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THEORETICAL AND PRACTICAL APPLICATION OF THE RESULTS OF MODERN SCIENCE

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MODERN SCIENCE»

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Romaniuk Oleksandr

Doctor of Technical Sciences, Professor, Vinnytsia National
Technical University

Kovalova Yulia

Managing Director of Smart Alpaca LLC

THE ROLE OF COMPUTER GRAPHICS AND VISUALIZATION IN THE TRAINING OF STUDENTS AND PUPILS

In the modern educational space, computer graphics and visualization have become integral components of preparing young people for life in the information society. The sharp increase in the volume of visual information, the digital transformation of education, the requirements for the development of creative thinking and interdisciplinary awareness create new challenges for educators. In this context, the use of computer graphics tools and visualization methods plays a key role in increasing the effectiveness of learning, adapting students to digital technologies, forming visual literacy, as well as in developing analysis, modeling, and self-presentation skills¹.

Computer graphics is considered as a set of means of creating, processing and reproducing graphic information by means of computer technology. Visualization is the process of transforming abstract, numerical or textual information into visual images to facilitate its understanding². Both of these areas have become not only technical tools, but also pedagogical means that significantly change the nature of teaching and perception of knowledge.

In school education, the use of graphic tools is increasingly going beyond the scope of computer science courses. For example, in biology, 3D models of cells, organs or ecosystems allow students to better imagine the structure and relationships between

¹ Bykov, V. Yu., & Shishkina, M. P. (2018). Computer-based educational environment: Theoretical and methodological principles of development. Kyiv: Pedagogical Thought.

² Romanyuk, O. N., Romanyuk, O. V., & Chekhmestruk, R. Yu. (2023). Computer graphics [Electronic textbook]. Vinnytsia: VNTU.

components. In physics, simulations of oscillations, wave processes or electromagnetic fields in an interactive form create the prerequisites for understanding complex phenomena without direct experimentation, which is sometimes dangerous or impossible in the classroom³.

Visualization tools are also actively used in the humanities. For example, in history teaching, interactive maps and timelines contribute to a better understanding of events and processes. In literature, mind maps help students analyze the composition of a work or the evolution of characters⁴.

Digital competence in modern schools is recognized as important at the level of educational standards. Mastering basic skills in working with graphic editors allows students to create infographics, logos, illustrations, design presentations and research projects. This not only contributes to a deeper understanding of the material, but also forms the skills of visual thinking, analysis, generalization and synthesis⁵.

According to research, visualization helps increase motivation, improve memory, and activate cognitive activity, especially in students with a visually dominant learning style⁶. It is thanks to the graphic presentation of the learning content that the individual cognitive characteristics of students are taken into account.

In the context of implementing STEM education, computer graphics serve as the basis for knowledge integration. Creating 3D models in Tinkercad or SketchUp, visualizing mathematical functions in GeoGebra, modeling engineering objects in

³ Romanyuk, O. N., Romanyuk, O. V., & Kovaleva, Y. O. (2025). The role of artistic competencies for students. In *Information Technologies in Education and Science: Proceedings of the IV International Scientific and Practical Conference* (Issue 14, pp. 382–387). Zaporizhzhia: Publishing House of B. Khmelnytskyi Moscow State University.

⁴ Romanyuk, O. N., Tsikhanovskaya, O. M., & Romanyuk, O. V. (2024). The use of three-dimensional graphics in the training of economists. In *XXII International Scientific and Practical Conference MicroCAD-2024: Information Technologies: Science, Engineering, Technology, Education, Health* (pp. 1036). Kharkiv: NTU "KhPI".

⁵ Romanyuk, O. N., Maidanyuk, V. P., Romanyuk, O. V., & Chekhmestruk, R. Yu. (2025). Features of training students in the discipline "Computer Graphics". In Sokol, E. I. (Ed.), *XXIII International Scientific and Practical Conference MicroCAD-2025: Information Technologies: Science, Engineering, Technology, Education, Health* (p. 1199). Kharkiv: NTU "KhPI".

⁶ Romanyuk, O. N., & Kovaleva, Y. O. (2025). Training of specialists in the field of computer design. In *Automation and Computer-Integrated Technologies in Production and Education: State, Achievements, Development Prospects. Proceedings of the All-Ukrainian Scientific and Practical Internet Conference* (pp. 194–195). Cherkasy.

AutoCAD - all this forms an understanding of the relationship between science, art, and technology⁷.

In high school, you can use programming environments with graphical capabilities, such as Processing, Python with the Matplotlib library, or Pygame, which allow you to create visual models, simulations, and educational games.

According to analytical data from the labor market, professions related to visual content – graphic designers, 3D modelers, UI/UX specialists, illustrators, motion designers – are among the most in-demand in the world⁸.

In higher education institutions, especially in engineering and IT specialties, computer graphics are part of professional training. Students learn the basics of 2D/3D modeling, working with graphics APIs, animation, computer vision, graphical interfaces and visualization of big data. Popular environments include Blender, Unity, Unreal Engine, SolidWorks, Matlab, Tableau⁹.

At the stage of preparing term papers, diploma, bachelor's and master's theses, the student is faced with the need to present large amounts of information. Here, data visualization comes to the rescue: building graphs, diagrams, heat maps, word clouds, ontological schemes. This allows you to effectively communicate the results of the study, establish patterns, and compare alternatives¹⁰.

Graphics are the language of modern visual culture. They allow not only to analyze information, but also to create new images, implement artistic ideas, and visual stories. In the educational process, they contribute to the development of creative potential, self-expression skills, and form aesthetic taste¹¹.

⁷ Zavadsky, I. V. (2020). Innovative approaches to teaching natural sciences at school. *Educational Space of Ukraine*, 3(91), 47–52.

⁸ Romanyuk, O. N., Romanyuk, O. V., & Velichko, N. P. (2024). Natural and mathematical education for the study of computer graphics. In *Technological and Professional Education: Problems and Prospects. Proceedings of the IV International Scientific and Practical Conference* (pp. 39–42). Hlukhiv: Hlukhiv National University named after O. Dovzhenko.

⁹ LinkedIn Economic Graph. (2023). Most in-demand skills 2023. <https://economicgraph.linkedin.com/research/2023-most-in-demand-skills>

¹⁰ Source № 5

¹¹ Berezina, T. V. (2019). Creativity in the system of art education: The role of digital technologies. *Art and Education*, 3, 29–33.

Computer graphics are also a means of inclusion. Students with special educational needs can more easily master knowledge and express their own thoughts through visual modeling, multimedia technologies, and pictograms.

According to Alan Pavio's dual coding cognitive theory, information is better absorbed when presented simultaneously in verbal and visual form. This is confirmed by numerous studies, according to which students who learn with visual support demonstrate a higher level of understanding and memorization of the material¹².

Computer graphics as an educational tool goes far beyond specialized courses in computer science or design. Its integration into the teaching of other disciplines is becoming increasingly important due to the need to visualize complex information, activate the cognitive activity of pupils and students, and form interdisciplinary connections. Modern educational approaches, focused on the development of thinking, analytical and creative abilities, increasingly include graphic and visual components in the structure of lessons and lectures.

In mathematical disciplines, computer graphics acts as a means of visual representation of functions, geometric figures, multidimensional spaces. With the help of programs such as GeoGebra, Desmos, Mathematica or MATLAB, you can build interactive graphs, explore the properties of curves, surfaces, sets, visualize solutions to equations or differential systems. This is especially useful when studying vector algebra, linear algebra, analytic geometry and mathematical analysis, where abstract concepts become understandable through visual representation.

In physics and chemistry, graphical simulations allow you to model processes that are impossible or difficult to implement in a laboratory setting. For example, the study of body motion, wave propagation, electric fields, and particle interactions takes on a dynamic form thanks to interactive visualizations. In chemistry, 3D models of molecules, animations of chemical reactions, and simulations of energy levels facilitate the understanding of molecular structure and reaction kinetics. Programs such as

¹² Baranenko, S. V. (2020). Computer graphics and visualization technologies in the training of programmers. Kyiv: NaUKMA.

ChemSketch, Avogadro, and PhET Simulation Toolkit are widely used both in schools and in higher education institutions.

Biology, as the science of complex living systems, greatly benefits from visual modeling. The study of human anatomy, cell structure, photosynthesis, genetic information transfer, ecosystem dynamics – all of this can be visualized using digital models and animations. Tools like BioDigital Human, Visible Body, or 3D4Medical allow students and pupils to explore the structure of internal organs, physiological processes, and the interaction of organs in systems in three-dimensional space.

In geography, the use of computer graphics includes the creation of interactive maps, visualization of climate change, analysis of spatial data, modeling of geomorphological processes. GIS technologies, such as ArcGIS, QGIS, Google Earth Engine, allow integrating geodata, statistics, satellite images into a single space, forming a comprehensive picture of natural phenomena, the ecological state of territories, and the distribution of resources.

History and social sciences are becoming more visual and accessible thanks to computer graphics. Interactive timelines, dynamic maps of historical processes, infographics on socio-economic indicators, visualization of data on migration, wars, demography help to make sense of large amounts of information and see the connections between events, processes, and consequences. For example, by creating maps of World War II events or infographics on the economic development of countries, students better understand the logic of historical changes and global trends.

In languages and literature, graphic tools play a role in building associative schemes, concept maps, analyzing the composition of a work, building models of relationships between characters, plot lines. Graphic elements can be used to create comics, visual reviews, and visual analysis of poems. For example, in the process of studying foreign literature, students create visual collages or posters based on works, which contributes to deeper emotional understanding.

In the arts, computer graphics open up a wide range of creative possibilities. Thanks to digital technologies, students can create their own paintings, animations,

cartoons, music videos, and posters that combine text, images, movement, and sound. This allows them to develop aesthetic taste, graphic literacy, and self-presentation skills. Programs such as Adobe Photoshop, Illustrator, Krita, GIMP, and Canva have become common tools in fine arts, design, theater, and media education courses.

In technology and labor training, computer graphics are used to create drawings, models, and technical documentation. Computer-aided design systems (AutoCAD, SketchUp, Fusion 360) allow you to design parts, buildings, furniture, and interiors. In combination with 3D printing, laser cutting, and robotics, this forms the basis of design activities and allows you to implement your own ideas in the material.

Computer graphics are becoming a universal didactic tool that allows for the visualization of knowledge, supports cross-curricular integration, activates the learning process and develops modern competencies of students. It is important not only in the aesthetic and instrumental aspects, but also in the context of the formation of imaginative thinking, creativity and the ability to convey complex information in a clear, effective form. Its value increases especially in conditions of distance or blended learning, when visual materials replace traditional forms of interaction between teacher and student.

In conclusion, the integration of computer graphics into other disciplines is not just a fashionable trend - it corresponds to profound changes in the structure of modern knowledge, thinking styles, and information culture of new generations. This is an important step towards building high-quality, inclusive, and modern education focused on the needs of the individual and the demands of a digital society.

Cognitive computer graphics is an interdisciplinary field that combines computer visualization technologies with research in cognitive psychology, pedagogy, and neuroscience. Its main goal is to create visual models that are optimized for human perception, processing, and memorization. In the context of modern digital education, the role of cognitive graphics is especially growing: it allows you to structure educational material in a form that is most convenient for thinking, increase learning efficiency, reduce cognitive load, and improve understanding of complex concepts.

Unlike traditional computer graphics, which is often focused on aesthetic effect or technical accuracy, cognitive graphics is based on the psychological characteristics of a person: attention, memory, perception of form, color, structure. It uses the principles of Gestalt psychology, the theory of dual coding (verbal and visual), cognitive ergonomics, and the concept of visual data processing. The main task of cognitive graphics is to help the user understand the content of the image as quickly and accurately as possible, to isolate the main points, to recognize patterns, and to establish cause-and-effect relationships.

In the context of learning, cognitive computer graphics perform several important functions. First, it optimizes the process of information perception. Thanks to the logical arrangement of elements, the successful choice of color palette, the use of size and spatial arrangement of objects, such graphics allow you to focus attention on key aspects. This is especially important when studying complex topics, for example, in physics, biology, mathematics, where a large number of concepts need to be organized.

Secondly, cognitive graphics increase the level of memorization of educational material. It actively uses associations, metaphors, mnemonics, iconography, and repetition of structures that help students form stable mental images. For example, to memorize the elements of a cell or types of chemical bonds, a graph can represent objects as easily recognizable symbols, supplemented with colors associated with function (red - energy, blue - structure, green - synthesis, etc.).

Thirdly, cognitive graphics contribute to solving educational tasks through interfaces that support the logic of thinking. Interactive models that respond to user actions allow you to explore phenomena in an experimental mode, see the consequences of changing parameters, and establish patterns. In environments such as GeoGebra, PhET, Labster, and Blender, students can control models, change conditions, and observe visual responses of the system. This develops analytical thinking and forms research skills.

Another important aspect is the role of cognitive graphics in explaining abstract concepts. Many topics in mathematics, chemistry, linguistics or social sciences are difficult to understand in text format alone. Visualization in the form of schemes, diagrams, structural models, trees or graphs allows you to transform abstraction into a concrete visual image. For example, in programming - class relationship graphs, in biology - evolutionary trees, in linguistics - syntactic sentence structures. Thanks to this, complex concepts become accessible for learning by a wide range of students, regardless of their cognitive styles.

Cognitive computer graphics also has great potential in ensuring inclusive education. It can adapt to the specific perceptions of students with visual, hearing, and neuropsychological disabilities.

In higher education, cognitive graphics play a role in preparing students to work with large amounts of data. Infographics, dashboards, database visualization, neural maps, analytical diagrams are becoming the main tool for presenting research. It is important that these visualizations are not just graphical, but cognitively effective: they correspond to the logic of the user's thinking, contain a minimum of unnecessary information, have an intuitive structure, and indicate cause-and-effect relationships.

The use of cognitive computer graphics also changes the paradigm of learning - from passive memorization to active construction of knowledge. Students not only consume ready-made images, but also create their own visual models, posters, mind maps, diagrams, presenting their own vision of the topic. In this way, graphics become a tool for thinking, reflection, and creativity.

Thus, cognitive computer graphics is a powerful means of implementing a modern approach to education - individualized, visualized, interactive.

The study of computer graphics is a complex and multifaceted process that encompasses technical, mathematical, artistic, and cognitive aspects. Depending on the educational level, specialization, and learning goal, different methods and approaches are used. The effectiveness of learning largely depends on how well the methods match the specifics of the perception of students, as well as how well they involve practice,

visualization, reflection, and creativity. In modern pedagogy, a number of methods have been developed that have proven their effectiveness in teaching computer graphics.

One of the most effective approaches is project-based learning, which involves learning graphic tools and techniques through the creation of real or simulated projects. These can be logos, 3D models, data visualizations, infographics, covers, game characters, mobile application interfaces, etc. This approach motivates active learning, allows you to see the practical application of knowledge, develops creativity and forms teamwork skills.

The second important method is step-by-step modular learning, in which a complex subject is divided into sequential, logically related modules. For example, in a 2D graphics course, basic shapes and transformations are first studied, then working with layers, masks, effects, color palettes, and then creating compositions. In 3D graphics, modeling simple shapes, texturing, lighting, animation, and rendering are studied. This approach promotes a gradual increase in complexity, conscious assimilation of the material, and minimizes cognitive overload.

Another important method is visual explanatory learning, which involves the use of video tutorials, animations, screencasts, and screen demonstrations with step-by-step commentary. This allows students to not only see how a particular operation is performed, but also to better understand the logic of actions. The method is especially useful for visuals, as well as in cases of studying complex or new interfaces for students. Many platforms (e.g., Coursera, Udemy, YouTube, Skillshare) provide high-quality video materials with graphics that can be integrated into training programs.

Interactive learning, based on practical exercises during classes with instant feedback, is also becoming increasingly important. These can be both exercises for mastering tools and tasks for creative interpretation. Programs with built-in simulators (e.g., Adobe Learn, Canva for Education) allow you to quickly test your knowledge and skills by automatically analyzing user errors.

Another effective method is the method of learning through error - performing tasks that contain typical errors that need to be identified and corrected. This method not only activates attention, but also teaches critical thinking, develops the ability to analyze graphic objects. In the process of discussing errors, students learn to recognize compositional violations, illogical colors, poor alignment, excessive detailing, or distortion of proportions.

One of the central methods is reflective learning, which consists of constant self-evaluation of one's own work, analysis of one's own style, choice of instruments, compositional decisions. Students are encouraged to maintain a digital portfolio, regularly update their works, compare them with previous versions, and justify their choices. This approach forms the ability to evaluate not only other people's works, but also one's own, and cultivates taste and responsibility for the creative product.

When working with a large number of students, the case method is effectively used. Pupils or students are offered a situation - an order from a client, a technical task, an example from professional practice - and they must complete the project, adhering to the requirements. The case may include evaluating competitors, analyzing references, and budget constraints. This method brings learning closer to real conditions, allowing for the integration of technical and communication skills.

It is also worth noting the "teach another" method. Students are invited to create instructions, videos, presentations, or explanations of certain tools or techniques for others. This contributes to a deeper understanding of the topic, since presenting the material clearly means truly mastering it. In addition, skills in public speaking, structuring information, and visual design of educational content are developed.

In the modern context, a gamified approach is also important, when the process of studying graphics is accompanied by a system of points, badges, levels, and competitions. This stimulates interest and reduces anxiety about complex topics, especially among younger students. Gaming platforms such as Classcraft, the use of mini-games, and quick challenges ("who can create the best logo in 10 minutes") diversify classes and maintain dynamics.

Finally, it is important to note the role of an interdisciplinary approach - it is advisable to integrate computer graphics into the study of other subjects: mathematics (construction of fractals, geometric patterns), history (creation of posters), biology (anatomical models), physics (visualization of forces). This expands students' ideas about the application of graphics in various areas of life and science, and forms a systemic vision.

In conclusion, effective study of computer graphics is based on a combination of different methods: practical activity, visual explanation, reflection, gamification, integration. The central place is occupied by the active role of the pupil or student himself - as a creator, researcher, analyst, presenter. Only through one's own activity, supported by methodologically competent support, can one achieve a deep understanding of graphic principles and form skills that are relevant in the modern digital environment.

Continuing to consider effective methods for studying computer graphics, it is important to pay attention to the role of individualization of learning. In modern conditions, when students have different levels of preparation, pace of information assimilation and motivation, an individual approach becomes key. Individualization involves not only different levels of difficulty of tasks, but also the ability to choose topics for projects according to personal interests, the use of educational platforms with personalized tracks, access to video instructions and tips at a convenient time for the student. Such an approach provides internal motivation and allows you to avoid frustration or boredom.

A special place among the methods is occupied by blended learning, which combines face-to-face classes with online formats. For example, students can learn the basic functions of a graphic editor at home through interactive modules or videos, and in classes implement creative projects, receiving support from a teacher. This model is especially effective for technical training, where a significant part of the time is spent on individual work with software. Blended learning also allows you to optimize the workload, increase flexibility and make the process more interactive.

It is also worth emphasizing the importance of assessment as a learning tool, not just a means of control. Formative assessment — regular feedback, self-assessment, peer assessment of work in groups — allows you to better understand your own progress, identify strengths and weaknesses. For example, after completing an assignment, a student can present their work, explain their approach, receive comments from others, and draw conclusions about improvements. Such practice develops critical thinking and analytical skills.

The successful mastery of computer graphics is also facilitated by the use of a professional learning environment. This means that students work with the same tools that are used in real projects - Adobe Photoshop, Illustrator, Blender, Figma, Unity, After Effects, AutoCAD, etc. Training courses should reflect current industry trends - for example, the implementation of artificial intelligence in image generation, the use of neural networks in design, adaptive interfaces. Familiarity with the portfolios of famous designers, analysis of examples from Behance, Dribbble or ArtStation forms an understanding of aesthetics and professional standards in students.

In addition, teamwork is an important method - collective implementation of graphic projects, distribution of roles (designer, manager, illustrator, presenter), mutual assistance and evaluation. Such experience simulates real conditions in companies, where each participant is responsible for a certain part of the work, but at the same time understands the general concept. Teamwork also contributes to the development of communication skills, management skills and responsibility.

Particular attention should be paid to the method of comparative analysis, when students are taught to analyze and evaluate different examples of graphics, consider several options for the design of one idea, determine the visual language of the brand or stylistic differences. This helps to form visual literacy, the ability to work with references, critically evaluate the quality of images, and make informed design decisions.

The role of emotional engagement should not be ignored. Studies show that interest and inspiration directly affect the quality of learning. Therefore, it is advisable

to include elements of gamification, competitions, public presentations of work, exhibitions, participation in hackathons or challenges in the program. Such events create a motivational environment, stimulate achievements, and contribute to increasing self-esteem and self-confidence.

Therefore, effective study of computer graphics is a combination of various methodological approaches that provide a balance between technical skills, creativity, analytics and communication. The central principle should be the active involvement of the student in all stages of the educational process: from setting the task to demonstrating the result. It is this integrated, adaptive and practice-oriented methodology that allows you to form a modern specialist who is able to work with visual information in conditions of rapid digital changes.

It is also important to note the role of adaptive learning technologies. This is an approach in which the educational system automatically adjusts to the level of knowledge, learning pace, perception styles and interests of a particular student. Within the framework of studying graphics, adaptive platforms can, for example, recommend personalized exercises, simplify the interface at the entry level, and provide hints when errors occur. This is especially useful for beginners, who often face overload from the large number of tools and functions of professional software.

Another modern method that is rapidly gaining popularity is the use of augmented and virtual reality (AR/VR) in the study of graphics. Thanks to these technologies, students can interact with three-dimensional objects in space, explore the structure of complex models, create virtual scenes, apply realistic lighting, textures and animation. Learning in environments such as Unity with VR plugins, Tilt Brush or Adobe Aero not only develops spatial imagination, but also prepares students for new professions in the field of metaverse, game design, digital art.

In addition to technological methods, it is worth noting the importance of interpersonal interaction in teaching computer graphics. The teacher not only transmits knowledge, but also acts as a facilitator, mentor, critic, and inspirer. Public review of works, constructive criticism, discussion of solution options, reflective conversations

about ideas - all this creates a culture of creative thinking, teaches to defend one's views with arguments, and to become more aware of one's own strengths. It is important that the teacher himself owns graphic technologies at a modern level and has experience in practical application.

As part of the training of IT, design, and engineering specialists, it is also advisable to use professionally oriented simulators. These include environments that simulate work on real projects: visualization of buildings in architecture (Revit, ArchiCAD), creation of covers in publishing (InDesign), 3D animation for advertising (Cinema 4D), generation of content for social networks (Adobe Express, Pixlr). Working in such simulators allows students to understand how the full cycle takes place — from receiving technical specifications to rendering and export.

Another innovative approach is the integration of AI into the learning process. For example, using generative models such as Midjourney, DALL·E or Adobe Firefly, students can create images based on text queries, analyze styles, trends, and combine traditional modeling with algorithmic design. This forms a new cognitive habit — to think not only technically, but also conceptually: how to ask the right question, how to critically evaluate the result of AI, how to use it as a tool, not a replacement for creativity.

In the school education system, the integration of computer graphics into cross-curricular projects is effective. For example, students can create an animated historical map, a digital encyclopedia about ecosystems, a 3D model of a cell or museum artifacts. Such projects simultaneously cover knowledge from biology, geography, art, history and IT. They contribute to the formation of systems thinking, presentation skills and interdisciplinary literacy - key for modern education.

In extracurricular activities, students can participate in hackathons, competitions, and design challenges, where the use of graphics has a practical purpose — creating interfaces, brand identities, and product visualizations. This creates learning situations that are as close to real-life as possible, allowing them to develop skills under time pressure, teamwork, and portfolio work.

In summary, it can be argued that effective study of computer graphics involves the use of a wide range of methods - from traditional demonstration to interactive simulations, from individual learning to team project activities. The key principles should be: flexibility, adaptability, reflexivity, practical orientation and creative approach. It is this methodology that ensures not only the mastery of tools, but also the formation of comprehensive visual competence - the ability to think, analyze, communicate and create through visual images. In a world where visual information dominates all areas of life, these skills become the basis of digital literacy and professional competitiveness.

In the modern education system, a computer graphics teacher performs not only the function of a translator of knowledge and technical skills, but is a comprehensive specialist - a mentor, a facilitator of creative development, a curator of individual progress of students. His role is constantly evolving in accordance with changes in the digital environment, the emergence of new technologies, tools, platforms, as well as in view of the transformation of pedagogical models: from instructional to interactive, from frontal teaching to student-centered learning.

The primary function of a computer graphics teacher is to form in students a system of knowledge about the means, principles and techniques of creating and processing images, which are based on a combination of artistic vision and technical implementation. He must not only be able to teach how to work with programs (Adobe Photoshop, Illustrator, Blender, Figma, AutoCAD, Unity, Midjourney, etc.), but also explain the logic of constructing a composition, the typology of visual elements, the peculiarities of color perception, typography, and the hierarchy of objects. The teacher must also develop in students the ability to critically evaluate images, form a visual taste and analytical thinking.

The second important function is the organization of the learning environment. Successful teaching of computer graphics requires the creation of a technically equipped, psychologically safe and creative space. This includes the selection of software, installation of programs, configuration of graphics tablets, optimization of

resource use (locally or in the cloud), preparation of templates, image databases, educational videos. The teacher acts as a coordinator of interaction between the student and the digital environment, helps to overcome technical difficulties and fear of complex interfaces.

Another important aspect of the activity is the creative inspiration of students, support for their self-realization, motivation and independence. The teacher should present graphics not as a set of dry technical commands, but as a living language of communication, a tool for visual thinking, a means of self-expression. Through the demonstration of high-quality examples, portfolios of famous designers, analysis of real cases from practice, invitations of specialists, holding exhibitions or competitions, he forms a value attitude towards the profession.

A modern teacher must be constantly open to learning. Due to the rapid evolution of technologies, new programs, algorithms, and approaches appear every few years — from vector graphics to generative AI, from classic 3D models to VR design. Therefore, one of the key competencies of a teacher is the ability to independently update knowledge, take online courses, certifications (for example, from Adobe, Autodesk, Coursera), and study modern trends. He must not only be familiar with new tools, but also understand how to didactically adapt them to the educational process.

The teacher must also have communicative and psychological skills, because teaching graphics is associated with subjective perception, assessment of creativity, design, aesthetics. The ability to give constructive feedback, support the student's individual style, develop it without suppressing creativity is critically important. The ability to pedagogical reflection - analysis of one's own teaching style, adaptation to the level of the group, revision of methods - forms the quality of the teacher as a professional.

Training of a computer graphics teacher can be carried out through bachelor's and master's programs in the specialties "Information Technology", "Art Pedagogy", "Digital Design", "Professional Education (Computer Technology)", as well as through advanced training courses. It is desirable that such training include both fundamental

knowledge of graphics and fine arts, and pedagogical, psychological and methodological training focused on adult education, taking into account the specifics of professional training.

In addition, modern pedagogy of computer graphics requires the teacher to master the methods of blended and distance learning. He must be able to organize classes in Learning Management Systems (LMS), develop interactive tasks, record his own video lessons, conduct streams with screen demonstrations, effectively check visual works, and provide feedback in an online environment. This is especially relevant in the context of the digital transformation of education.

Thus, a computer graphics teacher is not just a carrier of technical knowledge, but a multifunctional specialist who combines the role of an artist, engineer, teacher, manager, and researcher. His competence determines not only the quality of students' mastery of the topic, but also their interest in visual culture, the ability to freely use graphic tools in professional and everyday activities. The training and continuous training of such a teacher is the key to effective modernization of the educational process in the digital age.

In the context of the digital transformation of education and the growing role of visual technologies in all spheres of society, the need for computer graphics teachers in Ukraine is becoming not only relevant, but also strategically important. Ensuring high-quality training in the field of computer graphics at the level of schools, vocational schools and universities requires a sufficient number of professional teachers who are proficient in modern graphic technologies, teaching methods and are able to adapt to changes in the digital environment.

The current state of the education system in Ukraine demonstrates a growing demand for disciplines related to digital design, multimedia, data visualization and 3D modeling. Computer graphics is already included in the curricula of higher educational institutions, where it is taught at the faculties of computer science, design, architecture, computer science. At the same time, it is increasingly integrated into school courses in computer science, technology, art, and is also used in interdisciplinary projects.

There are over 150 higher education institutions in Ukraine that train specialists in IT fields, including courses in computer graphics, 3D modeling, web design, interfaces, AR/VR. Assuming that each higher education institution has at least one department or specialized discipline that covers computer graphics, and that each of these departments employs from 5 to 10 teachers, the estimated number of teachers in higher education is at least 1,000–1,200 people. However, even this figure is insufficient to provide high-quality coverage of all educational programs, especially given the growing demand for specialists in the field of game design, 3D animation, cyber art, and visual programming.

In secondary schools, the situation is even more complicated. Although some elements of graphic education are integrated into computer science lessons, only about 25–30% of teachers have the appropriate training or experience working with graphic tools. According to educational surveys, there are about 4,000 computer science teachers in Ukraine, and only about 1,200 of them are already implementing teaching using computer graphics. To fully cover the needs of all schools and implement modern programs in the field of "Information Technologies and Digital Design", it is necessary to train at least 2,500–3,000 more teachers who are able to teach graphics qualitatively, adapting it to the age characteristics of students.

Thus, the total need for teachers and lecturers with professional training in the field of computer graphics is approximately 4,000–5,000 specialists throughout the country. This includes both new training of personnel and advanced training of existing teachers teaching related disciplines. Given the constant updating of software, changing digital literacy standards and labor market requirements, a teacher of computer graphics must regularly undergo certification, study at international courses, participate in trainings, workshops and master classes.

Additionally, it is worth considering the specifics of teaching graphics in vocational education and extracurricular activities. Youth development centers, IT schools, design and animation studios, and game development courses also need professional teachers who are able to teach schoolchildren and students through project

activities and real cases. This means approximately 500–1000 additional specialists who should be trained or involved in teaching activities.

In the context of meeting this need, it is important to create a national program for the training and retraining of computer graphics teachers. Such a program should include the development of curricula, the creation of certification centers, the development of infrastructure (including licensed software, graphics tablets, multimedia classrooms), the support of professional communities of teachers, partnerships with IT companies for the organization of internships and mentoring. In addition, it is advisable to introduce separate bachelor's and master's programs in computer graphics pedagogy, combining artistic, technical and methodological training.

Therefore, to fully meet Ukraine's need for high-quality teaching of computer graphics in all educational segments, it is necessary to train or retrain at least 4,000–5,000 teachers. Such an investment in education will not only increase the level of digital literacy of pupils and students, but will also lay the foundation for the formation of a competitive IT society in the global market, where visual thinking, creativity, and mastery of graphic tools are the basic skills of the future.

In the world, computer graphics is one of the most dynamic and sought-after fields, covering both scientific and technical and artistic and creative directions. There are a large number of academic programs, educational courses and professional specializations that train specialists in the field of 2D/3D graphics, animation, game design, data visualization, computer modeling, technical graphics and visual effects. Educational institutions of leading countries - the USA, Great Britain, Canada, Germany, Japan, South Korea - offer both classical university programs and applied training courses that prepare for real work in the digital economy.

In particular, in the USA there are bachelor's and master's programs in computer graphics at such institutions as Rochester Institute of Technology (RIT), DigiPen Institute of Technology, Savannah College of Art and Design (SCAD), University of Southern California (USC), Carnegie Mellon University. These programs combine the

study of programming, design, mathematical foundations of graphics, artistic modeling and the practice of creating visual content. They train specialists for the film industry, the gaming sector, digital advertising, architecture, and scientific visualization.

Similar programs are actively developing in Europe: in the UK, for example, there is the National Centre for Computer Animation at Bournemouth University, and in Germany there are educational platforms at the Hochschule für Gestaltung, Fachhochschule Aachen, etc. In Asian countries (Singapore, South Korea, Japan), academic training is combined with traditional art, technical modeling, and the digital content industry.

As for the salary of computer graphics specialists, it depends significantly on the level of qualification, country, experience, specialization and type of employer. According to CareerExplorer, the average annual income of a Computer Graphics graduate in the United States is approximately \$70,000, while specialists with extensive experience can earn over \$125,000 per year.

The average income of a graphic designer in the United States, according to official data from the Department of Labor, is about \$61,300 per year. The starting salary of a graphics specialist is about \$44,000–55,000, but after 3–5 years of experience it increases to \$70,000–90,000. In game design, especially in the areas of technical art or shader programming, the annual salary can reach \$120,000–150,000, and in management positions — up to \$200,000 and more.

Multimedia artists and animators working in video production studios earn an average of about \$88,000 a year, according to the U.S. Bureau of Labor Statistics. Motion designers, especially in advertising or the film industry, can earn \$90,000–120,000, and even more at major studios (Pixar, ILM, DreamWorks). At the same time, income levels are lower in Europe: the average annual income of a graphic designer in the United Kingdom is about £35,000–50,000, and in Germany — €40,000–60,000. Earnings in Scandinavian countries are higher — up to €70,000, but the tax burden is also higher.

The work of specialists in the field of 3D graphics for games and virtual reality is especially highly valued. Thus, the average income of a technical artist in the USA ranges from \$ 120,000 to \$ 180,000 per year, and in companies like Epic Games or Electronic Arts, senior technical artists can earn over \$ 200,000. A game artist with over 7 years of experience and specializing in AAA projects is one of the highest-paid areas.

It is worth noting that in recent years, the demand for data visualization designers, who combine knowledge of analytics, statistics, and graphic design, has been growing rapidly. Their income in the United States often exceeds \$100,000 per year. This is especially true in areas such as finance, healthcare, and government structures, where it is necessary to effectively convey complex information.

As a result, professions in the field of computer graphics are not only highly popular in the world's higher education system, but also provide competitive incomes. High demand, interdisciplinary nature, technical flexibility and the possibility of creative self-realization make these specialties attractive to young people and promising for development in the digital economy. Improving the level of training, participation in international competitions, mastery of modern tools and software ensure successful employment for specialists in this field in the global market.

In Ukraine, computer graphics as a branch of professional activity is developing at the intersection of art, engineering and information technology. This determines the presence of a wide range of educational programs in higher educational institutions, colleges, IT schools and training centers. Computer graphics is taught as a separate discipline in bachelor's and master's programs in the specialties "Computer Science", "Software Engineering", "Information Systems", "Design", "Art" and "Architecture". The content of the programs includes topics from the basics of 2D/3D modeling, animation, visualization, graphic design, shader programming, vector and raster graphics, typography, composition, interface design (, as well as data visualization.

Among the leading institutions that train specialists in computer graphics, we can note the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic

Institute", Kyiv National University of Technologies and Design, Kharkiv National University of Urban Economy, Vinnytsia National Technical University, Kharkiv State Academy of Design and Arts, Lviv National Academy of Arts. These institutions offer educational programs that cover computer graphics in the fields of engineering, visual arts, multimedia, architecture and applied design. For example, at KNUTD, the discipline "Computer Graphics and Visualization" is taught in six semesters and covers topics on the construction of raster and vector images, 3D modeling, transformations, animation and scene lighting.

As for the labor market, there is a stable demand for graphics specialists in Ukraine - both in the fields of advertising, marketing, publishing, game design, and related IT areas. According to the Work.ua platform, the average salary of a computer graphics specialist in the country is about 25,000 hryvnias per month, in Kyiv - up to 28,500 hryvnias, and in Lviv - about 25,000 hryvnias. Graphic designers earn an average of 24–27,000 hryvnias. Starting positions usually offer 10–15,000 hryvnias, but with experience, knowledge of English, and specialization in 3D or animation, the salary can reach 30–80,000 hryvnias. Some vacancies focused on international projects offer up to 90,000 hryvnias and higher.

According to IT resources, the average salary of a 3D generalist in Ukraine is about 18,000 hryvnias, but professionals with experience in architectural visualization, media, or game design can earn significantly more than the average. The salary situation depends significantly on the type of company: in small studios, salaries are lower, while in large IT companies or outsourcing studios, the level of income is comparable to international standards.

A special category are motion designers and video graphics specialists who work in digital marketing, film and television. Their salaries can be 40–60,000 hryvnias, and even more when working freelance or under foreign contracts. A separate area should be highlighted is the growing area of data visualization, where Ukrainian specialists work with BI platforms, Python/JavaScript visualization (Plotly, D3.js), Tableau and other tools.

In addition to higher education, IT schools (Projector, Hillel, Beetroot Academy, Logos, GoIT) play an active role in training graphic designers, offering intensive courses, mentoring, portfolio projects, and internships. Graduates of such programs usually adapt faster to market requirements, especially in the freelance, game design, and UI/UX sectors.

As a result, Ukraine has a developed system of training specialists in the field of computer graphics: from academic programs in higher education institutions to practical courses in private schools. The demand for graphic specialists is growing due to the development of digital communications, the gaming industry, advertising, architectural visualization and augmented reality. Starting salaries are 18–25,000 hryvnias per month, but with a professional portfolio, proficiency in 3D tools, English and flexible soft skills, a specialist can achieve an income of over 60–80,000 hryvnias. Ukraine has significant human resources potential in this area, and further integration with the global IT market will contribute to the growth of the level of qualification, remuneration and recognition of the profession of a graphic specialist as a key one in the digital age.

Computer graphics competitions play an important role in the learning process, serving not only as a means of motivating and demonstrating the creative abilities of students and pupils, but also as an effective pedagogical tool that allows you to deepen practical skills, develop critical thinking, form a professional portfolio and increase the level of professional training. Participation in creative and technical competitions stimulates interest in computer graphics as an educational subject, contributes to the integration of educational material into real tasks and increases the level of involvement of students in independent work.

One of the main factors of the effectiveness of competitions is the formation of target motivation. Participation in competitions gives students and pupils a specific goal - to create a high-quality graphic product within the established time frame in accordance with clear requirements. This encourages participants to deepen their understanding of techniques and tools, carefully study the elements of design, color

science, composition, and also requires mastering specific skills necessary to implement the task. This form of activity mobilizes internal discipline and encourages them to achieve the maximum possible result.

The second important advantage of competitive activities is the integration of theoretical knowledge and practical skills. As part of the preparation for the competition, students work on their own graphic projects, which are often interdisciplinary in nature. For example, tasks can combine knowledge from art history, cultural studies, marketing, photography, and programming. Thus, competitions contribute to the comprehensive application of acquired knowledge, develop flexible thinking and the ability to adapt to new requirements.

Competitions also serve as a real assessment of professional level. The works of participants are evaluated by an independent jury, which includes teachers, specialists from IT companies, artists, designers. This approach allows you to get feedback from the labor market, identify the strengths and weaknesses of training, and adjust curricula in accordance with modern requirements. Thanks to competitions, participants themselves are better aware of the level of their own competence and directions for further development.

Another important aspect is the formation of a portfolio. Graphic works completed within the framework of competitions usually have a high level of presentation. Students can include them in their professional portfolio, which is a necessary element of employment in the field of design, animation, game development, advertising. The presence of award-winning projects in the portfolio significantly increases the chances of a graduate for a successful start to his career.

It is worth noting the role of competitions in the development of soft skills - the ability to work in a team, publicly present your ideas, accept criticism, meet deadlines. In team competitions, participants distribute roles, discuss creative concepts, resolve conflicts and maintain communication, which simulates real working conditions in a professional environment. Competitions are also often accompanied by exhibitions,

presentations, pitching, which develops communicative and presentational competence.

Participation in competitions provides an opportunity to get acquainted with the works of peers from other educational institutions, regions, and countries, which contributes to broadening the worldview, exchanging ideas, acquiring new knowledge and acquaintances. National and international competitions create an environment of cooperation, creative competition, and improving the quality of graphic products. Participation in international competitions, such as Adobe Design Achievement Awards, WorldSkills (Graphic Design category), Behance Portfolio Reviews, where participants represent not only themselves, but also the level of their education and country, is especially important.

Ukraine also hosts many professional competitions: All-Ukrainian Student Olympiads in Computer Design, graphic art festivals, student project competitions in the field of design (in particular, "Art&Design", "ITalent", "VinArt", competitions within the Scientific Schools of Design and Visual Arts at leading universities). Such events not only improve the quality of training, but also form an educational environment focused on innovation, digital creativity and professional mobility.

Thus, computer graphics competitions are an effective means of deepening knowledge, developing practical skills, stimulating professional growth and creative activity of pupils and students. They ensure the integration of theory and practice, form a responsible attitude to the result, promote motivation for self-study and create a competitive educational environment. Involving students in such competitions should become an organic part of the educational process in the field of graphic design, visual arts and digital technologies.

Participation in computer graphics competitions is an important factor in improving the quality of training of future specialists in the field of visual technologies. These competitions contribute to the development of creative abilities, improvement of professional skills, formation of a competitive portfolio, as well as establishment of connections with the professional community. Every year many prestigious

competitions are held in the world, covering both the artistic and technical components of computer graphics.

One of the most famous is Adobe Creative Jam, organized by Adobe. It is a global competition for students and young designers, covering the categories of graphic design, UX/UI, 3D modeling, illustration and animation. Participation in Creative Jam allows participants to try themselves in real tasks, receive mentoring support and present their projects to professionals from the creative industries. Another influential competition is The Rookies - an international competition for students and beginners in the fields of visual effects, game design, concept art, 3D art and animation. It is supported by world-class studios such as Weta Digital, ILM, Epic Games. Winning The Rookies often opens the door to internships or jobs at top companies.

SIGGRAPH Art Gallery and Student Research Competition is a highly respected event, part of the SIGGRAPH international conference, which is the most prestigious event in the field of computer graphics. It presents scientific and artistic works, rendering technologies, VR/AR projects, CGI films and animated shorts. Another example of a large-scale competition is WorldSkills International, where a separate category “Graphic Design Technology” allows participants from different countries to demonstrate their skills in working with graphic editors, layout, identity, and layout. Ukraine has been participating in WorldSkills since 2016, and contestants undergo a complex selection and preparation.

Other well-known international competitions include the Animago Award (Germany), which specializes in CGI, animation, and visual effects; the CGTrader Digital Art Competition, which is aimed at 3D designers and visualizers; the Sketchfab Challenges for WebGL models; and the Behance Student Showdown, which evaluates the quality of creative portfolio design.

Ukraine also hosts a number of important competitions that promote computer graphics among students and schoolchildren. One of the most famous is the All-Ukrainian iTalent competition, which covers categories in graphic design, 2D/3D modeling, animation, video editing, AR/VR. The competition is organized with the

support of the Ministry of Education and Science of Ukraine and is aimed at students who aspire to develop in IT and digital creativity.

Another notable event is the international competition in computer graphics and design, held at Vinnytsia National Technical University. Students and schoolchildren from Ukraine and other countries participate in it. The nominations cover 2D and 3D graphics, web design, interface solutions, video graphics, interactive projects. The competition's feature is its emphasis on interdisciplinarity, innovation, and creativity. VNTU records the largest number of victories in graphics competitions among universities in Ukraine, which was included in the Book of Records.

Thus, both in the world and in Ukraine, computer graphics competitions are an important part of the educational process and professional development of specialists. They contribute to improving the quality of training, expand the boundaries of creative search, provide feedback from the expert environment and help young specialists declare themselves at the national and international levels. Participation in competitions stimulates creativity, develops technical skills, forms team spirit and provides motivation for self-realization in the digital age.

Conclusions

Thus, computer graphics and visualization are powerful educational tools that contribute to qualitative changes in the education system. They help adapt to the digital world, promote the development of critical and creative thinking, ensure inclusiveness and interdisciplinarity, and prepare young people for the professions of the future. Their systematic introduction into the educational process at all levels — from primary school to university — should be a priority task of modern pedagogy.