

Introduction of Digital Technologies in Vocational Education: Tools for Transforming the Learning Process and Improving the Quality of Staff Training

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Abstract: The relevance of the study is determined by the processes of digital transformation in the transport industry and the need to modernize the vocational education system aligned with European standards for the development of digital and professional competencies of railway transport specialists. The purpose of the article is to examine the impact of digital technologies and tools on the quality of professional training of future railway industry specialists in the context of the digitalization of education. The research methodology is based on a combination of analysis of scientific sources, generalization of the results of pedagogical pedagogical experiments and student surveys, a comparative analysis of indicators reflecting the development of digital and professional competencies. The findings indicate that the integration of interactive digital instructional materials contributes to increased learning motivation, the development of digital competence, and improved practical training for future railway transport specialists. It has been proven that digital tools provide a closer link between theoretical learning and practical professional activity, as well as facilitates the development of students' critical thinking skills and independent work skills among students. It has been shown that the introduction of digital solutions into professional training is consistent with the principles of competence-oriented education and increases the adaptability of graduates to the demands of the modern labor market. The theoretical significance of the results lies in the generalization of approaches to the digitization of vocational education within the framework of European education policy; the practical significance of the study lies in the applicability of its findings for enhancing the content, formats, and methods of training transport specialists, as well as for the design and implementation of contemporary digital educational resources.

1 INTRODUCTION

Digital transformation is one of the key characteristics of modern European development, covering the economy, transport infrastructure, and education system. Rail transport plays a strategic role in ensuring sustainable mobility, economic integration, and environmental safety, which leads to increased requirements for the professional preparation of industry specialists. In this context, there is an increasing demand for specialists capable of effectively operating digital management systems, automated technologies, and intelligent transport solutions.

The vocational education and training (VET) system in European countries is gradually

transforming in line with the principles of digital education, lifelong learning, and a competency-based approach. At the same time, the problem of insufficient the integration of digital technologies into the training of technical specialists remains a pressing issue for many education systems, particularly in light of the need to align with the requirements of the European labor market.

In this regard, the implementation of interactive digital instructional teaching materials that combine theoretical content, multimedia elements, and practical tasks using simulators is becoming particularly relevant. Such tools contribute to improving the quality of education, developing digital competence, and shaping the professional readiness of future railway transport specialists.

The purpose of the article is to provide a comprehensive analysis of the impact of digital technologies and tools on the quality of training for railway transport specialists within the framework of the European digital transformation of education.

2 LITERATURE REVIEW

The digitization of vocational education and the professional training of technical and transport specialists is widely represented in contemporary scientific research. A significant body of literature focuses on examining the role of digital technologies in transforming educational systems, fostering digital competence development, and aligning vocational education with contemporary labor market demands. Recent studies also highlight the importance of blended learning models and the readiness of teaching staff as key factors influencing the effectiveness of digital transformation in vocational education [1].

In the works of Ukrainian researchers [2], [3], digital technologies are regarded as a critical driver of improving the quality of professional training by fostering interactive learning, individualizing educational trajectories, and enhancing the development of practical skills. The authors emphasize the need to shift from traditional instructional models toward innovative, learner-centered approaches that actively engage students through multimedia and network-based resources. Similar ideas are further developed in the studies by Sazhko, Strutynska, and Umryk [4], [5], where the digitization of education is interpreted as a systemic transformation of pedagogical approaches and educational environments driven by the dynamics of the digital society. At the same time, researchers emphasize the growing role of artificial intelligence and deep learning technologies in expanding access to vocational education and improving learning outcomes [6].

A distinct line of inquiry focuses on the formation and advancement of digital competence among teachers and students in vocational education. Research in this field underscores the significance of information and communication technologies as instruments for strengthening pedagogical professionalism, fostering continuous professional development, and ensuring the meaningful integration of digital educational resources into the instructional process [7]. These findings are complemented by research emphasizing the importance of competence-based models in vocational education under conditions of crisis and

systemic change, where digitalization serves as a tool for maintaining sustained delivery of education and quality [7]. In this context, particular attention is paid to the development of meaningful learning experiences through innovative digital pedagogy, which enhances student engagement and supports practice-oriented training [8].

An essential aspect of educational digitalization pertains to the management and governance of educational institutions, as these factors directly determine the effectiveness of implementing digital innovations implementation Kubitskyi et al. [9] argue that the digital transformation of higher education management enhances institutional capacity, supports sustainable development, and creates favorable conditions for the systematic adoption of digital educational tools. This managerial perspective is highly relevant for vocational and technical education institutions, where organizational readiness and strategic leadership play a critical role in the successful integration of digital learning environments. Furthermore, the integration of digital technologies in vocational education is increasingly associated with the principles of Industry 5.0, which emphasize human-centered and technologically enhanced learning environments [10].

The digitization of training for transport and railway specialists is considered in studies focusing on the application of intelligent systems, automated control technologies, and digital security solutions. Akulov et al. [11] demonstrate that computer-based training tools significantly contribute to the development of practical skills in students, increasing their readiness to work with complex technical systems. Similarly, Vinichenko [12] emphasizes the importance of technology-oriented models of training personnel in the transport industry, highlighting the role of digital simulations and applied learning technologies in professional training. These approaches are supported by studies that identify emerging technologies, including virtual environments and digital platforms, as effective tools for developing industry-relevant competencies in vocational education [13].

At the same time, several authors draw attention to the barriers hindering the effective implementation of e-learning in railway and transport education. Fraszczyk and Piip [14] identify limited resources, insufficient digital infrastructure, along with disparities in digital preparedness among stakeholders in the educational process, as significant factors limiting the scalability and long-term sustainability of digital initiatives learning solutions.

International policy-oriented studies and analytical reports further contextualize these findings. Initiatives aimed at increasing flexibility and innovation in apprenticeship and technical training systems emphasize the role of digital technologies in enhancing accessibility, adaptability, and lifelong learning opportunities [15]. These approaches align with broader European and global trends that prioritize digital competence as a core skill across all levels of education and professional training.

Despite the growing body of research on educational digitalization, the analysis of scientific sources indicates that insufficient attention has been paid to the comprehensive use of interactive digital learning materials specifically in the training of railway transport specialists within vocational education systems. This research gap underscores the need for further studies aimed at substantiating the pedagogical effectiveness of digital tools and identifying the conditions necessary for their successful and sustainable implementation in vocational railway education.

3 METHODOLOGY

The study is grounded in a comprehensive integration of theoretical and empirical methods aligned with European frameworks of evidence-based education and established quality assurance standards in vocational education and training. The theoretical stage involved a systematic analysis of scientific publications, analytical reports from international organizations, and regulatory and methodological documents aimed at studying the processes of digitization of vocational education, the development of digital competence, and the modernization of training for technical and transport specialists.

The empirical part of the study included a questionnaire, expert assessment, self-assessment, and a pedagogical experiment. The study involved a total sample of 43 students enrolled in railway-related vocational education programs, including 21 students in the control group (CG) and 22 students in the experimental group (EG). The sample was formed using a purposive sampling approach, ensuring the comparability of groups in terms of educational level and specialization.

The questionnaire was used to identify the dynamics of learning motivation, students' satisfaction with the overall quality of education, and the formation of digital and professional competencies of students. The questionnaire consisted of 9 items combining single-choice,

multiple-choice, and open-ended questions. In particular, it included: 1) frequency of digital technology use; 2) types of digital tools used; 3) perceived effectiveness of digital technologies in learning; 4) advantages of digital tools; 5) challenges and barriers; 6) evaluation of the level of digitalization in the institution; 7) open-ended suggestions for improving digital learning; 8) attitudes toward studying digital-oriented disciplines; and 9) demographic data (gender).

To measure students' perceptions, ordinal scales were applied (e.g., frequency scales and 5-level evaluation scales ranging from "very high" to "very low" or from "very strong" to "no impact"). Multiple-choice questions allowed respondents to select several relevant options, enabling a broader analysis of digital tool usage and perceived benefits. Open-ended responses were used to capture qualitative insights into students' needs and expectations.

The content validity of the questionnaire was ensured through alignment with the research objectives and prior studies in the field of digitalization of vocational education, as well as through expert review. Reliability was supported by the consistency of responses across related items and the standardized structure of the questionnaire.

The expert assessment was aimed at determining the pedagogical expediency, methodological validity, and practical significance of digital learning materials. The expert group included 5 educators with experience in vocational and technical education, who evaluated the developed digital manual based on criteria such as relevance, usability, interactivity, and pedagogical effectiveness using a 5-point scale. The self-assessment method made it possible to evaluate the level of awareness of students' readiness for professional activity in a digital educational environment.

A key element of the empirical study was a pedagogical experiment aimed at testing the effectiveness of introducing an interactive digital manual on the course "Digital Technologies in Railway Transport" into the professional preparation of prospective railway transport specialists within the vocational education framework. The experimental design incorporated a comparative evaluation of learning outcomes across control and experimental groups, enabling an objective assessment of the effects of digital tools on academic performance.

For data analysis, descriptive statistical methods were applied, including percentage distribution of responses and comparative analysis between groups. The results of the questionnaire were visualized using diagrams to reflect trends in digital technology usage,

perceived benefits, and existing challenges. To assess differences between control and experimental groups, comparative analysis of percentage changes in learning outcomes was conducted.

The methodological approach used ensures the scientific validity, reliability, and reproducibility of the research results and meets current European requirements for evaluating the effectiveness of digital innovations in the vocational education system.

4 RESULTS AND DISCUSSION

4.1 Findings on the Implementation of Digital Technologies

The findings of the study are derived from an analysis of the integration of digital technologies into the educational processes of vocational (technical) education. The main focus is on assessing the impact of digital solutions on the quality of education, the development of professional and digital competencies of students, as well as the effectiveness of using interactive educational resources in training future specialists in the railway industry.

The key practical result of the research was the development and implementation of an interactive multimedia guide for the course “Digital

Technologies in Railway Transport,” created on the Book Creator platform. This resource combines theoretical material, multimedia elements, and practice-oriented tasks aimed at developing digital competence, professional thinking, and the ability to apply modern technologies in production activities.

The structure of the interactive manual includes an introduction with a definition of the objectives and expected learning outcomes, a list of literature and sources for independent study, as well as thematic modules:

- 1) Topic 1. Introduction to digital technologies in rail transport: overview of key concepts and trends;
- 2) Topic 2. Internet of Things (IoT), Artificial Intelligence (AI), and their application in rail transport;
- 3) Topic 3. Digital infrastructure monitoring and management systems;
- 4) Topic 4. Automated train control systems (ATCS);
- 5) Topic 5. Digital technologies in the maintenance and repair of rolling stock;
- 6) Topic 6. Digital freight transport management systems;

- 7) Topic 7. Innovations and future directions for the advancement of digital technologies in rail transport;
- 8) Topic 8. The role of digital technologies in promoting the sustainable development of rail transport;
- 9) Topic 9. Practical dimensions of implementing digital technologies in rail transport.

The course is structured based on the principle of gradually increasing the complexity of the material, from the basic concepts of railway digitalization to the practical aspects of implementing digital systems, innovations, and sustainable development in the industry.

4.2 Results of the Questionnaire and the Ascertaining Stage of the Experiment

At the descriptive stage of the study, a survey was conducted among students enrolled in railway-related programs to assess the extent of digital technology and tool utilization within the educational process. The findings indicated that the integration of digital solutions was insufficient: more than half of the respondents rarely use digital technologies in their studies (see Fig. 1).

How often do respondents use digital technologies and tools in learning?

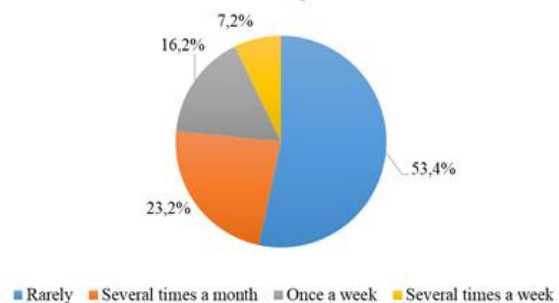


Figure 1: How often do respondents use digital technologies and tools in learning?

Analysis of the responses showed that portable devices and educational platforms (Moodle, Google Classroom), as well as interactive whiteboards, are most commonly used in the learning process (see Fig. 2). At the same time, innovative tools such as simulators, virtual and augmented reality, gamified assessment platforms, and digital manuals are rarely used.

Digital technologies and tools most commonly used in education

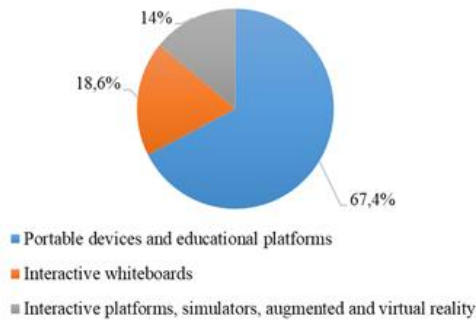


Figure 2: Digital technologies and tools most commonly used in education.

Despite this, most respondents positively assess the impact of digital technologies on learning: respondents noted their significant help in mastering the material (see Fig. 3).

How much do digital technologies and tools help you in your studies?

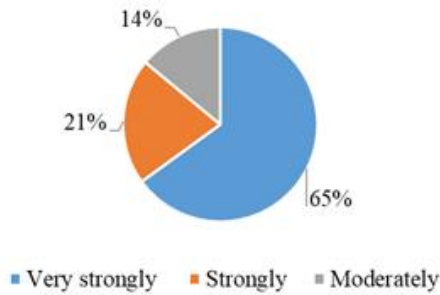


Figure 3: How much do digital technologies and tools help in learning?

The main advantages of using digital tools are convenience and mobility, as well as improved access to educational information (see Fig. 4).

Advantages of using digital technologies and tools in education

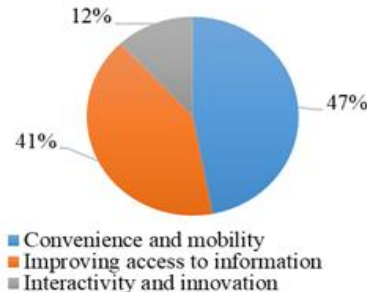


Figure 4: Advantages of using digital technologies and tools in education.

At the same time, a number of problems were identified that hinder the digitization of the educational process. Among the main difficulties, respondents cited insufficient digital skills, technical problems, and the high cost of equipment and software (see Fig. 5).

Difficulties in using digital technologies and tools

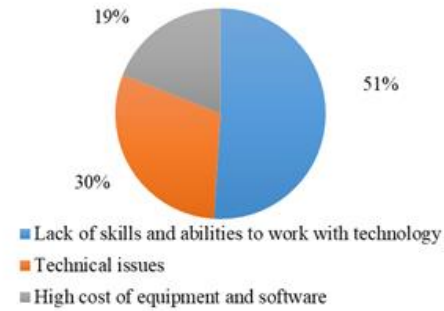


Figure 5: Difficulties in using digital technologies and tools.

Thus, the analysis points to a clear mismatch between the positive perception of digital technologies and their limited practical use in the educational process. Although students recognize the benefits of digital tools in improving learning outcomes, accessibility, and convenience, their use remains largely limited to basic platforms and devices. The identified barriers – insufficient digital skills, technical limitations, and financial constraints – highlight the need for a more systematic and targeted approach to digital integration, creating conditions conducive to the broader and more effective integration of digital technologies.

4.3 Formative Stage of the Experiment and Comparative Analysis of Findings

Based on the outcomes of the diagnostic (ascertaining) stage, a formative pedagogical experiment was organized. The students were divided into a control group (CG) and an experimental group (EG). The initial indicators of the level of knowledge and skills in the field of digital technologies in both groups were comparable and were characterized by a predominance of average and low levels (Table 1).

Table 1: Results of the diagnostic assessment of students in the ascertaining experiment.

Level of knowledge and skills acquired by students	Students who participated in the experiment	
	CG	EG
High	14% (3 students)	9% (2 students)
Average	57% (12 students)	50% (11 students)
Low	29% (6 students)	41% (9 students)

During the formative stage, the experimental group consistently employed the interactive manual and digital tools in the completion of practical assignments, whereas the control group received instruction through a traditional instructional model. After the experiment was completed, a repeat diagnosis was conducted, the results of which are presented in Table 2.

Thus, comparative analysis showed a significant increase in the level of digital knowledge and skills among students in the experimental group. In particular, the proportion of students with a high level of training increased significantly, while the number

of students with a low level decreased. Only minor changes were recorded in the control group, indicating the limited effectiveness of traditional approaches without the active use of digital resources.

4.4 Discussion of Results and SWOT Interpretation

The empirical data obtained were summarized and interpreted using SWOT analysis (Table 3), which made it possible to systematically assess the impact of digital technologies and tools on the quality of training of railway industry specialists.

The strengths include expanded access to educational information, interactivity and personalization of learning, increased digital literacy among learners, and improved competitiveness in the labor market. Opportunities are linked to the implementation of innovative academic courses, the expansion of international collaboration, and the advancement of distance and flexible learning formats.

Table 2: Findings of the diagnostic assessment conducted during the ascertaining stage of the experiment.

Level of knowledge and skills acquired by students	Experimental groups					
	CG			EG		
	Constatative stage	Formative stage	Difference (%)	Constatative stage	Formative stage	Difference (%)
High	14% (3 students)	14 % (3 students)	+0%	9% (2 students)	36% (8 students)	+27%
Average	57% (12 students)	62 % (13 students)	+5%	50% (11 students)	55% (12 students)	+5%
Low	29% (6 students)	24 % (5 students)	-5%	41% (9 students)	9% (2 students)	-32 %

Table 3: SWOT analysis of the impact of digital technologies and tools on the quality of education and training of specialists.

Strengths	Weaknesses
<ol style="list-style-type: none"> 1) A significant increase in the proportion of students with high levels of digital competence in the experimental group (+27%). 2) Improving learning effectiveness through the use of an interactive digital guide. 3) Students have a positive view of digital technologies (the majority note their usefulness in learning). 4) Improved learning outcomes in the EG compared with the CG (a consistent upward trend). 	<ol style="list-style-type: none"> 1) Initially, there was a high proportion of students with poor digital skills (41% in the EG). 2) Limited use of advanced digital technologies (VR, simulators) in the actual teaching process. 3) The lack of digital literacy among some students, which makes it difficult to implement complex digital tools. 4) The limited availability of teaching materials adapted for digital formats in traditional courses.
Features	Threats
<ol style="list-style-type: none"> 1) Expanding the use of the interactive digital guide to other subjects. 2) Further improvement of students' digital skills, building on the positive results of the pilot scheme. 3) The integration of more advanced technologies (VR/AR, simulators) into the learning process. 4) Expanding the use of blended learning based on the results of the experiment. 	<ol style="list-style-type: none"> 1) Dependence on technical infrastructure (risk of disruptions to digital systems). 2) The rapid obsolescence of digital technologies and the need to constantly update resources. 3) Unequal access for students to digital resources outside the educational institution. 4) The lack of digital literacy among some teachers hinders the full implementation of innovations.

At the same time, potential weaknesses and risks encompass financial limitations, technical malfunctions, unequal access to digital resources, insufficient professional development of teaching staff, cybersecurity challenges, and the rapid obsolescence of technological solutions. This requires a strategic approach to the digital transformation of education.

4.5 Generalization and Educational Implications

The results of the study confirm that digital technologies are not only an auxiliary tool, but also a systemic factor in improving the overall quality and effectiveness of vocational education. The implementation of interactive multimedia manuals enhances students' learning motivation, fosters the development of practical digital competencies, and strengthens their preparedness for professional activity within the ongoing digital transformation.

Therefore, the strategic and purposeful integration of digital technologies into the educational process contributes to significant qualitative transformations in the professional training of specialists.

5 CONCLUSIONS

The results of the empirical study demonstrate not only the general effectiveness of digital technologies, but also specify the conditions and tools that ensure measurable improvements in the professional training of future railway specialists. In particular, the implementation of the interactive multimedia guide developed on the Book Creator platform proved to be an effective pedagogical solution that integrates theoretical content, multimedia elements, and practice-oriented tasks into a unified digital learning environment.

The comparative analysis of the control and experimental groups confirmed a statistically significant positive dynamic in the development of students' digital and professional competencies. In the experimental group, the proportion of students with a high level of knowledge increased from 9% to 36% (+27%), while the share of students with a low level decreased from 41% to 9% (-32%). In contrast, the control group demonstrated only minor changes, which indicates the limited effectiveness of traditional instructional approaches without systematic digital support.

The findings also revealed a contradiction between students' positive perception of digital

technologies and their limited actual use in the educational process. Despite recognizing their effectiveness for improving accessibility, flexibility, and learning outcomes, students primarily use only basic digital tools (e.g., learning platforms and portable devices), whereas advanced technologies such as simulators, virtual and augmented reality, and interactive digital manuals remain underutilized.

The study identifies key barriers to the effective integration of digital technologies, including insufficient digital competence of participants in the educational process, technical limitations, and financial constraints. These factors necessitate a systematic approach to digital transformation that includes targeted teacher training, modernization of digital infrastructure, and the integration of specialized interactive learning resources into curricula.

Thus, the novelty of the study lies in substantiating the pedagogical effectiveness of interactive multimedia learning tools specifically for the training of railway transport specialists and in identifying the organizational and methodological conditions required for their successful implementation. The practical significance of the results is reflected in the possibility of scaling the developed digital resource and adapting it for other vocational education programs in technical fields.

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