.22
7.	Problems on composing equations	11	61.11	15.	Inequalities	4	22.22
8.	Irrational equations	14	77.79				

Source: compiled by the authors

The main shortcomings of higher technical education include: a narrow worldview understanding of the interconnection of processes and phenomena; insufficient interdisciplinary links in teaching; a reduction in the volume of study; a decrease in student motivation; narrow specialisation, etc. All these problems are also inherent in the training of EEM students. Fourteen credits are allocated to the study of higher mathematics for this speciality over two semesters, of which 36% are classroom hours and 64% are independent study hours. Therefore, there is an urgent need to clearly divide the material for independent and classroom study. This division should continuously ensure the possibility of consistent study of the full scope of material in higher mathematics and help focus attention on the

material used in mastering specialised disciplines, reflecting interdisciplinary continuity.

The first section of higher mathematics is "Fundamentals of Linear Algebra", the main result of which is the ability to solve systems of linear algebraic equations using the Gauss method, determinants (Cramer's formula) and the inverse matrix. The theoretical material of this section is used in the study of: vector algebra (transition to a new basis, finding vector and mixed products in coordinate form); analytical geometry (equations of a plane through three points, finding the points of intersection of geometric objects; transition from a parametric equation of a straight line in space to a canonical one); functions of several variables (finding critical points when studying local and global extrema of functions,

Lagrange multiplier method); integration (method of undetermined coefficients); differential equations (finding solutions using the method of variation of arbitrary constants and linear homogeneous and non-homogeneous second-order differential equations with constant coefficients), etc. The mathematical apparatus for this topic is used in physics in calculations of branched electrical circuits and electrical circuits in Kirchoff's laws.

It should be noted that the organisation of the educational process in Ukrainian universities differs from the similar process in the United States of America. G. Strimel *et al.* (2018) clarified that engineering programmes require additional study of higher-level mathematics, so they include several semesters for the formation of priority knowledge. They go beyond the study of algebra, trigonometry and applied calculus and should have greater practical value. The first year of study is the basis for writing term papers in mathematics, natural sciences and engineering design, which provides an opportunity to begin studying specialised disciplines. Unlike Ukrainian universities, the training of future engineers does not

include the study of special sections of higher mathematics and taking exams. The goal is to consolidate basic mathematical concepts and the ability to solve engineering problems. The applied part of higher mathematics is only studied in the second year of study.

In the current conditions of educational institutions, preference is given to distance learning during the semester, and the session is held in a mixed format. To improve the quality of knowledge, it is proposed to prepare basic reference material in electronic form for each topic, which is not only information-rich in terms of familiarisation with methodological approaches, theoretical knowledge and examples of their application to the topic, but also has explanatory functions, shows the strengths and weaknesses of each methodology, and the conditions for their use in each specific case. In addition, Google Classroom should provide extended material on the topic, which includes a component for independent study. An example of such a presentation of material on the topic "Integration of trigonometric functions" is given in Table 4.

Table 4. Form of presentation of basic material on the topic "Integration of trigonometric functions"

No.	Integral of the form	Substitution	Methodological recommendations
Objective: transition from trigonometric functions to algebraic functions $\int R(\cos x, \sin x) dx \rightarrow \int R(x) dx$.			
1	Universal trigonometric substitution $\int R(\cos x; \sin x) dx$	$tg \frac{x}{2} = t; \frac{x}{2} = \text{arctgt}; x = 2\text{arctgt};$ $dx = \frac{2dt}{1+t^2};$ $\cos x = \frac{\cos x}{1} = \frac{\cos^2 \frac{x}{2} - \sin^2 \frac{x}{2}}{\cos^2 \frac{x}{2} + \sin^2 \frac{x}{2}} =$ $= \left[: \cos^2 \frac{x}{2} \right] = \frac{1 - tg^2 \frac{x}{2}}{1 + tg^2 \frac{x}{2}} = \frac{1 - t^2}{1 + t^2};$ $\sin x = \frac{\sin x}{1} = \frac{2 \sin \frac{x}{2} \cos \frac{x}{2}}{\cos^2 \frac{x}{2} + \sin^2 \frac{x}{2}} =$ $= \left[: \cos^2 \frac{x}{2} \right] = \frac{2tg \frac{x}{2}}{1 + tg^2 \frac{x}{2}} = \frac{2t}{1 + t^2}.$	<p>Despite its versatility, it requires significant algebraic transformations and can lead to the integration of overly complex rational fractions. Therefore, recommended to apply it after considering partial approaches to the integration of trigonometric expressions. For example:</p> $\int \frac{5+6 \sin x}{\sin x(4+3 \cos x)} dx = \int \frac{\left(5+\frac{6-2t}{1+t^2}\right) \frac{2dt}{1+t^2}}{\frac{2t}{1+t^2} \left(4+\frac{3(1-t^2)}{1+t^2}\right)} = \dots$
Partial substitutions			
2	$\int \cos m x \cdot \cos n x dx;$ $\int \sin m x \cdot \sin n x dx;$ $\int \sin m x \cdot \cos n x dx.$	$\cos m x \cdot \cos n x = \frac{1}{2}(\cos(m-n)x + \cos(m+n)x);$ $\sin m x \sin n x = \frac{1}{2}(\cos(m-n)x - \cos(m+n)x);$ $\sin m x \cos n x = \frac{1}{2}(\sin(m+n)x + \sin(m-n)x).$	When the integrand is the product of the functions $\sin n x$ and $\cos m x$, i.e., with multiple arguments. The transition from the product of trigonometric functions to their sum or difference, which will lead to the use of linear substitution.
3	$\int R(\sin x) \cos x dx;$ $\int R(\cos x) \sin x dx.$	$1. \int = \left[\begin{matrix} \cos x = t, \\ \sin x dx = -dt \end{matrix} \right] = -\int R(t) dt.$ $2. \int = \left[\begin{matrix} \sin x = t, \\ dt = \cos x dx \end{matrix} \right] = \int R(t) dt.$	When the integrand consists of a product of functions that contain only sines and the expression $\cos x dx$ or only cosines and the expression $\sin x dx$. In fact, this is a method of variable substitution in an indefinite integral.
4	$\int R(tgx) dx;$ $\int R(ctgx) dx.$	$1. \int = \left[\begin{matrix} tgx = t \\ x = \text{arctgt} \\ dx = \frac{dt}{1+t^2} \end{matrix} \right] = \int R(t) dt.$ $2. \int = \left[\begin{matrix} ctgx = t \\ x = \text{arcctgt} \\ dx = -\frac{dt}{1+t^2} \end{matrix} \right] = \int R(t) dt.$	When substituting, incorrect rational fractions are usually obtained, which require the whole part to be separated. When converting the original, it is necessary to take into account that, $\text{arctg}(tgx) = x$, $\text{arcctg}(ctgx) = x$.

Table 4. Continued

No.	Integral of the form	Substitution	Methodological recommendations
5	$\int \cos^m x \cdot \sin^n x dx$ where m and n – even numbers	$\cos^2 x = \frac{1}{2}(1 + \cos 2x),$ $\sin^2 x = \frac{1}{2}(1 - \cos 2x).$	To transition to tabular integrals, use the formula for lowering the degree. For example: $\cos^4 x = (\cos^2 x)^2 = \left(\frac{1}{2}(1 + \cos 2x)\right)^2 = \frac{1}{4}(1 + 2\cos 2x + \cos^2 2x) = \frac{1}{4}(1 + 2\cos 2x + \frac{1}{2}(1 + \cos 4x)).$
6	$\int \cos^m x \cdot \sin^n x dx$ where at least one of the values m or n is an odd number	Transition to integrals of the form $\int R(\sin x)\cos x dx$ and $\int R(\cos x)\sin x dx$	An odd power is represented as the product of an even power and the first power. For example: $\cos^3 x = \cos^2 x \cdot \cos x$. The basic trigonometric identity is applied to even powers $\sin^2 x + \cos^2 x = 1$. For example: $\cos^2 x = 1 - \sin^2 x$.

Source: compiled by the authors

The use of such visual material allows applicants to form clear algorithms of actions for each specific case of integration, which leads to a conscious approach to the use of integration methods, achieves better learning outcomes and lays the foundation for the assimilation of the following topics: definite integrals, improper integrals, multiple integrals, and

differential equations. To really get how well someone's trained in a certain field, it is important to break down the material into three areas: general, professional, and "propaedeutic." For the EEM speciality, the theoretical and practical material of a general nature is reflected in the diagram (Fig. 3), in which the sections are marked with solid lines.

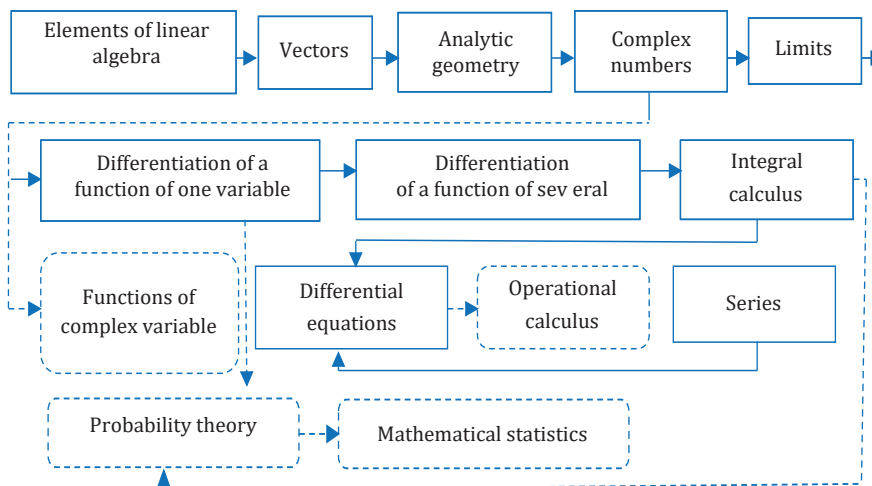


Figure 3. Algorithm for the sequence of studying higher mathematics material

Source: compiled by the authors

The sequence of basic topics shown in Figure 3 is logical, and each subsequent topic builds on knowledge from previous topics and covers the entire higher mathematics course. Solving professional problems is an integral part of practical knowledge. Some educational institutions offer applicants an elective course entitled "Mathematical Problems in Energy" (Vinnytsia National University, National University of Water and Environmental Engineering, Kyiv Polytechnic Institute, etc.), which allows to go beyond the scope of the "Higher Mathematics" course to deepen professional knowledge. Most teachers include practical problems as examples of the application of theoretical

knowledge in electrical engineering. For example, when studying derivatives, they consider the problem of current strength, and when studying second-order differential equations, they consider the mathematical model of electrical circuits.

The general material does not include sections that are referred to in the diagram (Fig. 1) as "propaedeutic" material and marked with dotted lines in Figure 3, namely "Functions of complex variables", "Operational calculus", "Probability theory", "Mathematical statistics", the study of which largely determines the formation of competencies provided for by the educational and professional programme in this speciality. The absence of

material from the “propaedeutic” sections should be an impetus for closer contacts between the teacher of the discipline and the head of the department, the guarantor of the educational and professional programme, and interested teachers of the specialised department. This will allow for certain adjustments to be made by monitoring the disciplines on which mathematical knowledge is based, including forecasting and statistical data processing. This knowledge will be a priority in the study of higher mathematics. All of the above materials have determined the structure of the methodology for filling and forms of conveying knowledge of higher mathematics to applicants. This made it possible to highlight the interdisciplinary connections of higher mathematics and, in particular, for the EEM speciality for the qualitative training of future specialists.

The formation of this and other views on the interpretation of the essence of education quality is based on the ESG Standards and Guidelines, presented in Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) (2015), which form the basis of Law of Ukraine No. 1556-VII (2014). Given that the main burden of responsibility for the quality training of higher education applicants lies with educational institutions, internal departments for quality assurance in education have been created. They are aimed at implementing a number of measures: checking educational programmes; providing the educational process with appropriate resources; evaluating the knowledge of applicants and the qualifications of scientific and pedagogical workers, etc. According to the author O. Liuta (2018), the result of ensuring the quality of education can be a number of requirements: level of qualification; competitiveness in the labour market; the presence of characteristics such as competence and responsibility; the ability to navigate not only in one's own field of activity, but also in related fields; readiness for professional growth and achievement of world standards; mobility, etc.

To identify trends in the quality of secondary education, which is the basis for higher education, one can use the international PISA studies on the quality of education (Ukrainian Centre for Educational Quality Assessment, 2024), which began in 1997. Ukraine joined these studies only in 2016, and the first monitoring of education quality took place in 2018. The next study is scheduled for 2025 with a three-year cycle. Not only fifteen-year-old schoolchildren are surveyed, but also the administration of educational institutions in order to determine the impact of the following factors: the level of professional training of teachers; teaching methods; curricula and work programmes, etc. (Ukrainian Centre for Educational Quality Assessment, 2024). According to the latest study in 2022, in which eighteen regions of the country participated, knowledge of mathematics, reading and natural sciences was tested with the participation of 3,876 students from 164 educational

institutions. PISA defines mathematical literacy as the ability to think and formulate mathematically, applying mathematical knowledge to solve real-world problems. According to the 2022 results, 42% of Ukrainian schoolchildren did not reach the basic level (441 points) of mathematical literacy. This indicates a lag of one and a half years behind the results obtained in the countries of the Organisation for Economic Co-operation and Development (OECD). It should be noted that the lag behind their peers in these countries is 1.6 years, while the previous result (2018) recorded this lag at only 0.7 years. In other words, there is a general trend towards a deterioration in mathematical knowledge. As for natural science disciplines, which include physics, the basic level achievement is 66%, and the lag behind peers is 1.8 years, compared to the previous value of 0.7 years. Based on the results of these studies, a general trend towards a decline in the conscious study of mathematics and physics was noted, which involves using the acquired knowledge and skills in possible life situations and challenges (Ukrainian Centre for Educational Quality Assessment, 2024). Based on the general trend of annual deterioration in schoolchildren's knowledge, it is necessary to test their residual knowledge of the school mathematics course before they start higher education. Without such a measure and an assessment of its results, it is difficult for teachers to orient themselves to the mathematical level of preparation of applicants and to choose specific corrective approaches in each particular case. Due to the lack of classroom time, various forms of correction are possible, namely, consultation, independent work under the supervision of a teacher, the formation of additional reference materials, etc.

It is important for the formation of Ukrainian educational experience to familiarise oneself with world experience, which was summarised by L. Mykhailenko (2020). The author summarised the experience of monitoring the methodological training of mathematics teachers as a key component in the formation of a system of quality knowledge. The author drew attention to the TEDS-M report of the International Association for the Evaluation of Educational Achievement, in which testing showed a direct relationship between the level of professional training of teachers, the content of educational programmes and the results obtained. The researcher cited the results of the German COACTIN study on the content of knowledge, which identified the main conditions for effective learning: maximum use of teaching time; the ability to encourage students to engage in cognitive activity; and quality support for students during learning. Noteworthy is the study by S. Huber *et al.* (2024), who, in addition to analysing the results of education quality monitoring by various international organisations, conducted a study on the motivation of teachers themselves in their professional activities. The authors concluded that most teachers

pay more attention to evaluating their personal results than to the learning outcomes of students.

Researchers O. Strakh & T. Lukashova (2021) and N. Honhalo (2022) proposed various approaches to improve the quality of professional training. For example, changing methodological approaches when teaching certain sections of higher mathematics, which is appropriate and depends on the complexity of the material and the students' preparation for perceiving specific material. According to M. Kovalchuk (2020), a broader approach involves creating a system of tasks for professional training and methodological guidelines at the level of educational institutions. The author concluded that systematic basic knowledge is important, without which it is difficult to acquire specialised knowledge. Based on research on the definition of the "level of development of mental action techniques", the scientist determined that only up to 25% of students have a high level of development. Therefore, M. Kovalchuk (2020) proposed moving on to algorithmic knowledge, which correlates with the material of this article, in which this approach is considered not a basic but an additional tool. The professional training goals formulated by the scientist are general in nature (intellectual development, the ability to meet the requirements of related disciplines from a mathematical point of view, etc.), but there is no specification of these goals in accordance with educational and professional programmes for each specific speciality.

According to I. Maksimov *et al.* (2021), it is proposed to use a system of professionally-oriented tasks in teaching mathematics, some of which were used by leading university scientists when writing their dissertations. This not only demonstrates the practical application of mathematical tools, but also motivates students to engage in scientific research and fulfils educational functions, enhancing the authority of the teacher. A. Kokarieva (2019) examined the procedural and activity-based component of engineer training in close connection with the requirements of social demand, taking into account both Ukrainian and international standards. To achieve this, in the author's opinion, universities should ensure at a minimum: software and hardware equipment; educational and methodological support; electronic resources; emotional and motivational components, etc. For this purpose, a classification of the professional training system was proposed, depending on regulatory provision, aims, and objectives, which includes components, structure, content, methods, and results of training. However, all these interpretations were exclusively general in nature and deserve to be considered when creating a system for quality training of students in specific specialities.

The research by O. Baryl'nyk-Kurakova & I. Korobova (2020) on the implementation of interdisciplinary connections is based on an analysis of regulatory documents that ensure a competence-based approach. The

researchers developed a classification of professional and educational competencies into external and internal. They considered the main goal of the interdisciplinary approach to be the creation of prerequisites for broadening the perspective on the subject of research, which leads to a more thorough analysis of the discipline's content, closer interaction with administrative and teaching structures, and the selection of the most appropriate forms and methods for organising the educational process. All the measures listed are only individual links in the creation of a systemic approach to learning, but they do not encompass the whole picture. Educator O. Zayika (2025) called inter-subject connections "integrated", meaning they are embedded in the system of knowledge, without which quality training of future specialists is impossible. In particular, an example of such an approach in teaching mathematical statistics is given by researchers such as V. Kovalchuk & T. Kovalchuk (2021) in the form of reference notes for the systematisation and evaluation of large and small samples. Researcher O. Sulima (2025) also linked the effectiveness of distance learning with the use of: online learning platforms (Moodle, Google Classroom, Zoom, MS Teams, etc.) to ensure communication between the lecturer and the student; adaptation of educational and methodological material to the online format; and the use of interactive tools (GeoGebra, MATLAB, Wolfram Mathematica, Maple, etc.). These statements emphasised the importance of mastering internet technologies and adapting the educational process to distance learning formats.

The lack of unified educational and work programmes is a hindrance to the development of interdisciplinary connections. In the United States of America, this problem was resolved through the Washington Accord (The Institution of Engineers of Kenya, 2021), signed in 1989, which focuses on academic programmes related to professional-level engineering practice and the accreditation of engineering academic programmes. The Accord became a key foundation for professional-level engineering practice. Professors and lecturers at the Kenyan University of Technology noted that the Accord provides a list of knowledge, the main of which is engineering knowledge, which includes knowledge of mathematics for solving engineering problems. Identifying, formulating, researching, and analysing engineering problems to achieve substantiated conclusions using the principles of mathematics, natural sciences, and engineering sciences is the main goal of training.

Researcher D. Kanundu (2021) drew attention to the crucial importance of engineering and technological education, for which the country's universities must be at the centre of the latest innovative research. The author identified a correlation between the availability of engineering personnel and the country's development, whereby for every 1 engineer there are: 6,300 people in

Kenya; 3,166 people in South Africa; 543 people in Malaysia; 389 people in the USA; 311 people in Great Britain; 285 people in South Korea; 227 people in Brazil; 157 people in India; 130 people in China. Given the rapid development of China and India, and the innovative achievements of South Korea, which are the most technologically advanced in the Asian region, this statistic once again underlines the importance of training qualified personnel for the vital activity and development of any country. Studying the experience of teaching organisation indicates that all the highlighted problems are inherent at both school and higher education levels. The presented studies on creating a holistic system of quality knowledge for a future specialist at each stage of its formation are important tasks for the functioning of educational institutions.

■ Conclusions

According to the results of the research, the set goal was achieved. Unlike the existing approaches of a number of Ukrainian scientists to individual components of the educational process and analysis of world experience, the authors have created a comprehensive system of qualitative knowledge that improves the methodology for training specialists in technical specialities. The main elements of the system, which outlined a number of components of the organisational and methodological mechanism, have been substantiated. Methodological principles for testing residual knowledge have been developed, which include two main stages of research. The first stage involves the development of the form and content of school mathematics course assignments. At the second stage, an algorithm for assessing residual knowledge was developed and criteria for its assessment were defined. Instead of an average score, an interval assessment was proposed, which took into account the discrepancy in assessment, which made it possible to determine

the result for the maximum number of applicants. The methodology was tested on the example of training students of electrical engineering, which made it possible to identify the part of the school material that was subject to correction during higher education.

The established correspondence between the volume of material and the hourly workload enabled the basic material for classroom teaching to be established. To improve the quality of knowledge in distance learning, visual reference notes have been developed, the main purpose of which is both cognitive and explanatory. In order to acquire professional competencies, in addition to the basic material and professional material in higher mathematics provided for in the work programme, it is proposed to extend it to “propaedeutic” material in the form of extracurricular forms of training. A list of sections of “propaedeutic” material for electrical engineering specialities is presented. The system of forming qualitative knowledge is not limited to its use only for technical specialities, but can be extended to others, which is the subject of further research. Based on the analysis of problems in teaching higher mathematics and the solutions proposed by scientists, conclusions have been made regarding the need to take into account both regional factors and the specifics of professional training of engineering specialists. All this helps to prepare engineering personnel who will be competitive both in the Ukrainian labour market and in the markets of other countries.

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Методичні засади забезпечення якісної підготовки фахівців технічних спеціальностей у закладах вищої освіти

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■ **Анотація.** Набуття компетентностей здобувачами вищої освіти стикається з проблемами погіршення шкільних базових знань, а також неструктурованості і фрагментарності викладання вищої математики, які утруднюють засвоєння фахових дисциплін. Метою дослідження було вдосконалення методичного інструментарію для формування цілісної системи якісних знань та їх усвідомленого засвоєння. Було розроблено основні напрямки створення методичних та організаційних умов забезпечення наступності навчання та побудови міждисциплінарних зв'язків. Методологічно дослідження спиралося на використання методів аналізу та узагальнення при створенні наочного базового матеріалу. Статистичні методи застосовувалися при систематизації і обробці результатів перевірки залишкових знань студентів та оцінці результатів тестування як вибірок малого обсягу. Тестування знань шкільного курсу з математики та фізики студентів електротехнічних спеціальностей висвітлює недоліки їх підготовки, які необхідно враховувати при викладанні розділів вищої математики. Проаналізовано відповідність обсягів матеріалу дисципліни та часу на їх засвоєння, що дало змогу виділити із всього курсу вищої математики базові знання для забезпечення диференційованого підходу до набуття фахових знань. Розглянуто специфіку дистанційної форми навчання, що привело до створення наочних опорних конспектів з підвищеними роз'яснювальними функціями. Відповідно до фахових компетентностей запропонована класифікація матеріалу, що забезпечило міждисциплінарні зв'язки та розширило пропедевтичні можливості. Створений методичний підхід дозволив систематизувати навчальний матеріал з вищої математики, який може використовуватися професорсько-викладацьким складом, здобувачами та іншими учасниками навчального процесу, а також при розробці навчальних планів і складанні робочих навчальних програм

■ **Ключові слова:** якість навчання; методика; система знань; вища математика; електротехнічна спеціальність; пропедевтика