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DIGITAL TRANSFORMATION OF GRAPHIC TRAINING IN VOCATIONAL EDUCATION OF TECHNOLOGY TEACHERS

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The article analyzes the process of digital transformation of graphic training for future technology teachers within the system of professional higher education, using the example of Rivne State University of the Humanities. Theoretical foundations for the formation of graphic competence in future educators, as a key component of their professional training, are revealed. Special attention is paid to the integration of modern digital tools into the educational process, including Autodesk software, the Ukrainian-manufactured 3D printer Epo3D+, the AI-powered video platform Elai.io, the SimLab Composer software package for creating interactive 3D scenes and VR environments, the generative AI tool ChatGPT, and Google cloud services. The benefits of these technologies for developing spatial thinking, design, and project skills among higher education students are highlighted. Methodological approaches to organizing graphic training using digital tools are summarized. A practical example is presented: a student project on the topic "Designing a Drawing of an Interior Element" that illustrates the use of various digital instruments. Key challenges of digital transformation are outlined, such as equipment shortages, the need for teacher retraining, and the updating of curricula. The conclusions justify the necessity of systematic integration of digital technologies into graphic training for future educators and provide recommendations for further development. Prospective research directions include assessing the effectiveness of digital tools in graphic training, evaluating their impact on the development of students' graphic competence, and comparing traditional and digital approaches to teaching graphic disciplines.

Key words: *graphic training, digital learning tools, educational transformation, future technology teacher.*

ЦИФРОВА ТРАНСФОРМАЦІЯ ГРАФІЧНОЇ ПІДГОТОВКИ У ПРОФЕСІЙНІЙ ОСВІТІ ВЧИТЕЛЯ ТЕХНОЛОГІЙ

Ю. В. Фещук

У статті проаналізовано процес цифрової трансформації графічної підготовки майбутніх учителів технологій у системі фахової вищої освіти, на прикладі Рівненського державного гуманітарного університету. Розкрито теоретичні основи формування графічної

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компетентності педагогів, що є важливою складовою їхньої професійної підготовки. Особливу увагу приділено сучасним цифровим інструментам, які активно впроваджуються в навчальний процес: програмне забезпечення компанії Autodesk; 3D-принтер українського виробництва Epo3D+; хмарна платформа для створення відео за допомогою штучного інтелекту Elai.io; програмний пакет для створення інтерактивних тривимірних сцен, VR-середовищ і анімацій SimLab Composer; генеративний штучний інтелект ChatGPT, хмарні сервіси Google. Визначено переваги використання цих технологій для розвитку просторового мислення, конструкторських і проектувальних умінь здобувачів вищої освіти. Узагальнено методичні підходи до організації графічної підготовки із застосуванням цифрових засобів. Наведено приклад використання цифрових інструментів в процесі проектної діяльності здобувачів освіти на тему "Розробка кресленика елемента предмета інтер'єру". Виокремлено основні виклики цифрової трансформації – нестача обладнання, потреба у перепідготовці викладачів, оновлення змісту навчальних програм. У висновках обґрунтовано необхідність системної інтеграції цифрових технологій у графічну підготовку педагогічних кадрів та надано рекомендацій щодо її розвитку. Подальші дослідження у цьому напрямку можуть полягати у оцінюванні ефективності цифрових інструментів у процесі графічної підготовки майбутніх учителів технологій, з'ясування впливу цифрових інструментів на формування графічної компетентності здобувачів вищої освіти та порівняння традиційних і цифрових підходів до викладання графічних дисциплін.

Ключові слова: *графічна підготовка, цифрові засоби навчання, трансформація освіти, майбутній учитель технологій.*

Introduction of the issue. In the context of the rapid advancement of digital technologies, the education system is increasingly facing the necessity to revise both the content and methods of teacher training. Of particular importance is the graphic training of future technology educators, as it constitutes a fundamental component in the development of their professional competence within the domain of design and technological activities. The transition from traditional drafting tools to digital modeling environments necessitates a re-evaluation of the structure and methodology of the educational process.

Current state of the issue. Contemporary graphic training for future technology teachers in Ukraine in general, and at Rivne State University of the Humanities (RSUH) in particular, is grounded in a set of regulatory documents that govern the content, methods, and organizational forms of the educational process in higher pedagogical education. Among the key frameworks are: the Law of Ukraine "On Education" (which is relevant for the development of key teacher competencies, including digital and project-based, encompassing graphic training) [4]; the Law of Ukraine "On Higher Education" (which outlines requirements for academic programs, standards, and learning outcomes, including proficiency in specialized software, such as for graphic modeling) [3]; the Higher Education Standards (serving as a foundation for designing academic programs, curricula, and course content) [9]; the State Standards of Ukraine (DSTU), which regulate the formatting of drawings, diagrams, and graphic documentation [2]; model curricula and academic plans of higher education institutions (which include graphic disciplines such as "Descriptive Geometry and Technical Drawing", "Computer Graphics", and "Methods of Teaching Technical Drawing") [7]; and ministerial orders and methodological recommendations issued by the Ministry of Education and Science of Ukraine (regarding the digital transformation of education and informatization of the educational process) [12].

The issue of graphic training for students has been addressed in domestic academic literature by researchers such as I. Holiiad, L. Hrytsenko, O. Dzhedzhula, M. Koziar, H. Raikovska, T. Oliferenko, V. Sydorenko, and M. Yusupova, among others. Scholars emphasize the significance of graphic training as an integral component of future teachers' professional preparation.

In recent years, there has been growing academic interest in the integration of digital tools into the educational process. Liubov Khomenko, for instance, explores the digital transformation of visual collaboration in educational environments, highlighting the importance of effectively applying information and communication technologies to facilitate instructional interaction. Her research offers a detailed analysis of the Miro platform as an innovative tool, demonstrating its potential to support interactive learning and promote active student engagement in higher education [11].

A comprehensive overview of the technical and didactic potential of augmented and virtual reality technologies in education has been provided by Mykola Koziar and Oleksandr Tymoshchuk. Their work reveals the possibilities of optimizing the learning process through the use of these technologies, which contribute significantly to the development of students' logical, creative, and spatial thinking skills [5].

Aim of the research. The aim of this article is to substantiate the theoretical and methodological foundations of the digital transformation of graphic training for future technology teachers within the system of professional pedagogical education, and to analyze the potential of utilizing modern digital tools in this process.

The objectives of the study are as follows: to define the concept of "graphic training of technology teachers" in the context of educational digitalization; to analyze current trends in the digital transformation of pedagogical education in general, and graphic training in particular; to characterize the digital tools employed in the graphic training of future educators (such as AutoCAD, 3D printer Epo3D+, Elai, SimLab Composer, ChatGPT, Google) and to assess their functional capabilities; to identify the advantages and challenges associated with the use of digital technologies in the development of learners' graphic competence; to propose methodological approaches to integrating digital tools into the teaching of graphic disciplines; to outline the prospects for further research in the field of digitalization of graphic training and the development of adaptive digital learning environments.

Research methods. To achieve the aim of the study and address the outlined research objectives, a range of scientific methods was employed, including the following theoretical approaches: analysis of educational and methodological literature; review of scholarly publications relevant to the research topic; systematization and generalization of information; and examination of regulatory documents concerning the organization of the educational process in institutions of higher education.

Results and discussion. The essence of graphic training in the professional education of technology teachers lies in the development of students' knowledge, skills, and competencies necessary for creating, reading, interpreting, modeling, and visualizing objects using both traditional and digital graphic tools. This type of training is an integral part of the overall professional preparation of technology teachers, as it provides the foundation for project-based, design, artistic-technical, and creative activities.

The distinction between traditional and digitally-oriented graphic training for technology teachers manifests in the modes of instruction, content, tools, pedagogical approaches, and learning outcomes. A comparative overview of graphic training using traditional means versus digital tools is presented in Table 1.

The core components of graphic training for future technology teachers include the following:

1. Knowledge of the fundamentals of project-based graphics and technical drawing; familiarity with standards of graphic documentation; understanding the principles of 2D and 3D modeling;
2. Proficiency in graphic tools (both analog and digital, such as AutoCAD, SketchUp, SimLab, etc.); the ability to create technical drawings, sketches, mock-ups, and diagrams; experience with

3D printers, scanners, and graphic tablets;

3. Skills in communicating graphical information to students of various age groups; the development of educational and methodological materials using digital tools; the ability to integrate graphic activities into project-based learning, STEAM lessons, and modules of technological education;

4. Development of graphic competence as the capacity for visual and spatial thinking, technical literacy, and design creativity; fostering interdisciplinary connections with mathematics, computer science, design, physics, and visual arts.

Table 1

Comparative Characteristics of Graphic Training for Technology Teachers: Traditional Tools vs. Digitalization Context

Criterion	Traditional Graphic Training	Graphic Training in the Context of Digitalization
Learning tools	Drafting instruments, materials, and supplies	AutoCAD, graphic tablets, 3D printer, Elai.io, SimLab VR, ChatGPT, Google cloud services
Nature of learning activity	Manual drawing following a fixed algorithm	Digital design, modeling, integration with IT
Type of competencies	Graphic skills and fine motor abilities	Digital graphic competencies, media literacy
Format of results	Paper-based drawings	Electronic files (2D/3D), interactive videos, VR scenes
Teacher's role	Source of knowledge, evaluator	Facilitator, consultant, mentor in a digital environment
Learner's role	Passive assimilation, reproduction	Active content creation, project-based learning
Feedback	Delayed, during assessment	Instant, automated, adaptive
Learning flexibility	Static, limited error correction	Dynamic, easy editing, individualized learning paths
Application domain	Drafting in educational institutions, basic technological projects	STEAM projects, design, robotics, digital educational resources
Relevance to market demands	Partial alignment	High alignment with digital and engineering market needs

The digital transformation of education entails not only the technological modernization of learning environments but also a paradigm shift—from reproductive to activity-based learning, and from template-based to creative approaches. In the field of graphic training, this implies the integration of modern CAD systems, augmented reality platforms, online 3D modeling environments, and the use of intelligent assistants. At the same time, digitalization places new demands on educators' digital competence, the material and technical infrastructure of educational institutions, academic integrity, and the protection of intellectual property rights.

The graphic training of future technology teachers is determined by the content of the corresponding academic disciplines. The bachelor's degree curriculum in the specialty A4.10 "Secondary Education (Technology)" at Rivne State University of the Humanities (RSUH) includes the following graphic courses: Year 1 – "Descriptive Geometry and Technical Drawing" (210 hours – 7 ECTS credits); Year 2 – "Descriptive Geometry and Technical Drawing" (210 hours – 7 ECTS credits); Year 3 – "Computer Graphics" (120 hours – 4

ECTS credits) and "Methods of Teaching Technical Drawing" (120 hours – 4 ECTS credits). The total workload for these courses is 660 hours, equivalent to 22 ECTS credits [7].

An analysis of current practices in teacher training at RSUH reveals a number of digital tools employed in the process.

For instance, the university has been granted free access to Autodesk products for educational use [6]. One of the core applications, AutoCAD, is widely utilized for creating 2D and 3D drawings and enables the construction of precise technical models [13].

The following instructional approaches are proposed for integrating AutoCAD into the graphic training of future technology teachers:

- instruction in interface navigation, basic tools, and drawing creation;
- implementation of individual or group graphic projects (e.g., product models, furniture, interior designs);
- creation of models exportable in STL format for 3D printing;
- interdisciplinary connections with computer science, physics, mathematics, technology, and engineering (STEM/STEAM education).

The 3D models created in AutoCAD can be physically produced using a 3D printer. To this end, the Faculty of Arts and Technology at RSUH utilizes the Epo3D+ 3D printer, a device that enables the materialization of digital designs and contributes to the development of students' spatial thinking skills [10].

Both instructors and students at RSUH have been granted free access to SimLab VR Studio, a software suite for creating interactive 3D scenes, virtual reality environments, and animations. This tool offers new opportunities for immersive learning experiences [17].

Examples of integrating SimLab VR Studio into the graphic training process include:

- visualization of projects created, for example, in AutoCAD, for better understanding of spatial structures;
- material and surface texture modeling, as well as animation of object processing;
- in computer graphics classes, students design CAD models and export them to VR environments for project presentation and defense;
- during pedagogical internships – creation of virtual workshops or instructional laboratories [1].

The use of artificial intelligence (AI) in the graphic training of future technology professionals is considered particularly relevant, as it enhances learning effectiveness, aligns with labor market demands, and fosters the development of students' graphic, digital, and technological competencies.

Elai.io is an online AI-powered platform for video generation that enables the creation of multimedia instructional content without the need for filming or editing. It can be effectively integrated into the graphic training of future technology teachers as a modern tool for visualization, explanation, presentation, and didactic support of graphic content [14].

At RSUH, the educational use of Elai.io includes the following applications:

- development of voice-over video tutorials for explaining graphic concepts (e.g., constructing axonometric projections or unfolding geometric surfaces);
- creation of digital instructional materials (video lessons) for descriptive geometry, technical drawing, computer graphics (3D modeling), and working in AutoCAD, SimLab, etc.;
- presentation of student-created product or model projects;
- adaptation of graphic content for both visual and auditory perception (especially beneficial for students with special educational needs) [8].

For example, a student preparing a project using 3D modeling exports images from AutoCAD or Fusion 360, writes a commentary on the model, uploads the material to Elai.io, and generates a short video featuring a virtual presenter who explains and demonstrates the design process. Such materials can be used for

defending qualification (diploma) projects, building a professional portfolio, or as instructional resources.

ChatGPT, a generative artificial intelligence tool, has also found educational application in the graphic training of future technology teachers. It may serve as a digital assistant capable of explaining concepts, formulating graphic tasks, verifying results, and more [16].

The role of ChatGPT in the graphic training of future technology educators includes:

- generating lesson plans, practical activity scenarios, and instructions for graphic assignments;
- explaining concepts related to technical drawing, CAD graphics, file formats, etc.;
- creating exercises, graphic problems, test questions, and project-based case studies;
- assisting in formulating commands for use in other tools (AutoCAD, Fusion 360, Elai, SimLab);
- suggesting free software, online services, and instructional resources for practical application.

Cloud-based services such as Google Workspace for Education also play a significant role in the modernization of graphic training. Their advantages include free access, real-time collaboration, automatic saving of changes, cross-device availability, and a high level of integration among services. However, some limitations remain, including the need for a stable internet connection, constraints when handling large graphic files (e.g., DWG files >50 MB), and limited support for vector graphics in certain tools [15].

Examples of how Google cloud services can be used in the graphic training of future technology teachers include:

- storage of drawings, 3D models, and project documentation; creation of structured digital portfolios (Google Drive);
- drafting explanatory notes and graphic task instructions, collaborative editing of documents (Google Docs);
- visualization of graphic projects, creation of digital reports, and online project presentations (Google Slides);
- use of spreadsheets for calculations, development of specifications, and planning schedules (Google Sheets);
- creation of tests for graphic disciplines, surveys on content comprehension, and student self-assessment (Google Forms);
- collaborative visualization of graphic ideas and sketches (Google Jamboard);
- organization of a digital course in graphic training: course structure, assignments, instructions, assessment (Google Classroom);
- creation of digital student portfolios or virtual exhibitions of project work (Google Sites).

Google cloud services are considered a powerful tool for advancing the digitalization of graphic training for technology teachers. While they do not replace specialized CAD software, they effectively complement it-especially at the stages of organization, communication, presentation, and evaluation of graphic activities.

Table 2 provides an example of how these digital tools can be integrated into student project-based activities on the topic "Designing a drawing for an interior object (e.g., a book holder or decorative stand)".

Table 2

Use of Digital Tools in Project-Based Activities of Future Technology Teachers

Stage	Digital Tool	Description of Use
1. Task analysis and idea generation	ChatGPT	Idea generation, analysis of technical requirements, suggestions regarding standards (DSTU/ISO), explanation formulation
2. 2D drawing construction	AutoCAD	Creation of technical drawings with dimensioning; solving geometric problems

3. Conversion of drawing into a 3D model	AutoCAD / Fusion 360	Extrusion of contours into a 3D model; exporting the model in STL format
4. 3D printing of the object	Epo3D+ 3D printer	Printing the model from an STL file; evaluation of shape accuracy and ergonomics
5. Product visualization in VR	SimLab Composer	Creating a virtual reality scene with the object; enabling 360-degree exploration of the model
6. Video presentation preparation	Elai.io	Generating a video with an AI avatar describing the model, its design features, and applications
7. Presentation and result archiving	Google Cloud Services (Drive, Slides, Meet)	Storing all project materials, conducting an online presentation via Google Meet, and showcasing the project using Google Slides
8. Evaluation and feedback	Google Forms, ChatGPT	Online surveys (self-assessment, peer evaluation), generation of recommendations based on project results

Thus, the integration of these tools into the educational process enables future technology teachers to expand their repertoire of didactic resources, enhance teaching efficiency, and foster students' creativity.

The primary barriers to the digitalization of graphical training include limited technical infrastructure in educational institutions, a shortage of qualified instructors in digital technologies, a lack of updated instructional and methodological materials, and insufficient digital literacy among some learners.

To address these challenges, it is essential, in our view, to revise educational standards and curricula in line with contemporary digital realities; ensure access to open-source software; organize professional development courses focused on educators' digital literacy; and foster partnerships with IT companies to jointly modernize the educational process.

Conclusions and research perspectives. The digital transformation of graphical training for future technology teachers is a key factor in the modernization of professional education. It promotes the development of new forms of learning, the integration of contemporary digital tools, increased learner motivation, and alignment of training with the demands of the digital economy. The successful implementation of this transformation requires systemic institutional support and a high level of professional competence among teaching staff.

Further research in this area may focus on assessing the impact of tools such as AutoCAD, 3D printers, Elai, SimLab, ChatGPT, and Google services on the development of learners' graphical competence. Additionally, there is a need to compare traditional and digital approaches to teaching graphical disciplines.

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