7UDC: 378.862:621.01
ISSN: 2707-3092 (Online)
DOI: https://doi.org/10.32835/2707-3092.2024.28.185-196

Professional Pedagogics/1(28)'2024, pp. 185-196

DEFINITIONS AND CONDITIONS FOR THE FORMATION OF GRAPHICAL COMPETENCE OF FUTURE SPECIALISTS IN ELECTRONICS AND TELECOMMUNICATIONS THROUGH DIGITAL TECHNOLOGIES

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Abstract

Relevance: Radio electronics is a high-tech priority sector of the global economy with a stable and constantly growing demand, significant export potential, low material consumption, and high unit value of products, which stimulates the development of information and communication technologies and such industries as mechanical engineering, instrumentation, medicine, etc.; the efficiency of the professional activity of a specialist in the field of electronics and telecommunications depends on the combination of research, graphical, and inventive activities during their professional training.

Purpose: To research and define key concepts (definitions) that characterize graphical competence and to determine the conditions necessary for its effective formation during the professional training of future specialists in the field of electronics and telecommunications using digital technologies.

Methods: Theoretical (analysis of higher education standards, scientific and methodological publications reflecting the research problems, critical analysis of existing theoretical and methodological ways of solving the initiated problem in Ukraine and abroad concerning the formation of graphical competence of future specialists in the field of electronics and telecommunications by means of digital technologies); empirical (questionnaire; observation of the educational process; surveys of employers and experts).

Results: The theoretical positions regarding the formation of graphical competence of future specialists in electronics and telecommunications by means of digital technologies have been analyzed and substantiated; based on the conducted analysis of the theory and practice of forming graphical competence of future specialists during their professional training, a number of definitions characterizing the result of the process of forming graphical competence have been established and the conditions for its formation have been determined; the peculiarities of the professional activity of a specialist in the field of electronics and telecommunications have been determined; the main professional skills of graduates have been identified.

Conclusions: The peculiarity of professional training of a specialist in the field of electronics and telecommunications lies in the combination of research, graphical, and inventive activities; the result of their professional training should be the acquisition of skills and abilities relevant to the digital labor market (readiness for lifelong learning; the ability to improve existing and design new products, perform their sketches and models, model them using three-dimensional and two-dimensional graphics; the ability to work taking into account modern ergonomic requirements with subsequent graphical design of the product; creativity); in order to effectively form the graphical competence of future specialists in the field of electronics and telecommunications, three main conditions must be implemented (ensuring the interconnection of professional and graphical activities, which is a prerequisite for the effective performance of

professional tasks; forming readiness for change and the ability to adjust activities according to the changing demands of society; ensuring the formation of the overall professional culture of the specialist as a whole).

Keywords: *professional training, graphical competence, specialists in the field of electronics and telecommunications, higher education institutions.*

Introduction. Radio electronics is a knowledge-intensive priority sector of the global economy with a stable and continuously growing demand, significant export potential, low material intensity, and high specific value of products. This stimulates the development not only of information and communication technologies but also of such industries as instrumentation, mechanical engineering, military equipment, medicine, communication, and others. Accordingly, the design, production, and application of radio electronic products are highly specialized and integrated across various technical directions, which should be reflected in the specificities of professional training of future specialists in the field of electronics and telecommunications. Domestic scientists V. Herasymchuk, V. Nesterenko, and T. Sakalosh (2009) point out the following possible ways of developing the radio electronic industry in Ukraine: attracting foreign investors to supply raw materials to domestic manufacturers of microelectronics and solar energy components, using modern technological equipment, and involving highly efficient human resources; significantly reducing the time (to a few months) for the development of new types of products, ensuring motivation for professional growth of employees, among others. It is considered necessary to supplement these conditions for the development of the radio electronic industry with a significant improvement in the professional training of future specialists in electronics and telecommunications in higher education institutions through the use of modern innovative teaching technologies.

Sources. Given the relevance of the outlined research direction, the issue of professional training of future specialists, including in the field of electronics and telecommunications, has been the subject of study by numerous domestic and foreign scientists. New strategies of thinking in the process of forming the graphic competence of specialists were considered in the works of H. Havryshchak, A. Uruskyi (2021), I. Hevko, O. Pysarchuk (2018), V. Herasymchuk, V. Nesterenko, T. Sakalosh (2009), R. Hurevych, V. Harkushevskyi, S. Tsvilik (2014), O. Dzhedzhula (2007), O. Zharova (2014), Yu. Kozak (2016), M. Koziar, O. Parfenyuk, Z. Sasiuk (2021), P. Koliasa (2022), K. Lebedieva (2020), L. Martseva (2015), I. Nishchak (2017), N. Osadchuk (2019), O. Revyakina, O. Serdyukova (2014), S. Tsvilik, T. Asaulkova, S. Kordynal (2018), L. Tsvirkun (2017), H. Chemeris (2020), M. Yusupova (2010) and others. Abroad, the peculiarities of professional training of specialists in this field were studied by G. Amatori, H. Mesquita, R. Quelhas (2020), V. Bajrami (2019), H. Bakhshi, J. Downing, M. Osborne, P. Schneider (2017), U.-D. Ehlers, S. Kellermann (2019), A. Hussin (2018), D. Mitchell (2015), J. Mitchell, A. Nyamapfene, K. Roach, E. Tilley (2019), R. Morgan, S. Ion (2014), B. Norwich, A. Lewis (2005), J. Perkins (2013), F. Szabó (2017), and others.

Thus, the process of preparing competent specialists and creating conditions for their professional growth throughout their lives is an important condition for the development of the radio engineering industry. Currently, such training is carried out in three specialties: 171 Electronics, 172 Telecommunications and Radio Engineering, and 173 Avionics, each of which has certain differences from the others and its specific features.

The peculiarities of the professional training of junior specialists in the radio engineering profile are highlighted in the dissertation by L. Martseva (2015). The specificity of the cultural training of specialists in radio engineering specialties based on the acmeological approach was studied by N. Osadchuk (2019). The features and conditions of forming the information competence of future radio engineers in the process of professional training were clarified by O. Zharova (2019). In the dissertation by K. Lebedieva (2020), the ways of forming the professional competence of future specialists in the field of electronics and telecommunications based on the resource approach are determined.

Foreign researchers R. Morgan and S. Ion (2014), J. Perkins (2013) emphasized that the interest from manufacturing enterprises, professional associations, and students, whose needs are dynamic and change according to external conditions, has led to the necessity of reforming training programs for electronics specialists and the teaching style of professional disciplines in technical higher education institutions.

In the publication by researchers J. Mitchell, A. Nyamapfene, K. Roach, and E. Tilley (2019), an interesting experience in improving the educational process in this area of professional training of specialists is presented. Scientists planned and implemented a pedagogical experiment, the results of which substantiated the concept of educational reform and identified promising ways to ensure the quality of education. The research results demonstrated that forming the professional competence of specialists in the field of electronics and telecommunications is impossible without applying problem-based learning methods, developing soft skills, ensuring interdisciplinarity, and fostering motivation to acquire knowledge, master skills, and competencies, and forming general cultural and professional competence.

Researchers emphasized that the labor market is changing in response to new technologies. Therefore, future specialists must not only acquire professional knowledge and skills but also develop the ability to learn throughout their lives. It is no wonder that recently, the new term "Education 4.0" has been used to define the process of preparing specialists to work in the conditions of the fourth industrial revolution. Researcher A. Hussin (2018, pp. 92–98) believes that Education 4.0 involves implementing various methods and approaches introduced in higher education institutions to align educational programs for the most effective preparation of future graduates for work.

Significant attention by foreign researchers is devoted to creating educational programs for the inclusive professional training of students with special educational needs. The results of these researchers' studies are described in publications (Amatori, Mesquita, & Quelhas, 2020; Bajrami, 2019; Mitchell, 2015; Norwich, & Lewis, 2005).

Researchers have proven that the system of higher professional education needs significant improvement in the methods of forming and delivering educational content, which should correspond to the level of technological development in the field of electronics and telecommunications. Innovative methods, in particular, can include solving real industrial and research problems by future specialists. With this approach to teaching new material, students solve interesting practical and scientific tasks, and the teacher can integrate the results of their scientific research into the educational process.

The aim of the article is to study and define key concepts (definitions) that characterize graphic competence, as well as to determine the conditions necessary for its effective formation in the process of professional training of future specialists in the field of electronics and telecommunications using digital technologies.

Research methods: theoretical (analysis of higher education standards, scientific and methodological publications reflecting research problems, critical analysis of existing theoretical and methodological ways of solving the initiated problem in Ukraine and abroad regarding the formation of graphic competence of future specialists in the field of electronics and telecommunications using digital technologies); empirical (questionnaires; observation of the educational process; surveys of employers and experts).

Results and Discussion. The conducted analysis of the efforts concerning the formation of graphic competence of future specialists in the field of electronics and telecommunications by means of digital technologies, in particular, the publications by S. Tsvelyk, T. Asaulova, S. Kordinal, R. Hurevych, M. Koziar, and others (Цвілик, Асаулова, & Кординал, 2018; Гуревич, Гаркушевський, & Цвілик, 2014; Козяр, Парфенюк, & Сасюк, 2021), allows identifying contradictions inherent in the process of forming graphic competencies, in particular:

- between the high degree of abstraction of the basic concepts, their high degree of logical interconnections, the high level of hierarchical system of these concepts used in a specific field of knowledge, and the weak level of propaedeutic graphic training of students entering technical universities;

- the insufficient overall level of development of theoretical thinking to master graphic concepts and methods at an appropriate level;

- between algorithmic methods of data processing in information systems of computer graphics and non-algorithmic ways of thinking of students, leading to certain problems at the initial stages of learning computer graphics;

- between traditional methods of teaching graphic disciplines in universities and the need to improve this process in the context of forming graphic competence for the successful implementation of professional activities.

This leads to the emergence of certain psychological and cognitive barriers in the education of future specialists in the field of electronics and telecommunications and negatively affects the outcome of professional training – the formation of integral competence.

It is necessary to note that currently the successful formation of graphic competence of future specialists in the field of electronics and telecommunications by means of digital technologies in higher education institutions requires students to have a high level of skills and abilities to perform scientific-intensive work related to the use of graphic editors and design modules for intelligent computer-aided design systems in the educational process. Therefore, in modern technical universities, the graphic competence of future specialists is formed in the process of professional training using modern digital technologies.

The determination of the structure and content of the graphic competence of future specialists in the field of electronics and telecommunications necessitates the construction of a strategy for its formation by means of digital technologies, and hence the need to consider the theoretical foundations of the outlined issue.

The analysis of scientific publications on the outlined issue demonstrated that a significant part of the research on the conditions for the formation of graphic competence was devoted to considering the problem of forming the graphic competence of future art specialists or future programming specialists. This is explained by the fact that their professional activity mainly involves working with graphic information. However, there are several scientific studies focusing on the problem of forming the graphic competence of future technical specialists. Such publications emphasize the statement that there is a problem of the postmodern society's dependence on the qualitative visual presentation of a certain product or information. Consequently, graphic competence is an important component of the professional training of future specialists in technical universities.

Considering this, a significant number of enterprises in the field of electronics and telecommunications use computer modeling in the process of designing and developing products. Accordingly, the demand for specialists capable of performing such tasks using computer graphics methods has increased.

Based on the conducted theoretical analysis of the theory and practice of forming graphic competence of future specialists in the process of professional training, several definitions characterizing the outcome of the process of forming graphic competence were established, including such concepts as graphic activity and graphic training.

Graphic activity involves the future specialist in the field of electronics and telecommunications performing certain graphic tasks necessary for completing professional assignments, creating product sketches, and other activities that facilitate subsequent professional activity in production. These professional tasks may be aimed at analyzing production situations, finding optimal problem-solving algorithms, and developing (executing) project and design documentation for products. Carrying out graphic activities includes making drawings or other graphic images, analyzing forms, and the interaction of parts (phenomena) using graphic images.

Graphic training is a component of the professional training of future specialists in the field of electronics and telecommunications, characterized by acquiring a relevant system of knowledge and forming readiness for the effective application of acquired graphic knowledge and skills. Additionally, graphic training is a multifaceted and continuous process of forming graphic competence during professional training at higher education institutions for future specialists in electronics and telecommunications. Such training

is part of overall professional training and is based on mastering various aspects of applying graphic knowledge and skills, which are subsequently used for mastering the learning material of professional disciplines.

Theoretical analysis of sources on the research problem indicated that scientists consider the following tasks of graphic training for future specialists in technical fields to be relevant: integrating graphic knowledge into a unified complex aimed at stimulating students' cognitive and creative activity; clarifying definitions regarding the formation of graphic competence, considering the peculiarities of future professional activity; developing methodological ways to enhance the level of graphic training.

Modern scientific research is aimed at solving these tasks. For instance, O. Dzhedzhula (2007) proposed a methodological system of graphic training for students in technical higher education institutions, while M. Yusupova (2010) proposed a method of interactive teaching of graphic disciplines for students in technical specialties. H. Chemeris (2020) substantiated the need for forming graphic competence in future bachelors of computer science and suggested effective ways to address this pedagogical task. I. Hevko and O. Pysarchuk (2018) explored the problem of forming graphic competence in future professionals in vocational education. The solution to the problems of graphic training for future engineers was the goal of scientific research by L. Tsvirkun (2017). O. Revyakin and O. Serdyukova (2014) substantiated the significance of graphic training for students in engineering-pedagogical specialties, particularly in the context of improving the quality of specialist training. Researcher Yu. Kozak (2016) analyzed the content of graphic training in pedagogical higher education institutions and substantiated the importance of graphic competence in the professional training of future engineer-pedagogues. Author I. Nyshchak (2017) developed a methodological system for teaching graphic disciplines to future technology teachers.

Additionally, an important aspect is the use of digital technologies in the process of forming graphic competence. Scientific publications feature developments on substantiating certain pedagogical conditions for teaching graphic disciplines using digital technologies, computer-aided design systems, or methodological teaching systems for specific specialties. For example, M. Kozyar (2009) proposed a way to form graphic competence using digital technologies through the introduction of interdisciplinary integration into teaching. P. Kolyasa (2022) researched the effective use of digital technologies to form graphic competence in future specialists in vocational education. G. Havryshchak and A. Uruskyi (2021) considered the peculiarities of forming graphic competence in higher education students using computer-oriented technologies.

Analyzing the methods of teaching graphic disciplines in technical universities, it was found that there is no single didactic approach to teaching disciplines related to the study of digital technologies within a certain field of knowledge, taking into account its characteristics, development rates, and the requirements of modern society for the professional activities of future specialists in electronics and telecommunications. This necessitates the creation and implementation of such educational tools in the professional training of future specialists in electronics and telecommunications, which will contribute to the formation of their graphic competence using modern digital technologies. The creation and implementation of modern digital tools in all sectors of the national economy impose significant requirements on the scientific and technical training of future specialists.

Summarizing the available developments in this direction, it is asserted that the formation of graphic competence of future specialists in technical universities requires a comprehensive, systematic approach, particularly in the process of designing graphic information and determining the graphic characteristics of certain objects. In the process of forming graphic competence, the following conditions should be taken into account:

- improvement of the educational process in the direction of creating opportunities for the formation of graphic competence, constructing it as a consistent, purposeful system with appropriate methodological, organizational, and personnel support;

- the formation of a creative educational environment that will contribute to the development

of the future specialist's personality and the formation of an understanding of the value of graphic activity, particularly through the development and implementation of a structural-functional model for the formation of graphic competence of future specialists in electronics and telecommunications;

- the creation of a favorable socio-psychological climate in the educational environment;

- the formation in the minds of each future specialist in electronics and telecommunications of the relevance, role, place, and practical importance of graphic competence and skills in computer literacy for effective future professional activities.

The effective use of digital technologies in the professional training of future specialists in electronics and telecommunications is currently a priority in the process of modernizing the system of higher technical education. It should be noted that the development of digital technologies significantly outpaces the practice of their use in training at universities. Therefore, mastering the methods of independent work using digital technologies is one of the key issues in the professional training of future specialists in technical specialties.

The educational programs for the training of specialists in electronics and telecommunications at the bachelor's level of higher education include the study of such graphic disciplines as descriptive geometry, engineering and computer graphics, modeling, and analysis of electronic circuits. Descriptive geometry is the theoretical foundation for further study of graphic and professional disciplines. Engineering and computer graphics provide the skills for constructing images using digital technologies.

Digital technologies have an undeniable impact on the features of professional training for future specialists in the field of electronics and telecommunications, as well as the formation of their graphic competence. The creation of automated design systems has contributed to the development and implementation of graphic editors in the educational process, including such tools as AutoCAD, MathCAD, ArhiCAD, and others. These tools enable the development of documentation, the study of electronic models of developed parts and products. The digital design system has significant visualization capabilities, which not only forms students' graphic competence but also enhances their understanding of the functioning of electronic systems.

The creation of a digital graphic model is the initial stage in the design process and the subsequent production of ready-made products in the radio engineering field. This model facilitates calculations for the creation of the future design of the product, visualizes its image, checks how the product will work, develops the manufacturing technology, and organizes the design documentation. Thus, a feature of forming the graphic competence of future specialists in electronics and telecommunications is that it requires the unity of graphic and professional training of students, focused on creative innovative activity with the subsequent formation of readiness to implement innovations in professional activities.

At the same time, it should be remembered that higher education is moving towards increasing the volume of independent work at the expense of reducing the share of classroom work, involving students in real projects starting from the first years of study, which, in turn, demands well-formed graphic work skills. The professional development of specialists in the field of electronics and telecommunications occurs under the influence of several factors, such as the professional needs of students, stakeholder requirements, general requirements of the professional education system, as regulated in state documents and higher education standards. Today, the professional activity of specialists in electronics and telecommunications is impossible without the use of computer modeling principles and methods.

Currently, digital technologies make it possible to abandon traditional drawing methods and use appropriate software. Existing graphic models used in the process of professional training for future specialists in electronics and telecommunications are divided into two groups – two-dimensional and three-dimensional graphic models.

Two-dimensional graphic models use the computer as a replacement for paper and drawing tools; however, the construction process is more convenient thanks to the set of functions of the graphic editor. Two-dimensional graphic models include maps, images, plans, photo maps, drawings,

synthesized images, and more. Creating two-dimensional graphic models in the process of professional training for future specialists in electronics and telecommunications allows the formulation and solution of the following types of educational tasks: identifying images of a flat object, which is part of a real spatial object (in particular, printed circuit boards, which are the basis for creating a specific device); finding an image from several given ones for the studied flat object; evaluating the shape and size of a flat figure; creating images of the intersection of given flat figures, and so on.

The features of 2D graphic models are that they can combine geometric models (vector graphics), digital images (raster graphics), typed text (with specific content, font style and size, color, position, and orientation), mathematical functions, equations, and more. All components contained in a 2D model can be modified using geometric transformations, including parallel translation, rotation, scaling, and so on.

Three-dimensional graphic models. These models create the necessary conditions for carrying out project activities during which a model of a real object is created. Using 3D modeling, one can not only create an image of the appearance of an object but also determine its technical characteristics. 3D models are indispensable for presentations, exhibitions, and work with clients when it is necessary to visually show what the final result will be. Three-dimensional modeling allows for the creation of very accurate models that are as close to reality as possible. Modern graphic editors help ensure high detail. Moreover, this facilitates making any changes to the three-dimensional model. Special programs create opportunities for integration with any other professional software, including programs for production equipment, accounting software, engineering calculation applications, and more.

Today, computer graphics is the field of information technology that is developing the fastest. In education and scientific research, computer graphics is the tool that enhances the ability to think in complex spatial images and create models of products or processes through design. Computer graphics today have become tools for designers, researchers, constructors, and specialists in all sectors of the economy.

Conclusions. The peculiarity of the professional activity of a specialist in electronics and telecommunications lies in the fact that its effectiveness depends on the combination of research, graphic, and inventive activities. The specialist must be able to improve existing products and design new ones (methods), develop quality product mock-ups, model them using three-dimensional and two-dimensional graphics, and have a creative approach to the assigned task, which collectively involves possessing graphic activity skills and the ability to work in modern graphic editors. The main professional skills of a graduate include the ability to develop and execute sketches of products, mock-ups, and prototypes using design methods, considering ergonomic requirements with subsequent graphic design of the product.

The theoretical foundations of the formation of graphic competence of future specialists in electronics and telecommunications by means of digital technologies have been analyzed and substantiated. Based on the analysis of the theory and practice of training specialists, a number of definitions characterizing the result of the formation of graphic competence have been determined, and the conditions necessary for its effective development have been established. It has been found that the integration of digital technologies contributes to the increase in the level of graphic competence.

The results of the survey confirmed the hypothesis that employers consider such requirements as professional skills and abilities, work experience, the ability to construct, the ability to improve existing products, and the conduct of design activities using modern graphic editors to be appropriate. Therefore, in the process of professional training of future specialists in electronics and telecommunications, in order to effectively form their graphic competence, it is necessary to: implement the interconnection of professional and graphic activities, which is a prerequisite for the effective performance of professional tasks; develop readiness for changes and the ability to adjust activities according to the changing demands of society; ensure the formation of the general professional culture of the specialist as a whole.

This will allow determining the criteria and factors that affect the successful formation of graphic competence and, based on empirical research, propose specific changes to the educational programs to improve the professional training of future specialists in the field of electronics and telecommunications, which is the prospect of further scientific research.

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DOI: https://doi.org/10.32835/2707-3092.2024.28.185-196

ДЕФІНІЦІЇ ТА УМОВИ ФОРМУВАННЯ ГРАФІЧНОЇ КОМПЕТЕНТНОСТІ МАЙБУТНІХ ФАХІВЦІВ З ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ ЗАСОБАМИ ЦИФРОВИХ ТЕХНОЛОГІЙ

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Реферат:

Актуальність: радіоелектроніка є наукомістким пріоритетним сектором світової економіки із стабільним і постійно зростаючим попитом, значним експортним потенціалом, низькою матеріаломісткістю та високою питомою вартістю продукції, що стимулює розвиток інформаційно-комунікаційних технологій і таких галузей як машинобудування, приладобудування, медицина тощо; ефективність професійної діяльності фахівця в галузі електроніки та телекомунікацій залежить від поєднання науково-дослідної, графічної та винахідницької діяльності в процесі їхньої професійної підготовки.

Мета: дослідження та визначення ключових понять (дефініцій), що характеризують графічну компетентність, а також визначення умов, необхідних для її ефективного формування у процесі професійної підготовки майбутніх фахівців в галузі електроніки та телекомунікацій з використанням цифрових технологій.

Методи: *теоретичні* (аналіз стандартів вищої освіти, наукових і методичних публікацій, що відображають проблеми дослідження, критичний аналіз наявних теоретичних та методичних шляхів вирішення започаткованої проблеми в Україні та за кордоном щодо формування графічної компетентності майбутніх фахівців у галузі електроніки та телекомунікацій засобами цифрових технологій); *емпіричні* (анкетування; спостереження за навчальним процесом; опитування роботодавців і експертів).

Результати: проаналізовано та обґрунтовано теоретичні положення щодо формування графічної компетентності майбутніх фахівців з електроніки та телекомунікацій засобами цифрових технологій; на основі проведеного аналізу теорії та практики формування графічної компетентності майбутніх фахівців в процесі професійної підготовки було встановлено низку дефініцій, які характеризують результат процесу формування графічної компетентності та визначено умови для її формування; визначено особливість професійної діяльності фахівця в галузі електроніки та телекомунікацій; виявлено основні професійні уміння випускників.

Висновки: особливість професійної підготовки фахівця в галузі електроніки та телекомунікацій полягає у поєднанні науково-дослідної, графічної та винахідницької діяльності; результатом його професійної підготовки має стати набуття умінь і здатностей, актуальних на цифровому ринку праці (готовність до навчання впродовж життя; здатність вдосконалювати наявний і проєктувати новий виріб, виконувати його ескізи й макети, моделювати його за допомогою тривимірної та двовимірної графіки; вміння працювати з урахуванням сучасних вимог ергономіки з подальшим графічним оформленням виробу; креативність); з метою ефективного формування графічної компетентності майбутніх фахівців у галузі електроніки та телекомунікацій має бути реалізовано три основні умови (забезпечено взаємозв'язок професійної й графічної діяльності, що є передумовою ефективного виконання професійних завдань; сформовано готовність до змін і здатність до коригування діяльності відповідно до змінних вимог суспільства; забезпечено формування загальної професійної культури фахівця в цілому).

Ключові слова: *професійна підготовка, графічна компетентність, фахівці у галузі електроніки та телекомунікацій, заклади вищої освіти.*

Received: February 29, 2024
Accept: May 31, 2024