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Hennadii L. Korostylov, PhD in Humanities, Lecturer, Ivan Kozhedub Kharkiv National Air Force University. Kharkiv, Ukraine.
ORCID: 0000-0001-5736-0507
Liudmyla O. Petrova, Candidate of Philosophical Sciences (Ph.D.), Associate Professor, Ivan Kozhedub Kharkiv National Air Force University. Kharkiv, Ukraine.
ORCID: 0000-0002-9341-1030
Oleksii S. Bilozorov, Research Assistant, Ivan Kozhedub Kharkiv National AirForce University. Kharkiv, Ukraine.
ORCID: 0000-0003-4244-9108
Oleksandr V. Tsemma, Senior Lecturer, Ivan Kozhedub Kharkiv National AirForce University. Kharkiv, Ukraine.
ORCID: 0000-0002-6287-8404

Electrical engineering as a modern fundamental discipline and the logic of its teaching in military higher education institutions

Abstract: Understanding the processes that relate to the formation and transformation of the modern army and as a consequence of the modernization of the education system of the Military University, the article pays special attention to the formation of a modern officer as a specialist not only in military affairs, but also in military engineering. Military leaders must have electrical knowledge and the ability to choose and use appropriate modern military management technologies and information and technical means, the element base of which is electrical engineering, and the scientific and technical basis of Electrical Engineering is the synthesis of such fundamental sciences as mathematics, physics and chemistry. The aim of the study is scientific and methodological conclusions on updating the teaching methodology and mathematical tools of electrical education. In the Ukrainian literature, a discourse on this issue has already been formed. Examples include the monograph "Methodological System for Forming Integrated Knowledge in Physics in the Process of Training Technology Teachers", the article "Integration of Physics and Electrical Engineering in the System of Training Technology Teachers" and others. A. Didyk, L. Pavlyuk, and I. Petritsina describe intersubject relations and the role of physics as the basis of technical disciplines in more detail. These works deal with the scientific and methodological problems of electrotechnical education in modern universities. The authors point to the growing demand for professional training of Higher Education graduates, which entails the need to move from traditional teaching styles to innovative ones. The article emphasizes that in modern society, engineering education is of great significance, and as for military affairs, it has become its necessary component. Military personnel who have received a high-quality modern electrical engineering education usually have developed technical skills, understand the technological features of modern weapons, and have a common scientific base for innovations.

Keywords: military university, education, modernization of education, information technologies, simulation models, computer modeling languages.

Геннадій Леонідович Коростильов, доктор філософії (PhD), викладач, Харківський національний університет Повітряних сил ім. Івана Кожедуба. Харків, Україна.
ORCID: 0000-0001-5736-0507
Людмила Олександрівна Петрова, кандидат філософських наук, доцент, Харківський національний університет Повітряних сил ім. Івана Кожедуба. Харків, Україна.
ORCID: 0000-0002-9341-1030
Олексій Сергійович Білозьоров, молодший науковий співробітник, Харківський національний університет Повітряних сил ім. Івана Кожедуба. Харків, Україна.
ORCID: 0000-0003-4244-9108
Олександр Володимирович Цемма, старший викладач, Харківський національний університет Повітряних сил ім. Івана Кожедуба. Харків, Україна.
ORCID: 0000-0002-6287-8404

Електротехніка як сучасна фундаментальна дисципліна та логіка її викладання у військових вищах

Анотація: Розуміючи процеси, які відносяться до становлення та трансформації сучасного війська і як слідство модернізації системи освіти військового університету, в статті особливу увагу звернуто на формування сучасного офіцера як фахівця не тільки у військовій справі, але і у військово-інженерній. Військові лідери повинні володіти електротехнічним знанням і вмінням вибирати та використовувати відповідні сучасні військові управлінські технології та інформаційно-технічні засоби, елементною базою яких є електротехніка, а науково-технічним базисом електротехніки є синтез таких фундаментальних наук як математика, фізика і хімія. Метою дослідження є науково-методичні висновки щодо оновлення методлогії викладання і математичного інструментарію електротехнічної освіти. У вітчизняній літературі вже оформився дискурс, присвячених даній проблематиці. Прикладами можуть стати монографія «Методична система формування інтегрованих знань з фізики в процесі підготовки вчителів технологій», стаття «Інтеграція фізики та електротехніки в системі підготовки вчителів технологій» та інші. Більш детально описують міжпредметні зв'язки та роль фізики як основи технічних дисциплін А. Дідик, Л. Павлюк, І. Петрицина. В цих роботах розглядаються науково-методологічні проблеми електротехнічної освіти в сучасних університетах. Автори вказують на зростаючий попит на професійну підготовку випускників вищих навчальних закладів, що тягне за собою питання необхідності переходу від традиційних стилів викладання до інноваційних. В статті підкреслено, що у сучасному суспільстві інженерна освіта має величезне значення, а щодо військової справи, то вона стала її необхідною складовою. Військові, які отримали якісну сучасну електротехнічну інженерну освіту, зазвичай мають розвинуті навички технічного характеру, розуміються на технологічних особливостях сучасної зброї, мають загальну наукову базу для новацій.

Ключові слова: військовий університет, освіта, модернізація освіти, інформаційні технології, імітаційні моделі, мови комп'ютерного моделювання.

Abbreviations:

CMS is a computer mathematics system

Introduction

Understanding the processes that relate to the formation and transformation of the modern army and as a consequence of the modernisation of the education system of the Military University, the article pays special attention to the formation of a modern officer as a specialist not only in military affairs but also in military engineering. Military leaders must have electrical knowledge and the ability to choose and use appropriate modern military management technologies and information and technical means, the element base of which is electrical engineering, and the scientific and technical basis of Electrical Engineering is the synthesis of such fundamental sciences as mathematics, physics and chemistry.

The issue of professional training of future officer-engineers in the electrical engineering direction is one of the key issues in modern pedagogical theory and practice, which has a long pedagogical tradition. "Researchers have developed a fairly large fund of scientific knowledge that reveals various areas of University Electrical Engineering Education" (*Finin, 2020*). This is due, on the one hand, to the growing demand for modern electrical officers due to the complication of information and computer technologies of modern military equipment and, on the other, the rapid development of information technologies for comprehensive training. "The professionalism of a modern electrical engineering officer is not only his competence in various fields of information technology, computer languages of mathematical modelling but also his high qualification, which is the key to the successful performance of combat missions" (*Finin, 2020*).

We emphasise that "today, in covering the transformations of educational reality, it is necessary to rely not only on the methodology of pedagogy but also to consider the conceptual provisions of the philosophy of education and the philosophy of the development of modern society. Because it is they who strengthen the theoretical base of scientific studios" (*Korostylev & Dolskaya, 2022, p. 12*). The authors rely on the works of M. Castels (*2013*), V. M. Kremen (*2021*) and others, who draw attention to the need for "constant modification of educational practice in the context of the development of the information society" (*Kremen, 2021, pp. 11-20*). When developing the theoretical and methodological foundations of education to use new technologies that consider the virtual space, it is necessary to rely on the works of researchers who directly and indirectly worked on this problem: E. Giddens, E. Durkheim, P. Bourdieu, K. Meinheim, E. Masuda, R. Merton, T. Parsons, E. Toffler, etc.

You should also pay attention to the comments of the classics on the methodology of teaching mathematics. As M. Kline notes, there are several possible approaches to teaching it. Among them is "plural theoretic, axiomatic, also based on logic, intuition" (*Kline, 1980*; *Kline, 1984*). The choice of one of the teaching logic is largely determined by historical and cultural factors and the personal orientation of the teacher. Features of the mathematical method allow it to focus on specific concepts, which already makes it possible to discuss a new impetus in

teaching mathematics. George Polya also emphasised the importance of methodology as "a way of studying mathematics, suggesting that students not only focus on solving problems but also think about the methods and means that they apply" (*Polya, 1991, p. 448*).

The analysis of publications of Ukrainian scientists in the field of electrical Education shows that the practical and theoretical nature of reflection on the problems posed are interrelated. Therefore, "the general direction of all works, namely, theoretical and methodological," is natural (*Korostylev & Dolskaya, 2022, p. 12*). It is significant to emphasise the role of the works of specialists in the electrical industry in the context of the historical development of electrical engineering, which focuses on changes in the methodology of its teaching V. Savchenko, Yu. Lavrenenko (*2016*), N. Shvager (*2014, pp. 15-18*). This issue is becoming increasingly relevant, as modern information technologies directly and indirectly affect the organisation and methodology of teaching. "For the modern military education system to meet existing needs, certain transformations of the training system using modern information technologies are necessary. The main ideas are based on creating and maintaining information and educational environments of open, distance learning, developing new technologies for creating bases of educational materials and developing traditional technologies for developing electronic textbooks and educational portals. We can say that a new promising subject area is beginning to form – "Information Technologies in Education". This area includes the problems of intelligent learning systems, open education, distance learning, and information educational environments. Teaching methods and tools used in information technologies in education contribute to the fulfilment of increased requirements for the level of training of graduates of the higher military school" (*Korostylev & Dolskaya, 2022, p. 13*).

In Ukrainian literature, a discourse on this issue has already been formed. Examples include the monograph "Methodological System for the Formation of Integrated Knowledge in Physics in the Process of Training Technology Teachers" (*Shishkin, 2012*), the article "Integration of Physics and Electrical Engineering in the System of Training Technology Teachers" (*Shishkin, 2014*) A. Didyk (*2018*), L. Pavlyuk (*2020*), and I. Petritsina (*2013*) describe intersubject relations and the role of physics as the basis of technical disciplines in more detail. These works deal with electrotechnical education's scientific and methodological problems in modern universities. The authors point to the growing demand for professional training of higher education graduates, which entails the need to move from traditional teaching styles to innovative ones.

Study materials

In general, electrical engineering is not only a science but also a branch of technology that converts various types of energy into electrical energy, which is then used to change the composition of a substance, produce and process materials, transmit information, and so on. Modern, efficient technologies are somehow based on the use of electric energy. By combining the course of Electrical Engineering with other subjects of training, the topics of modern electrical engineering can take their proper place in the professional training of future military managers and provide the necessary basis for the successful training of cadets in military universities.

Electrical engineering is one of the first modern technologies. Like nothing else, electricity has primarily influenced the development of modern man-made civilisation and changed human

life. When we talk about electricity in general, we should understand that electricity is everything that surrounds us. Changes in the scientific, technical, technological and information-technological nature of warfare, which lead to qualitative technical and technological changes in production technologies and technical characteristics of modern types of weapons: drones, UAVs, high-precision artillery systems, GPS navigation, target detection location systems, Starling space communication systems, etc. It is worth noting that all these military technologies appeared due to the development of applied science, such as electrical engineering, and its transformation into a modern element base. These qualitative changes in the composition and technological structure of equipment put forward new modern requirements for training military electrical engineers as the leading specialists in the operation and repair of this equipment.

The subject of electrical engineering in the modern educational teaching structure plays a significant role in forming a particular physical reality, which combines knowledge of physics, mathematics, and chemistry. Thanks to this combination, didactics and methodology of teaching electrical engineering are aimed at intersubject relations: "Electrical knowledge is widely used in many technological processes of modern military equipment and technical means of controlling troops. Given that physics and mathematics are the fundamental basis of electrical engineering, the relationship between teaching these disciplines is particularly important in military universities. Implementing intersubject relationships in teaching physics, mathematics, and electrical engineering creates favourable conditions for creative application of the general principles of didactics in teaching" (*Korostylev, 2020*).

Since the study of electrical engineering affects the perception and understanding of the modern technological world, we will specify some key aspects that confirm the fundamental nature of this subject:

- studying electrical engineering helps cadets understand the role of technology in the modern world;
- studying electrical technologies helps cadets develop critical thinking about technical solutions, the effectiveness of techno-technological systems, possible actions with them and their consequences.

Based on electrical engineering and its main task – creating a particular reality that occupies an intermediate position between nature and man – the modern educational structure has a problem of narrow methodological foundations and practical tools. Using the example of electrical education in modern military universities, the authors tried to show the nature of changes in the educational space analyse and systematise them.

Justification of changes in the methodology of teaching electrical engineering

Since one of the central tasks of military education is primarily to acquire technical and engineering education, it is necessary to outline the components of technical science. "Technical science is formed based on complex processes associated with the formation of engineering activities and is the result of a combination of natural science and technological knowledge. The first component of developing and forming technical sciences is the stage of obtaining natural science knowledge, which leads to the ontologization of technology" (*Korostylev & Dolskaya, 2022, p. 12*). For D. Willis, we have the process of creating mechanisms that he built himself, from simple to complex. According to the principle of "from simple to complex", objects and knowledge of classical technical sciences are formed (*Korostylev & Dolskaya, 2022, p. 13*). In

addition, research engineers sought to explore the entire field of engineering capabilities, i.e., they tried to understand what other characteristics and calculations of an engineering object could be obtained. During the analysis, "the research engineer sought to gain knowledge about objects, describing their construction, functioning, individual processes, dependent and independent parameters, relationships between them, etc." (*Korostylev & Dolskaya, 2022, p. 13*).

An equally important stage in the development of the technical sciences is their mathematical process. "From a certain stage in developing technical science, researchers move from using individual mathematical knowledge or fragments of mathematical theories to using entire mathematical apparatuses (languages) in technical science. This was prompted by the need to carry out in the course of design not only analysis but also the synthesis of individual processes and their structural elements" (*Korostylev & Dolskaya, 2022, p. 13*).

Using a mathematical apparatus affects the process of designing any technical object model. As a rule, ideal objects of technical science (such as drawings, structured diagrams, mathematical models, etc.) "start" a long process of development and construction to get the status of engineering objects in the future. In other words, the process of ontologising technical objects is unfolding. "From this point on, the engineer gets the opportunity to (a) successfully solve the problems of synthesis and analysis; (b) investigate the entire area of engineering objects for theoretically possible cases; (c) go to the theory of ideal engineering devices. Each mechanism begins to be considered as a mathematical circuit consisting of one or more closed circuits and several closed circuits that connect the contour link to the main links of the mechanism. In the theory of mechanisms, it becomes possible to obtain new design schemes of mechanisms by deductive method" (*Korostylev & Dolskaya, 2022, p. 13*).

Teaching electrical engineering in modern military universities could not help but feel specific changes. "From the mid-20 to the beginning of the 21st century, electrical engineering teachers focused on engineering and applied mathematical support for electrical processes. For the modern military education system to meet existing needs, certain changes in the training system using modern information technologies are necessary" (*Finin, 2020*; *Nikitenko et al., 2023*). Today, many concepts related to virtual reality are used, and computer mathematics is becoming a necessary component in teaching electrical engineering. The best authors in the world present computer programming languages: "The new military education continues to change along with the change in the overall engineering picture of the world. The main emphasis is placed on using virtual products, on creating so-called simulation models of existing military weapons" (*Korostylev, 2022*).

Computer mathematics plays a unique role in this process. The best authors in the world represent computer programming languages: S. McConnell (*2006*), E. Thomas and D. Hunt (*1999*), M. Fowler (*2018*), R. Martin (*2019*), D. Knut (*2020*). Computer mathematics should be defined as a set of theoretical, algorithmic, hardware and software tools designed to effectively solve all mathematical problems on computers with a high degree of visualisation of calculation stages (*Tyutyunnik & Mikhalevich, 2013*). The latter plays a crucial role in CMS implementation in education. Modern CMSs are influential electronic reference books and databases on all sections of modern mathematics, practical tools for solving most mathematical problems, and tools for creating high-quality electronic lessons, articles and books. When we talk about computer mathematics, we mean computer programming languages.

How can you not remember the most famous names of those who devoted their thoughts to the inventions of virtual reality and opened the way for innovative changes in the technical world? "Given the questions raised, we will need work that deals with reviews of technical means of virtual reality systems. These are the works of Linus Torvalds (developed the Linux operating system), Tim Bernes (developed the program for Hypertext documents and hyperlinks), James Gosling (author of the Java programming language), Anders Heilsberg (developed the software Borland Delphi, C#, TypeScript, Turbo Pascal), Mark Zuckerberg (founder of Facebook), Bram Cohen (author of the Bit Torrent protocol), Brendan Ike (founder of the JavaScript programming language, was the chief engineer of Mozila Firefox), Bjarne Stroustrup (founder of the C++ programming language)" (*Korostylev & Dolskaya, 2022, p. 12*).

What programmes are used to create new divisions in educational processes? The primary virtual environments include PhET, Multisim, Electronics Workbench, LabVIEW, etc. Particular attention should be paid to PhET, a free site for creating interactive simulations in natural sciences and mathematics; the Electronics Workbench program is compatible with the P– SPICE programme, i.e., provides the ability to export and import measurement diagrams and results to various versions of it; Grapher and Postprocessor are Multisim programs that allow you to display simulation results in graphical form, etc. all programmes allow you to work in virtual laboratories, and this is the realisation of the ability to conduct experiments without direct contact with the actual installation or in its absence (*Korostylev & Dolskaya, 2022, p. 13*).

Modern teachers and scientists emphasise the need to use interactive technologies in teaching (we find this in the works of A. Didyk (*2018*), G. Shishkin (*2012*), I. Petritsin (*2013*). "According to military analysts, the need to use virtual models for educational purposes and scientific activities is an urgent need" (*Korostylev & Dolskaya, 2022, p. 13*).

Based on their experience of teaching electrical engineering subjects, it is necessary to emphasise the following: for improving the theoretical knowledge of cadets, practical training is of great importance – conducting laboratory classes. The methodological basis for conducting laboratory classes is the development of methodological manuals for conducting laboratory classes and the development of visualised programmes for computer interactive training. With the help of a user-friendly interface, cadets have the opportunity to compose, simulate, and study electrical circuits in their free time.

Programmes of schematic modelling of analogue, digital and analogue-digital circuits allow the laboratory workshop to draw up an equivalent circuit of the device using library components, to simulate almost any electrical or electronic circuit, to change the nominal values of its elements with a healthy check, to show on the monitor actual waveforms of signals at any point of the circuit. It becomes possible to demonstrate simulated circuit errors and their impact on specific electrical circuit parameters.

There are also disadvantages to working in the virtual world, e.g., one of them is the inability to conduct objective research on electrical circuits and radio components, affecting the ability of cadets to comply with safety regulations when working with live electrical equipment. At the same time, an ordinary computer, in combination with auxiliary devices, can be used as a powerful research laboratory. Using computer programs such as oscilloscope, pulse generator, millivoltmeter, spectrum analyser, and microphone input of a sound card, you can perform much real laboratory work without spending significant material resources.

Thus, in modern education, particularly in the teaching of electrical engineering, we observe the use of computer mathematics, which determines changes in the teaching of natural sciences. "Today, these changes are tied to the active use of virtual reality with the language of computer mathematics" (*Korostylev & Dolskaya, 2022, p. 16*).

Conclusion

The article emphasises that engineering education is of great significance in modern society and has become a necessary component of military affairs. Military personnel who have received a high-quality modern electrical engineering education usually have developed technical skills, understand the technological features of modern weapons, have a joint scientific base for innovations, and so on. It is impossible not to emphasise that modern, innovative electrical engineering education contributes to a systematic vision of problematic issues of a purely military nature.

The education of the future officer is complicated due to the integrated nature of teaching natural, technical, and technological sciences. These sciences' methodologies are related to innovative processes and require the use of increasingly complex computer mathematics tools.

It is worth emphasising that today it is increasingly necessary to turn to computer mathematics because the functioning of technical objects is directly and indirectly related to the appeal to the possibilities of virtual reality. Computer programming languages have become an active tool in the organisation of theoretical and practical tasks of electrical engineering, so introducing computer mathematics into educational programmes is becoming an objective necessity.

Using software products PhET, Electronics Workbench, Multisim, and many other alternative simulators of electrical and electronic circuits with similar functionality allows future military specialists to significantly expand their capabilities and improve their understanding of educational topics while performing laboratory workshops and control tasks. Also, it encourages a deeper study of the virtual object to create, calculate and test electrical circuits at all stages of their operation.

Conflict of interest

The authors declare that there is no conflict of interest.

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