

DEVOPS AS A PEDAGOGICAL FRAMEWORK FOR INTEGRATING INFORMATION AND COMMUNICATION TECHNOLOGIES INTO THE PROFESSIONAL TRAINING OF IT SPECIALISTS

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Abstract. The article discusses updating the content and methods of professional training for information technology (IT) specialists in the context of digital educational transformation. The labor market requires university graduates to have in-depth knowledge of programming and administration, as well as the ability to work in integrated teams and use modern information and communication technologies and automation tools. However, traditional training models have been found to focus primarily on fundamental components, creating a gap between academic education and employer demands. To bridge this gap, the article proposes using the DevOps methodology as a pedagogical framework to integrate ICT into the educational process. A conceptual model of professional training for IT specialists has been developed that includes target, content, procedural-technological, and result-oriented blocks. In this model, DevOps is considered an element that forms the system of the educational process, combining theoretical training, practice-oriented tasks, and the use of innovative technology. Particular attention is paid to developing DevOps competence as an integrated skill set encompassing cognitive, activity-oriented, communicative, and reflective components. The results showed that implementing the DevOps pedagogical framework significantly increased the level of professional competence. Students in the experimental groups demonstrated confidence in using DevOps tools, the ability to work effectively in teams using information and communication technologies and awareness of the importance of continuous improvement. A comparative analysis of the control and experimental groups' results, confirmed by statistical methods, proved the data's reliability. This study's practical significance lies in its potential application in higher education institutions and professional development systems. This approach can modernize IT education programs and produce graduates who can operate effectively in the modern labor market and digital economy.

Keywords: DevOps pedagogical framework, information and communication technologies, professional training of IT specialists, DevOps competence, digital transformation of education.

1. INTRODUCTION

The current stage of societal development is characterized by a large-scale digital transformation. This transformation encompasses the economy, manufacturing, public administration, and education. In this digital age, the education system must overhaul its content, methods, and forms of teaching. This is particularly true for the professional training of information technology (IT) specialists.

The rapid growth of the IT industry creates new requirements for specialists. Graduates are expected to have in-depth knowledge of programming, administration, and testing. Employers also need them to be able to work in interdisciplinary, integrated teams. They must be able to interact effectively, organize

joint processes, and utilize modern automation tools. Equally important is a willingness to continuously improve professional activities.

Traditional approaches to student training often focus primarily on foundational knowledge. This creates a gap between academic education and the real needs of the labor market. There is a need for methodologies and educational models that provide practical training and develop students' professional competencies.

In this context, the DevOps methodology is especially important. Although it originated as a technological approach in IT, its scope extends far beyond the purely technical sphere. DevOps can be viewed as a pedagogical framework that establishes a new organizational logic for the educational process. Integrating DevOps with information and communication technologies (ICT) effectively combines theoretical training with real-world IT industry practices.

This raises the question of how to use the DevOps methodology to integrate ICT into the professional training of IT specialists, thereby increasing their competitiveness and expertise.

2. LITERATURE REVIEW

Contemporary scholars have devoted considerable attention to the digital transformation of education (Esin & Büyüköztürk, 2023; de S. Oliveira & De Souza, 2022; Konrad, Volkogon, Noga, Gajewska, & Sulkowski, 2024; Polishchuk, 2025) as well as the use of information and communication technologies (Abdul & Kusnafi Zal, 2024; Bilan et al., 2023; Guaña-Moya et al., 2022; Radanliev et al., 2024). Other works (Zou et al., 2025; Lee & Chang, 2025; Slippchysyn et al., 2024; Gurevich et al., 2023) focus on studying digital educational environments. These studies also aim to examine their development. The authors emphasize the importance of using ICT to improve the effectiveness of the educational process. They also highlight the importance of tailoring educational paths and cultivating students' professional competencies.

Foreign works extensively discuss the DevOps methodology. It is presented as an innovative approach in the IT industry (Sánchez-Cifo, Bermejo, & Navarro, 2023). Other research describes DevOps as a cultural and technological paradigm (Khan et al., 2022). DevOps ensures the speed of development, the quality of software, and the reliability of its operation. Vangala (2025) emphasizes the need for close interaction between development and administration teams.

Scientific publications from the last decade reveal another trend, particularly the works of Fernandes et al. (2022) and Mekić et al. (2024). DevOps is considered an educational tool as well as a technology. The authors emphasize the importance of incorporating DevOps into university and corporate academy curricula. This gives students the opportunity to gain practical experience that closely resembles the conditions of the IT industry.

Domestic scientists are also beginning to pay attention to integrating DevOps into higher education systems (Luchkevych, Luchkevych, & Shakleina, 2025). Some studies have already been conducted on applying DevOps to the training of computer science teachers (Pavlenko et al., 2023) and IT specialists developing mobile applications (Diemientiev et al., 2025). However, the pedagogical aspects of this methodology have not yet been sufficiently explored. Currently, there is a lack of comprehensive studies that combine the technological content of DevOps with its pedagogical potential.

Additionally, the interaction between DevOps and information and communication technologies in the professional training of IT specialists has not been extensively studied. Most existing publications focus on technical aspects, particularly automation, security, and cloud technologies. Nevertheless, the question of how to integrate these tools into a comprehensive educational model remains unanswered.

An analysis of scientific sources reveals a significant gap. This gap is characterized by a lack of thorough pedagogical understanding of DevOps as a framework for organizing the educational process based on ICT. This gap underscores the relevance of the chosen research topic.

The research goal. This article aims to theoretically justify and experimentally verify DevOps as a

pedagogical framework for integrating ICT into the professional training of IT specialists.

3. RESEARCH OBJECTIVE, METHODOLOGY AND DATA

A set of interrelated methods was employed to achieve the goal of the work. These methods were selected based on the specifics of the research and the need for reliable results.

Theoretical methods included analyzing, synthesizing, comparing, and classifying scientific sources. These methods enabled us to assess the development stage of the issue in domestic and foreign science. They also identified key trends in the digital transformation of education and highlighted approaches to integrating DevOps into the professional training system for IT specialists.

We used the modeling method to develop the DevOps pedagogical framework. This created a conceptual model that combined target, content, procedural-technological, and result blocks. Using this method ensured the scientific novelty of the research and helped verify its hypothesis.

Empirical methods included a pedagogical experiment, questionnaires, testing, and expert evaluation. The pedagogical experiment verified the effectiveness of the proposed model in real educational settings. Questionnaires and testing helped identify students' level of DevOps competence. Expert evaluation guaranteed the objectivity of the results and enabled qualitative interpretation.

Statistical methods were necessary for quantitatively and qualitatively processing the obtained data. We employed methods of variational statistics, mean value comparison, and the calculation of Student's t-test and chi-squared. These methods determined the statistical significance of the differences between the experimental and control groups.

Combining theoretical, empirical, modeling, and statistical methods ensured the study's comprehensiveness. This combination enabled the theoretical justification, practical verification, and scientific interpretation of the results.

4. RESULTS AND DISCUSSION

The conceptual foundations of the DevOps pedagogical framework model

The study resulted in the development of a DevOps pedagogical framework model (Fig. 1), which incorporates information and communication technologies into the professional training of future IT specialists. This systematic model consists of four interconnected blocks: target, content, procedural-technological, and result-oriented. DevOps is considered a pedagogical system that combines the principles of joint activity, automation, iterative improvement, and team responsibility, as well as a technological approach.

The target block outlines the objective of cultivating DevOps proficiency, an all-encompassing professional skill encompassing cognitive, activity-based, communicative, and reflective elements.

The content block combines foundational IT knowledge with hands-on proficiency in DevOps tools (GitLab CI/CD, Docker, Kubernetes, Ansible, and Prometheus). Particular emphasis is placed on using ICT as a medium for educational interaction.

The procedural and technological block describes learning organization methods and forms, including project-based and problem-based learning, team activities, DevOps simulation labs, cloud platforms, containers, and automated pipelines.

The results block outlines the criteria for evaluating DevOps competence in the cognitive, activity-based, communicative, and reflective domains. Each domain has four levels: initial, basic, productive, and professional.

The developed model integrates educational objectives and technological tools into a unified pedagogical system that streamlines the shift from theoretical learning to practical training. The system is grounded in the principles of systematicity, continuous improvement, ICT integration, teamwork, and accountability.

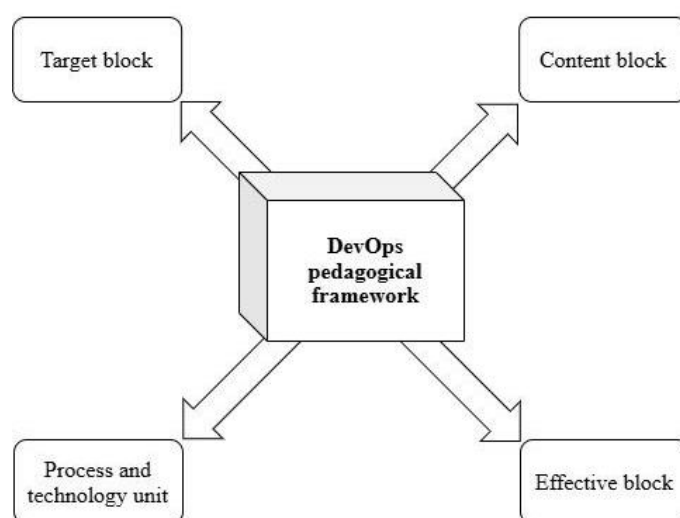


Fig. 1: DevOps Pedagogical Framework Model

Source: compiled by the author

The organisation and methodology of pedagogical experiments

The effectiveness of the model was tested at Lviv Polytechnic National University. Students from the Department of Information Systems and Networks at the Institute of Computer Science and Information Technology participated in the study.

Of those students, 64 enrolled in the Distributed Information Systems program took part in the study. To ensure the purity of the experiment, the students were divided into two groups. The first group consisted of the experimental group, for which the educational process was carried out using the developed model. The second group consisted of the control group, which received training according to the traditional program without DevOps integration.

The main goal of the pedagogical experiment was to determine whether the proposed DevOps-based model provides more effective professional competency development. Particular attention was paid to verifying the extent to which DevOps contributes to the integration of ICT into the educational process as a pedagogical framework, as well as its ability to increase the level of professional training of graduates.

A generalized diagram (Fig. 2) was created to illustrate the logic of the study and the relationships between its key components. The diagram shows the sequence of transitions from the initial problem to the primary solutions and forms the conceptual basis of the study.

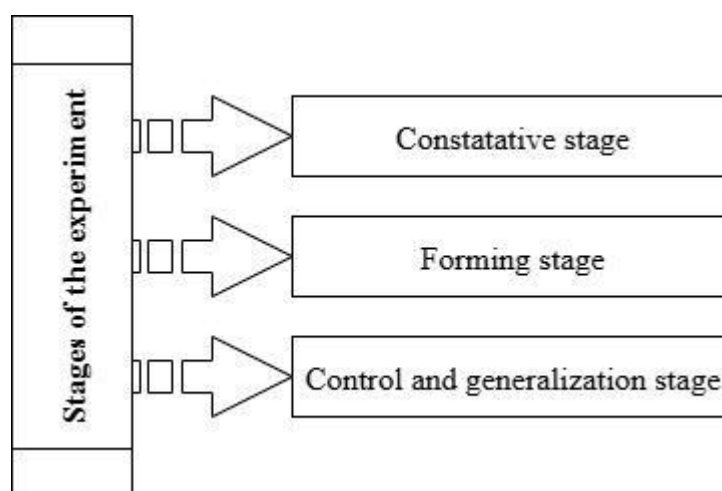


Fig. 2: Stages of the Experiment

Source: compiled by the author

At the initial stage, the level of DevOps competence among the students was determined. Four criteria were used for this purpose:

- cognitive criterion reflected the students' knowledge of DevOps concepts.
- activity criterion determined the ability to work with CI/CD, Docker, and Kubernetes tools.
- communication criterion assessed the ability to collaborate effectively with a team using ICT.
- reflective criterion showed how much students realized the importance of continuous improvement in their professional activities.

The results revealed a general picture. Most students in both the experimental and control groups demonstrated a low or medium level of DevOps competence. This confirmed the need to introduce new pedagogical approaches.

During the formative stage, the author implemented the DevOps pedagogical framework model with the experimental groups. This involved several areas of work:

- use of cloud environments and containerization during laboratory classes,
 - implementation of student projects using GitLab CI/CD, Ansible, Kubernetes, and Prometheus tools,
 - organization of team DevOps hackathons to develop practice-oriented competencies,
- the use of problem- and project-based learning to develop independent thinking and teamwork skills.

The learning process in the control groups was carried out traditionally. The program did not involve the use of DevOps tools or related teaching methods. This made it possible to objectively compare the results of both groups.

Dynamics of change and quantitative results

Initially, most students in both the experimental and control groups demonstrated a low or medium level of DevOps competence. This indicated that DevOps approaches had not been sufficiently integrated into the educational process and that the training content and methods needed updating.

Following the formative stage, however, the experimental group showed a significant increase in all components of competence. Positive dynamics were observed in the cognitive, activity, communication, and reflective components (Table 1).

Tab. 1

Changes in DevOps competence levels among students

Competence component	Indicator	Before the experiment, %	After the experiment, %	Increase (Δ), %
Cognitive	Level of proficiency in DevOps principles (CI/CD, containerization, automation)	14	45	+31
Practical component	Performing DevOps tasks using Docker, GitLab CI/CD, Kubernetes	28	80	+52
Communication	The effectiveness of teamwork during DevOps hackathons and projects	32	73	+41
Reflective	Understanding the principle of continuous improvement	36	78	+42
Average indicator	Integral level of DevOps competency development	27,5	69,0	+41,5

Source: Author's own elaboration

A similar table for the control groups (not shown here) revealed only minor changes; the average increase did not exceed 10%. This confirms the statistical significance of the differences between the experimental and traditional learning models ($p < 0.05$).

Cognitive Component: Students in the experimental groups demonstrated a significant deepening of their understanding of the fundamental DevOps principles, both theoretical and practical. They gained a better understanding of continuous integration and continuous deployment, recognized the importance of containerization for ensuring the stability of the execution environment, and learned how automation fits into the software development cycle.

By the end of the course, students progressed from repeating DevOps concept definitions to explaining the logic behind CI/CD pipeline construction. They could trace the connections between the stages of the software life cycle, from writing code to testing, deployment, and monitoring. This indicates a transition from fragmented knowledge to a more systematic understanding of the technological process.

After analyzing the test results, it was found that the students had begun to distinguish between the roles of developers and administrators with confidence and understand how interaction between these roles affects development quality and speed after the formative stage. A significant proportion of participants learned to justify the suitability of choosing certain DevOps tools based on project context.

While only 14% of students had a high level of knowledge prior to the experiment, this figure increased to 45% after implementing the pedagogical framework. This demonstrates a qualitative change in thinking, shifting from the mechanical reproduction of information to a conceptual understanding, not just an increase in the number of correct answers. These results confirm the effectiveness of the DevOps approach as an intellectual framework that promotes deeper knowledge acquisition and the formation of a systematic vision of professional activity.

Practical Component: During the experimental stage, students in the test groups made significant progress in applying DevOps tools to practical and laboratory tasks. They learned to use individual automation tools and how these tools interconnect as part of a holistic technological process.

The students confidently deployed containers using Docker, created their own images, tested them in different environments, and configured network interactions between containers. While working with GitLab CI/CD, the students developed pipelines for the automated assembly, testing, and deployment of software. Some teams configured Kubernetes independently for service orchestration, which allowed them to gain a deeper understanding of scaling principles, load balancing, and fault tolerance. They also used Prometheus to monitor system status and analyze metrics, integrating it into their projects.

Their comprehensive use of these tools created a learning environment that closely resembled real-world IT industry conditions. The students progressed from following sample instructions to designing DevOps processes independently. This included initializing a repository and automatically deploying containers in a test cluster. This demonstrated their ability to plan, implement, and analyze their own decisions while considering the principles of automation and process repeatability.

The proportion of students who completed all stages of automation independently during laboratory work increased by 52%. This reflects an improvement not only in technical skills but also in technological autonomy - the ability to work independently while focusing on process logic and DevOps engineering standards.

These results confirm the effectiveness of a practice-oriented approach that facilitates the transition from passive knowledge acquisition to active digital product creation. Using DevOps as a pedagogical framework fostered a new type of activity-based competence in students - one that is integrated, dynamic, and adaptable to the real needs of modern IT teams. Thus, the experiment demonstrated that the activity component of DevOps competence is a key indicator of the effectiveness of the proposed professional training model.

Communication component. High results were also recorded in teamwork, which is a key component of DevOps culture. During the training process, students in the experimental groups

participated in DevOps hackathons, group projects, and laboratory workshops, all of which were based on the principle of joint problem-solving. These activities required participants to demonstrate technical knowledge and effective communication skills, as well as the ability to distribute responsibilities and coordinate actions within time constraints.

While working on team projects, students utilized modern information and communication technologies. These included collaborative project management systems, such as GitLab Issues and Trello; instant messaging tools, such as Slack and Microsoft Teams; and presentation platforms, such as Zoom and Google Meet. These tools helped students develop the skills needed to interact within distributed teams, a common practice in IT companies today. Learning situations also required adherence to the principles of shared responsibility, prioritization, coordination, and continuous communication, thus replicating the real DevOps practice of the “feedback loop.”

Particular attention was given to the distribution of roles within teams. Students were given responsibilities relating to development, testing, continuous integration/continuous delivery (CI/CD) automation, and monitoring. This approach enabled each participant to understand their roles in the collective process and the interdependency between the stages of the software product life cycle. Participants learned to defend their positions with arguments, listen to their colleagues, agree on technical solutions, and collectively adopt compromises.

According to the expert evaluation results, the level of teamwork increased by 41%. This confirms students’ growing ability to engage in constructive dialogue, respond flexibly to changes in the team environment, and maintain positive group dynamics. Honing their communication skills also helped students develop soft skills such as negotiating, delegating authority, resolving conflicts, planning joint activities, and taking collective responsibility for the final result.

The results demonstrate that incorporating the DevOps approach into the pedagogical model fosters a team culture of learning. In this culture, communication is a central factor in the effectiveness of the educational process, not just an auxiliary tool. This prepares students for professional work in distributed IT teams, where interaction, transparency, and rapid information exchange are crucial.

Reflective component. Students’ attitudes toward the learning process and the outcomes of their activities have significantly changed. While most of them initially viewed laboratory tasks as a compulsory part of the course, the introduction of the DevOps-oriented learning model prompted them to reconsider their learning motivation. Students began to realize that their professional development effectiveness depends on their ability to constantly analyze their actions, identify shortcomings, and plan ways to overcome them.

This realization is directly related to the fundamental DevOps principle of continuous improvement — the ongoing enhancement of processes and outcomes. During laboratory and project work, students practiced short reflection cycles after each sprint. They discussed what they had achieved, the difficulties they had encountered, and the changes to be made in the next iteration. This approach contributed to the development of self-regulated thinking, in which learning is viewed as a series of interconnected improvements.

Gradually, students’ ability to self-assess and self-correct increased. They began using task logs more actively to record mistakes, compare their results with benchmarks, and find ways to optimize independently. Students proposed changes to pipeline configurations, refined automatic testing parameters, and improved project documentation more frequently.

An important outcome was the development of students’ ability to use mistakes as a resource for growth rather than as a basis for punishment or failure. This attitude toward learning indicates the development of mature professional reflection - the ability to evaluate the final product and the process of its creation. This approach aligns with modern pedagogical concepts of fostering critical and systematic thinking in the context of digital education.

According to expert assessment, the level of reflective competence increased from 36% to 78%. This reflects an increase in the amount of information absorbed and a profound transformation in students’

cognitive attitudes. Students began analyzing their own results more often, retesting software products, and proposing solutions to optimize the CI/CD process.

In summary, introducing the DevOps pedagogical framework stimulated reflective and analytical activities among students, fostering a stable orientation toward self-development and professional growth. Thus, the reflective component has become an important factor in establishing a new learning culture centered on responsibility, initiative, and the desire for improvement. It is also an indicator of the experiment's effectiveness.

Positive changes were also observed in the control groups, but they were insignificant. The proportion of students with a high level of competence increased from 13.1% to 18.5%. These results confirm that using the DevOps pedagogical framework was a decisive factor in improving learning outcomes qualitatively.

The data showed a statistically significant difference between the control and experimental groups ($p < 0.05$). These results suggest that integrating the DevOps approach into the professional training of future IT specialists improves their knowledge and practical, communicative, and reflective skills, all of which are necessary for success in the digital economy.

The generalized results lead to an unambiguous conclusion. Implementing the DevOps pedagogical framework alongside information and communication technologies effectively develops professional competencies. This approach yields better results than traditional learning methods.

For greater clarity, the results of the pedagogical experiment are summarized in Table 2. The table shows how the main components of DevOps competence changed among students in the experimental groups. By comparing the situation before and after implementing the author's model, we can track the effectiveness of the proposed approach.

Tab. 2

*Dynamics of Changes in the Components of DevOps Competence Among Students
in the Experimental Groups*

Components of competence	Pre-experiment status	Status after the experiment
Cognitive	Low to moderate knowledge of DevOps	There was a significant increase in knowledge and understanding of DevOps concepts
Agency	Limited skills using CI/CD, Docker, and Kubernetes tools	Confident use of DevOps tools for automation and teamwork
Communicative	Insufficient experience collaborating with a team using ICT	Ability to coordinate joint activities effectively using information and communication technologies
Reflective	Fragmented understanding of the importance of continuous improvement	Awareness of the role of iteration and continuous improvement in professional activities formed

Source: Author's own elaboration

As the table shows, all components of DevOps competence changed significantly after the experiment ended. The cognitive component improved through systematic study of DevOps' theoretical principles. The activity component improved through the completion of practical tasks using modern CI/CD, Docker, and Kubernetes tools. The communication component increased through active use of ICT to organize teamwork. The reflective component developed through an awareness of the importance of

iteration and continuous improvement in professional activities.

Thus, the results confirm the effectiveness of the DevOps pedagogical framework in integrating ICT into the professional training of IT specialists.

5. CONCLUSIONS

The study confirmed that DevOps can be considered a pedagogical framework. It integrates information and communication technologies into the professional training of IT majors. In this context, DevOps serves as an innovative approach that unites technological and pedagogical elements, creating new opportunities for developing modern competencies.

The DevOps pedagogical framework model increases students' competence in DevOps. It aligns IT specialist training content with labor market requirements. This makes the educational process more practical and closer to real working conditions in the IT industry.

The results of the pedagogical experiment proved the model's effectiveness. Implementing the model revealed that students who studied using the new methodology exhibited a higher level of professional training than those who studied using the traditional program.

The practical significance of this work lies in its potential application in higher education institutions through the DevOps pedagogical framework. This framework can be integrated into bachelor's and master's degree programs, as well as postgraduate education systems. It could also be useful for advanced training courses for IT professionals and corporate training.

Several avenues for further research have emerged. First, we need to develop the concept of an educational DevOps environment that combines academic learning, industrial practices, and digital innovations. Integrating artificial intelligence and machine learning technologies into IT specialist training is also relevant. Expanding partnerships between universities and IT companies to create joint educational projects is equally important. These partnerships will make graduates more competitive and ensure that a new generation of specialists receives high-quality training.

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Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, and Writing – review & editing were carried out by the sole author.

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У статті розглянуто проблему оновлення змісту та методів професійної підготовки фахівців з інформаційних технологій у контексті цифрової трансформації освіти. Ринок праці вимагає від випускників університетів не лише ґрунтовних знань у сфері програмування та адміністрування, а й уміння працювати в інтегрованих командах, використовувати сучасні інформаційно-комунікативні технології та впроваджувати інструменти автоматизації. Визначено, що традиційні моделі підготовки переважно зосереджуються на фундаментальній складовій, що породжує розрив між академічною освітою та запитами роботодавців. Для подолання цієї суперечності запропоновано використати методологію DevOps як педагогічну рамку, що здатна інтегрувати інформаційно-комунікативні технології в освітній процес. Розроблено концептуальну модель професійної підготовки ІТ-фахівців, яка включає цільовий, змістовий, процесуально-технологічний та результативний блоки. У моделі DevOps розглядається як системоутворювальний елемент освітнього процесу, що поєднує теоретичну підготовку, практико-орієнтовані завдання та використання інноваційних технологій. Особливу увагу приділено формуванню DevOps-компетентності як інтегрованої якості, що охоплює когнітивну, діяльнісну, комунікативну та рефлексивну складові. Результати засвідчили, що впровадження педагогічної рамки DevOps сприяє істотному зростанню рівня сформованості професійних компетентностей. Студенти експериментальних груп продемонстрували впевнене застосування DevOps-інструментів, ефективну командну взаємодію з використанням ІКТ та сформоване усвідомлення значення безперервного вдосконалення. Порівняльний аналіз результатів контрольних і експериментальних груп, підтверджений статистичними методами, засвідчив достовірність отриманих даних. Практичне значення роботи полягає у можливості використання запропонованої моделі у закладах вищої освіти та системах підвищення кваліфікації. Розроблений підхід може стати основою для модернізації освітніх програм з інформаційних технологій, а також сприяти підготовці конкурентоспроможних випускників, здатних ефективно діяти в умовах сучасного ринку праці та цифрової економіки.

Ключові слова: педагогічна рамка DevOps, інформаційно-комунікативні технології, професійна підготовка ІТ-фахівців, DevOps-компетентність, цифрова трансформація освіти.