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# FINANCING STAFF DIGITALIZATION AS A STRATEGY FOR MANAGING CHANGES IN EDUCATIONAL INSTITUTIONS FOR SUSTAINABLE CLUSTER DEVELOPMENT OF INNOVATIVE INFRASTRUCTURE

## ABSTRACT

The article examines the role of financing personnel digitalization as a key strategy for managing changes in educational institutions in the context of sustainable cluster development of innovation infrastructure. Particular attention is paid to the analysis of the dynamics of the number of students, scientific and pedagogical staff, and financial indicators of institutions of different accreditation levels, which are leading in the formation of educational clusters. The authors of the article used economic and mathematical models to assess the individual effects of digital transformation, forecast results for the medium term, and identify factors affecting the competitiveness of educational institutions. The results of the study show that effective financing of personnel digitalization increases the competitive advantages of universities, colleges, and lyceums, strengthens human resource potential, contributes to financial stability, and creates added value for regional educational clusters. It is determined that universities have better starting positions for launching self-supported digital transformation programs due to greater financial resources, while colleges and vocational lyceums require greater institutional and state support. The importance of cluster interaction, which ensures the synergy of financial flows and the scaling of digital innovations at all levels of education, is substantiated. The paper emphasizes that financing the digitalization of personnel should be considered not as an expense, but as a strategic investment in improving the quality of education, competitiveness, and integration of the Ukrainian education system into the global digital space.

**Keywords:** digital transformation, personnel, change management, educational institutions, competitive strategies, sustainable cluster development, innovative infrastructure, leaders, financial results, income, expenses

**JEL Classification:** I20, I25, O33, M53, L26, R11

## INTRODUCTION

Modern challenges associated with global digitalization, integration into the European educational space, and the need for sustainable recovery after crisis events form new requirements for the management system of educational institutions. One of the defining areas is the digitalization of personnel, which acts not only as a tool for improving the quality of the educational process, but also as a strategic factor in change management. It is the financial support of digital transformation that determines the pace and depth of innovative shifts in the education system, as it allows you to modernize the infrastructure, develop digital competencies of teachers and students, and also form competitive advantages of educational clusters.

The research is aimed at the theoretical, methodological, and practical substantiation of models of financing digitalization of personnel, which ensure a balance between income and expenses of educational institutions and increase their ability to adapt to the conditions of the digital economy. Particular attention is paid to assessing the individual effects of digital changes in different types of institutions – universities, colleges, and

lyceums – taking into account their role in the sustainable cluster development of innovation infrastructure.

## LITERATURE REVIEW

Digital transformation of personnel in educational institutions plays an important role in shaping competitive change management strategies that contribute to the sustainable development of innovation infrastructure. The scientific literature emphasizes the need to integrate digital technologies to improve the efficiency of management processes and promote the development of innovation clusters, which can become the basis for the competitiveness of educational institutions. According to modern research, the adaptation of personnel to changes associated with digital technologies is critically important for the implementation of strategic goals, which include innovative development and the integration of new forms of learning.

The first group of authors, as an example (Abad-Segura et al., 2020), considers strategies for the digital transformation of higher education, in particular in the context of sustainable management and global trends. The authors analyze the importance of digital technologies for improving the quality of education and integrating sustainable management methods in universities, which is important for the development of innovation clusters. Rayetset et al. (2023) emphasize the importance of leadership in stimulating innovation and developing the creative potential of the team. This can be useful for understanding the role of management in managing change in educational institutions and promoting innovation in the educational process.

Gryshchenko et al. (2021) explore how universities can use the competitive advantages of innovation clusters to achieve sustainable development in the educational services market, which is a direct link to change management and the use of innovation for the sustainable development of higher education institutions. Brunetti et al. (2020) discuss the challenges of digital transformation, taking into account many stakeholders. They propose strategies for adapting and applying digital technologies in organizations, which can be useful for educational institutions in managing change.

Voznyuk et al. (2021) focus on interdisciplinary educational technologies based on the concept of functional asymmetry of the brain. This approach can be used to improve teaching methods and digital transformations in education. Gillani et al. (2024) analyze the key factors contributing to digital transformation, as well as the stages and archetypes of this transformation. They offer useful strategies for educational institutions experiencing stages of digitalization and innovation.

The second group of authors, Oseredchuk et al. (2022), offer new approaches to monitoring the quality of higher education in distance learning, which is an important aspect for analyzing changes in educational infrastructure during digital transformation. Dankevych et al. (2022) focus on European legal standards for community-based local development, which can be useful for sustainable development strategies of innovative educational clusters. Magyari et al. (2022) explore knowledge management to support green transformation. This is an approach that can be useful for sustainability and digital transformation strategies in education, especially in the context of environmental and innovation initiatives.

The third group of authors, as an example, Vashchenko et al. (2023), proposed a non-standard methodology of scientific research that can be applied in educational institutions to personalize personnel training. Voronina et al. (2022) analyze the strategic management of competitive advantages in the branches of the innovative economy, which is relevant for educational institutions in the context of digital transformation. They prove that management decisions focused on the innovative development of personnel are decisive for long-term competitiveness.

Priharsari et al. (2023) consider the development of national digital strategies, which is useful for understanding approaches to the digitalization of educational institutions. The scientific article emphasizes the importance of comprehensive planning and adaptation of international experience in the implementation of digital changes. Furman et al. (2023) investigate the motivation and stimulation of employees in enterprises, highlighting key aspects of effective personnel management in a period of change. The conclusions in the article can be applied to increase the involvement of education workers in the processes of digital transformation.

Cheremisina et al. (2023) monitored and assessed the effectiveness of the development of territorial communities, which allows for identifying the best approaches to the management of educational clusters. The work emphasizes the role of systems analysis and digital tools in improving management processes. Tan (2006) studies the growth of industrial clusters and innovations using the example of the Beijing Science Park, which is relevant for the development of educational clusters.

The experience of such an approach can be used in the formation of an innovative infrastructure of education. Dankevych (2021) considers the ecological and economic management of the innovative activities of enterprises, which can be adapted

to the strategies of sustainable development of educational clusters. The use of ecological and economic criteria in the digital transformation of personnel will contribute to increasing the efficiency of resource management. The following group of authors, Khodakivska et al. (2021), conducted an interstate assessment of economic competitiveness in the context of European integration, which is important for the digital development of the education sector. The work allows us to assess the effectiveness of digital transformations in the international dimension.

Saienko et al. (2023) used a non-standard system of combining indicators and methods that can be offered within the framework of our scientific research. Loorbach and Wijsman (2013) investigated the management of business transformations and their role in the transition to sustainable development, which is relevant for the digital transformation of educational institutions. They emphasized the importance of integrating innovative approaches for sustainable development, which can be applied in the field of education to adapt personnel to changes.

Zhyvko et al. (2022) examined the issues of digitalization in the field of management accounting and finance in the context of globalization, which is an important aspect for the digital transformation of educational institutions. The authors emphasize the need to ensure the security of digital data, which is a critical factor in the digital environment of educational institutions. Dankevych et al. (2023) explore the concept of global peace, which encompasses military, terrorist, and information threats that can affect the security of digital educational platforms. Understanding these threats allows educational institutions to develop strategies for protecting the information environment and digital personnel.

Kopishynska et al. (2021) analyze the features of the use of the case method in teaching disciplines related to information technology and IT project management. This approach can be used to train educational institution staff in effective digital change management. Moore and Manring (2009) explore the development strategies of small and medium-sized enterprises towards sustainable development and creating added value. The use of these approaches in education will allow institutions to develop effective models of digital transformation of personnel.

Palaščáková et al. (2024) analyze social intelligence in the context of professional self-education, which is important for the digital transformation of personnel in educational institutions. The authors emphasize the importance of gender aspects in the implementation of modern educational technologies.

The next group of authors, Kubitskyi et al. (2023), investigate new management tools for higher education institutions that contribute to their development in the digital era. The use of these tools allows to increase the effectiveness of change management strategies in the field of education. Annosi et al. (2024) analyze the relationship between digital transformation and sustainable development in agribusiness, which can be adapted for educational institutions. The authors propose approaches to the implementation of digital innovations that can contribute to the sustainable development of educational infrastructure.

Pysarenko et al. (2020) consider the formation of a marketing and logistics business model based on specialization, which can be useful for developing strategies for the digital transformation of educational institutions. The use of such models allows you to optimize the educational process and increase the efficiency of personnel management.

Su and Wu (2024) investigate digital transformation and sustainable development of enterprises, which directly affects educational institutions in their transition to a digital environment. The use of digital technologies contributes to the modernization of personnel management in educational institutions. Zoria et al. (2022) consider theoretical and methodological aspects of investment support for the innovative development of agricultural production, which can be adapted to financing the digital transformation of educational institutions.

Kalinichenko (2021) developed methodological guidelines on economic and mathematical methods and models that can be useful for developing change management algorithms in educational institutions and optimizing digital transformation processes. Vashchenko et al. (2022) investigate the methodology for determining the relationship between genetic polymorphism and productivity of farm animals, which can serve as an example for the use of digital technologies in the collection and analysis of big data in the field of education.

Kyryliuk et al. (2021) analyze organizational and economic factors for ensuring the safety and quality of products, which can be adapted to the security management of educational online platforms and digital content. Barroso and Laborda (2022) reviewed digital transformation and the emergence of the fintech sector, which is important for modernizing the financial strategies of educational institutions and developing the digital competencies of staff.

Kubitskyi et al. (2024) model the impact of innovative technologies on global competitiveness, which can be useful for assessing the effectiveness of the digital transformation of educational institutions. Shevchenko (2014) examines panel data that can be used to analyze the dynamics of digital transformation of education and its impact on the effectiveness of human resource management.


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Matyukh (2013) examines the role of higher education institutions in socio-economic development, which is important for shaping a strategy for sustainable digital development of educational institutions. Chervak-Smerichko (2013) models the analysis of longitudinal data that can help assess the effectiveness of implementing digital technologies in the educational process.

The statistical sources for our scientific article were the official websites of educational institutions and the information resource of the International Organization for Migration.

The sources we reviewed provide a wide range of views on the role of digital technologies in the transformation of education, in particular their impact on teaching methods, organizational changes, and pedagogical practices. They emphasize the importance of integrating the latest technologies, such as artificial intelligence, virtual reality, mobile learning, blockchain, and gamification, into the educational process to prepare students for future challenges and opportunities in the era of digital change.

## AIMS AND OBJECTIVES

The purpose of the article is to provide a theoretical, methodological, and practical justification for financing personnel digitalization as a strategic direction of change management in educational institutions aimed at ensuring sustainable cluster development of innovation infrastructure.

To achieve the set goal, the study provides a solution for solving the following tasks:

1. To reveal the essence and economic nature of financing personnel digitalization as a tool for increasing the efficiency of change management.
2. To analyze current trends in the digital transformation of universities, colleges, and vocational schools in the context of their participation in educational clusters.
3. To form original economic and mathematical models for assessing the effectiveness of financing personnel digitalization.
4. To test models using the example of leading Ukrainian educational institutions, taking into account the dynamics of their financial and personnel indicators.
5. To determine strategic guidelines and practical tools for financial support of digital transformation to strengthen the innovative capacity of educational clusters.

## METHODS

The article uses a set of economic, mathematical, and statistical methods that allow us to study the transformation of personnel in competitive change management strategies in educational institutions. First, a cluster analysis was conducted to group educational institutions by accreditation levels and clustering, which determines the main segments of the studied sample. Then, an analysis of the dynamics of the number of students and teaching staff was carried out, and the income and expenses of educational institutions were analyzed based on open data, which allows us to assess financial stability and the development of innovative infrastructure. The main methodological basis is the construction of spatial (panel) data models with fixed effects, which allows us to take into account both general and individual characteristics of each institution. To estimate the parameters of these models, the least squares method was used, which allows us to obtain the coefficients of individual effects of personnel transformation. The analysis also used correlation-regression analysis to establish relationships between factor characteristics (the share of doctors of sciences, associate professors, teachers of the highest category, etc.) and the performance indicator (number of students). In addition, ranking and rating methods were used to compare the results obtained, which allows identifying leaders among educational institutions by the individual effects of personnel transformation. Thus, the use of a comprehensive approach that combines cluster analysis, economic and mathematical modeling, regression analysis, the least squares method, ranking, graphical representation, and forecasting provides a deep understanding of personnel transformation processes in the context of competitive change management strategies in educational institutions. For study, research, analysis, modeling, and forecasting, educational institutions were selected that are leaders in sustainable cluster development of innovative infrastructure by accreditation levels: I level of accreditation - technical schools, schools, II level of accreditation - colleges, III and IV - academies, universities, and institutes. They were grouped by clustering (Table 1).

**Table 1. Educational institutions of Ukraine by clustering.**

| Higher education institution | College | Lyceum (school) |
|---|---|---|
| Sumy National Agrarian University https://snau.edu.ua/ | Separate structural unit "Sumy Professional College of Sumy National Agrarian University" (further on in the text - SSU "Sumy Professional College of SNAU") https://collegesnau.com/ | State educational institution "Sumy Interregional Higher Vocational School" http://mvpu.edukit.sumy.ua/ |
| National Transport University http://www.ntu.edu.ua/ | Separate structural unit "Kyiv Transport and Economic Vocational College" http://www.ktek.kiev.ua/ | State educational institution "Kyiv Center for Vocational and Technical Education" https://cpto.kyiv.ua/ https://cpto.kyiv.ua/informacijna-vidkritist/ |
| Semyon Kuznets Kharkiv National University of Economics https://www.hneu.edu.ua/ | Kharkiv Socio-Economic Vocational College https://khoeti.com.ua/ | Vocational and Technical Education Center No. 2, Kharkiv https://cpto2.at.ua/ |
| Kyiv National University of Technologies and Design https://knutd.edu.ua/ | Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" (further on in the text - SSU "PCAD of the KNUTD" https://fkmd.knutd.edu.ua/ | Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art https://kapi.com.ua/ |
| Polesie National University https://polissiauniver.edu.ua/ | Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" https://www.fkbad.com.ua/ | Zhytomyr Professional Polytechnic Lyceum http://zppl.org.ua/ |
| Poltava State Medical University https://www.pdmu.edu.ua/ | Professional Medical and Pharmaceutical College of Poltava State Medical University (further on in the text - Professional Medical and Pharmaceutical College of PSMU) https://college.pdmu.edu.ua/ | Kremenchuk Medical College https://k-m-k.com.ua/ |

The results of the study were visualized using graphical methods, which facilitate visual comparison of data, and predictive models were also built to assess changes in the number of students and individual effects for the next three years (2025–2027).

## RESULTS

Digital transformation of personnel in competitive change management strategies in educational institutions as leaders of sustainable cluster development of innovative infrastructure must be carried out with data analysis. Indicators of competitive change management strategy and innovative infrastructure are the number of students. According to open data of selected educational institutions, we will analyze the number of students over the last seven years (Table 2).

**Table 2. Dynamics of educational institutions by clustering, 2017-2023.** *(Source: compiled taking into account official data of educational institutions reflected in Table 1).*

| Indicators | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| Sumy National Agrarian University | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 6568 | 6970 | 7172 | 8374 | 8576 | 8778 | 10980 |
| National Transport University | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 3635 | 3852 | 3969 | 4286 | 4703 | 5220 | 5737 |
| Semyon Kuznets Kharkiv National University of Economics | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 7920 | 7100 | 7280 | 7460 | 7640 | 7720 | 8000 |
| Kyiv National University of Technologies and Design | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 7112 | 7818 | 8524 | 9230 | 9936 | 10642 | 11048 |

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**Table 2.** Continued.

| Indicators | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|
| Polesie National University | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 3311 | 3672 | 4132 | 4593 | 5053 | 5514 | 5974 |
| Poltava State Medical University | | | | | | | |
| Number of students at a higher education institution (higher education applicants), persons | 2838 | 3291 | 3744 | 4197 | 4650 | 5103 | 5556 |
| SSU "Sumy Professional College of SNAU" | | | | | | | |
| Number of students, persons | 510 | 539 | 564 | 588 | 626 | 659 | 692 |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | | | | | | | |
| Number of students, persons | 1353 | 1324 | 1295 | 1260 | 1230 | 1239 | 1160 |
| Kharkiv Socio-Economic Vocational College | | | | | | | |
| Number of students, persons | 663 | 701 | 733 | 764 | 814 | 857 | 900 |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | | | | | | | |
| Number of students, persons | 410 | 466 | 493 | 565 | 751 | 878 | 936 |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | | | | | | | |
| Number of students, persons | 540 | 610 | 680 | 750 | 820 | 890 | 960 |
| Professional Medical and Pharmaceutical College of PSMU | | | | | | | |
| Number of students, persons | 710 | 823 | 936 | 1049 | 1163 | 1276 | 1389 |
| State educational institution "Sumy Interregional Higher Vocational School" | | | | | | | |
| Number of students, persons | 322 | 355 | 406 | 536 | 482 | 538 | 603 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | | | | | | | |
| Number of students, persons | 311 | 336 | 395 | 418 | 416 | 311 | 437 |
| Vocational and Technical Education Center No. 2, Kharkiv | | | | | | | |
| Number of students, persons | 314 | 355 | 398 | 340 | 390 | 410 | 475 |
| Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art | | | | | | | |
| Number of students, persons | 318 | 351 | 402 | 384 | 408 | 366 | 461 |
| Zhytomyr Professional Polytechnic Lyceum | | | | | | | |
| Number of students, persons | 336 | 369 | 420 | 403 | 427 | 384 | 480 |
| Kremenchuk Medical College | | | | | | | |
| Number of students, persons | 444 | 477 | 528 | 540 | 549 | 526 | 615 |

Analysis of the dynamics of the number of students in educational institutions for 2017-2023 indicates a general trend towards growth, which indicates the growing popularity of educational institutions and their role in regional development. Higher educational institutions demonstrate a significant increase in the number of education seekers.

Further analysis of the transformation of personnel in competitive change management strategies in educational institutions will be carried out by determining the number of teaching staff of the studied educational institutions, their dynamics over the past five years, and absolute and relative deviations in the number of staff over the five-year period. For analytical research, information that is publicly presented on the websites of educational institutions was used.

The dynamics of the number of scientific and pedagogical staff in educational institutions for 2019-2023 indicate a general trend towards growth in the teaching staff. At Sumy National Agrarian University, the number of teachers increased by 3.11%, while the number of doctors of sciences remained stable, and the number of associate professors and candidates of sciences decreased slightly. At the same time, there was an increase in the share of senior teachers and assistants, which may indicate a renewal of personnel. At the National Transport University, the total number of teachers almost did not change, but the number of doctors of sciences and candidates of sciences increased, while the number of senior teachers and assistants decreased. At the S. Kuznets Kharkiv National Economic University, a significant increase in staff by 9.3% was recorded, which was accompanied by an increase in the number of doctors of sciences, associate professors, and assistants. A similar trend is observed at the Kyiv National University of Technologies and Design, where an increase

in the share of doctors of sciences in the total staff is also observed. Polesie National University demonstrated an increase in the number of teaching staff, with a moderate increase in the number of doctors of sciences and candidates of sciences. Poltava State Medical University also showed positive dynamics, although the share of doctors of sciences in the total staff has slightly decreased. Professional colleges in general demonstrate positive dynamics of growth in the number of teaching staff. In Sumy Professional College of SNAU and Kyiv Transport and Economic Professional College, the number of teachers of the highest category, as well as candidates of sciences, has increased significantly. Kharkiv Socio-Economic Professional College increased the number of teachers by 12.87%, which was accompanied by an increase in the number of teachers of the highest category. State educational institution "Sumy Interregional Higher Professional School" was noted for an increase in the total number of teaching staff, although the number of teachers decreased, and the share of master's in industrial training has increased significantly. In general, the dynamics indicate an increase in the scientific potential in universities and advanced training among teaching staff in colleges, which may be a consequence of the active implementation of advanced training programs and the digital transformation of education. We observe dynamic processes in the number of scientific and pedagogical personnel over the last studied period at different levels of educational institutions, which indicates the activity of pedagogical workers in the educational sector. To visualize the obtained data and compare them, their graphic representation is possible.

Next, we analyze the dynamics of income and expenses of the studied educational institutions over the last five years, as elements of the innovative infrastructure of the educational sector. Their share is shown in Table 3.

**Table 3. Dynamics of income and expenses of educational institutions, 2019-2023.** *(Source: calculated taking into account official data of educational institutions shown in Table 1).*

| Indicators | 2019 | 2020 | 2021 | 2022 | 2023 | On average for 2019-2023 | Absolute deviation 2023 from 2019, +, - | Relative deviation 2023 from 2019,% |
|---|---|---|---|---|---|---|---|---|
| Sumy National Agrarian University | | | | | | | | |
| Share of income in financial results, % | 49.67 | 49.72 | 50.55 | 51.06 | 51.55 | 50.51 | 1.88 | X |
| Share of expenses in the financial result of activities, % | 50.33 | 50.28 | 49.45 | 48.94 | 48.45 | 49.49 | -1.88 | X |
| National Transport University | | | | | | | | |
| Share of income in financial results, % | 49.79 | 50.38 | 50.95 | 51.51 | 52.05 | 50.94 | 2.26 | X |
| Share of expenses in the financial result of activities, % | 50.21 | 49.62 | 49.05 | 48.49 | 47.95 | 49.06 | -2.26 | X |
| Semyon Kuznets Kharkiv National University of Economics | | | | | | | | |
| Share of income in financial results, % | 66.32 | 48.37 | 52.45 | 69.49 | 67.41 | 60.81 | 1.09 | X |
| Share of expenses in the financial result of activities, % | 33.68 | 51.63 | 47.55 | 30.51 | 32.59 | 39.19 | -1.09 | X |
| Kyiv National University of Technologies and Design | | | | | | | | |
| Share of income in financial results, % | 50.67 | 50.26 | 50.07 | 50.17 | 50.08 | 50.25 | -0.59 | X |
| Share of expenses in the financial result of activities, % | 49.33 | 49.74 | 49.93 | 49.83 | 49.92 | 49.75 | 0.59 | X |
| Polesie National University | | | | | | | | |
| Share of income in financial results, % | 50.26 | 48.32 | 46.95 | 55.21 | 54.23 | 50.99 | 3.98 | X |
| Share of expenses in the financial result of activities, % | 49.74 | 51.68 | 53.05 | 44.79 | 45.77 | 49.01 | -3.98 | X |
| Poltava State Medical University | | | | | | | | |
| Share of income in financial results, % | 50.58 | 51.72 | 46.32 | 49.56 | 41.98 | 48.03 | -8.59 | X |
| Share of expenses in the financial result of activities, % | 49.42 | 48.28 | 53.68 | 50.44 | 58.02 | 51.97 | 8.59 | X |

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**Table 3.** Continued.

| Indicators | 2019 | 2020 | 2021 | 2022 | 2023 | On average for 2019-2023 | Absolute deviation 2023 from 2019, +, - | Relative deviation 2023 from 2019,% |
|---|---|---|---|---|---|---|---|---|
| SSU "Sumy Professional College of SNAU" | | | | | | | | |
| Share of income in financial results, % | 50.87 | 51.10 | 51.11 | 47.52 | 52.21 | 50.56 | 1.34 | X |
| Share of expenses in the financial result of activities, % | 49.13 | 48.90 | 48.89 | 52.48 | 47.79 | 49.44 | -1.34 | X |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | | | | | | | | |
| Share of income in financial results, % | 50.87 | 50.94 | 51.11 | 47.36 | 52.08 | 50.47 | 1.21 | X |
| Share of expenses in the financial result of activities, % | 49.13 | 49.06 | 48.89 | 52.64 | 47.92 | 49.53 | -1.21 | X |
| Kharkiv Socio-Economic Vocational College | | | | | | | | |
| Share of income in financial results, % | 50.87 | 51.10 | 51.23 | 47.64 | 52.21 | 50.61 | 1.34 | X |
| Share of expenses in the financial result of activities, % | 49.13 | 48.90 | 48.77 | 52.36 | 47.79 | 49.39 | -1.34 | X |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | | | | | | | | |
| Share of income in financial results, % | 49.39 | 42.81 | 46.53 | 48.10 | 46.44 | 46.65 | -2.95 | X |
| Share of expenses in the financial result of activities, % | 50.61 | 57.19 | 53.47 | 51.90 | 53.56 | 53.35 | 2.95 | X |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | | | | | | | | |
| Share of income in financial results, % | 56.77 | 55.02 | 53.45 | 52.03 | 50.75 | 53.61 | -6.03 | X |
| Share of expenses in the financial result of activities, % | 43.23 | 44.98 | 46.55 | 47.97 | 49.25 | 46.39 | 6.03 | X |
| Professional Medical and Pharmaceutical College of PSMU | | | | | | | | |
| Share of income in financial results, % | 56.77 | 55.02 | 53.45 | 52.03 | 50.75 | 53.61 | -6.03 | X |
| Share of expenses in the financial result of activities, % | 43.23 | 44.98 | 46.55 | 47.97 | 49.25 | 46.39 | 6.03 | X |
| State educational institution "Sumy Interregional Higher Vocational School" | | | | | | | | |
| Share of income in financial results, % | 51.90 | 51.19 | 50.74 | 50.57 | 51.65 | 51.21 | -0.25 | X |
| Share of expenses in the financial result of activities, % | 48.10 | 48.81 | 49.26 | 49.43 | 48.35 | 48.79 | 0.25 | X |
| State educational institution "Kyiv Center for Vocational and Technical Education" | | | | | | | | |
| Share of income in financial results, % | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | X |
| Share of expenses in the financial result of activities, % | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 0.00 | X |
| Vocational and Technical Education Center No. 2, Kharkiv | | | | | | | | |
| Share of income in financial results, % | 51.90 | 51.19 | 50.85 | 50.69 | 51.65 | 51.26 | -0.25 | X |
| Share of expenses in the financial result of activities, % | 48.10 | 48.81 | 49.15 | 49.31 | 48.35 | 48.74 | 0.25 | X |
| Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art | | | | | | | | |
| Share of income in financial results, % | 51.90 | 51.19 | 50.74 | 50.57 | 51.65 | 51.21 | -0.25 | X |
| Share of expenses in the financial result of activities, % | 48.10 | 48.81 | 49.26 | 49.43 | 48.35 | 48.79 | 0.25 | X |
| Zhytomyr Professional Polytechnic Lyceum | | | | | | | | |
| Share of income in financial results, % | 50.54 | 51.59 | 50.53 | 51.57 | 49.47 | 50.74 | -1.07 | X |
| Share of expenses in the financial result of activities, % | 49.46 | 48.41 | 49.47 | 48.43 | 50.53 | 49.26 | 1.07 | X |
| Kremenchuk Medical College | | | | | | | | |
| Share of income in financial results, % | 50.54 | 51.59 | 50.53 | 51.57 | 49.47 | 50.74 | -1.07 | X |
| Share of expenses in the financial result of activities, % | 49.46 | 48.41 | 49.47 | 48.43 | 50.53 | 49.26 | 1.07 | X |

Analysis of data on the dynamics of income and expenditure of educational institutions during 2019-2023 shows certain changes in the financial result of various educational institutions, which indicate changing financial strategies and the impact of economic factors on the education sector. According to general indicators for all educational institutions, the share of income in the financial result of activities fluctuates around 50%, which indicates stability in financial activities. At the same time, the share of expenses also remains within 49-50%, with small deviations from year to year, which may be the result of changes in the cost of resources or financing needs.

In some institutions, such as Sumy National Agrarian University, National Transport University, and VSP "Sumy Professional College SNAU", a moderate increase in the share of income in the financial result of activities is observed, which indicates their ability to maintain stable financing and the ability to provide more resources for development. This trend is an important indicator of financial sustainability.

On the other hand, some educational institutions, such as Poltava State Medical University, Professional Medical and Pharmaceutical College of PDMU, and Professional College of Arts and Design of Kyiv National University of Technologies and Design, show a decrease in the share of income in the overall financial result. This may indicate a decrease in revenues or insufficient resources to cover needs, which is an important signal for adapting the financial strategy and finding additional sources of financing.

Deviation of the share of income and expenses: A significant decrease in the share of income in the financial result, for example, in Poltava State Medical University, where a decrease of 8.59% occurred by 2023, may indicate inefficient use of financial resources or a decrease in state funding. At the same time, in some universities, such as Semyon Kuznets Kharkiv National Economic University, the dynamics of the share of income and expenses are more stable, which may indicate effective budget management and the ability to maintain financial balance.

The average level of expenditures for educational institutions also shows small changes, with a tendency to reduce the share of expenditures compared to revenues, which may indicate some optimization of expenditures and improvement of resource efficiency. However, in some institutions, in particular, in Poltava State Medical University, there is an increase in the share of expenditures, which may be the result of increased labor costs, infrastructure upgrades, or other factors.

Some institutions, such as the State Educational Institution "Kyiv Center for Vocational and Technical Education", demonstrate a complete lack of revenues, which indicates a possible crisis situation or a change in the organizational structure of financing, which requires careful analysis and adjustment of financial strategies.

In general, the analysis of financial indicators indicates the need for further optimization of finances, as well as the importance of effective management of expenditures to ensure the sustainable development of educational institutions in conditions of economic instability. For some institutions, it is necessary to pay attention to the growth of expenditures and a decrease in revenues, which may affect their financial sustainability in the future.

The next stage of research into personnel transformation in competitive change management strategies in educational institutions, as leaders of sustainable cluster development of innovation infrastructure, is the study of this process from an economic and mathematical perspective.

To choose a method and methodology that is appropriate for obtaining certain results from the point of view of further transformation of personnel in competitive strategies of change management in educational institutions, as leaders of sustainable cluster development of innovative infrastructure, it is necessary to determine the elements that make up the educational management system and directly affect the effectiveness of activities. It is for these reasons that the authors have determined the effective indicator of the study of personnel transformation in competitive strategies of change management in educational institutions, as leaders of sustainable cluster development of innovative infrastructure, the number of students of educational institutions.

The following factors were selected for universities: the share of doctors of sciences in the total teaching staff and the share of associate professors, candidates of sciences in the total teaching staff; for colleges: the share of teaching staff of the highest category, candidates of sciences in the total teaching staff and the share of teaching staff of the highest category in the total teaching staff; for lyceums and schools: the share of pedagogical workers in the total teaching staff and the share of senior masters in the total teaching staff, %/ the share of department heads in the total teaching staff. These factor characteristics were not chosen by chance, because it is the scientific and pedagogical staff of an educational institution that is the driving force behind innovation, novelty, development, improvement, and effectiveness of activities in attracting and forming a personality.

So, in conclusion of the theoretical part of the study, we can say that this information encourages us to study, model, and forecast the indicator (number of students) and certain factors of the personnel transformation system in competitive


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strategies of change management in educational institutions as leaders of sustainable cluster development of innovative infrastructure using economic and mathematical methods and models, in particular spatial (longitudinal, panel) data models with fixed effects, correlation and regression analysis, simultaneous analysis of several educational institutions by clustering, the least squares method, the method of comparison, ranking, rating, graphical representation and comparison and forecasting.

So, educational institutions for research, economic, and mathematical methods and models have been preliminarily selected, then we proceed to the practical part of the study, analysis, modeling, and forecasting of the effective indicator (number of students) and selected factors of personnel transformation in competitive strategies of change management in educational institutions as leaders of sustainable cluster development of innovative infrastructure. The study is conducted in several stages. Previously, statistical data on the number of students in educational institutions and the share of scientific and pedagogical staff were formed (Table 2 and Table 3).

Next, the next stage is to consider building a spatial data model with fixed effects in the study of personnel transformation in competitive change management strategies in educational institutions, as leaders of sustainable cluster development of innovative infrastructure over the recent period. The coefficients of spatial data models with fixed effects in the study of the effectiveness of educational institutions by clustering, 2019-2023, were obtained:

- for higher education institutions:

| | |
|---|---|
| b | -232,91 |
| | -333,07 |

- for colleges:

| | |
|---|---|
| b | 73,02 |
| | -17,93 |

- for lyceums, schools:

| | |
|---|---|
| b | 3,45 |
| | 4,41 |

We find the individual effects of personnel transformation in competitive change management strategies in educational institutions, as leaders of sustainable cluster development of innovation infrastructure for each educational institution, using the formula:

$$\alpha i = T1t = 1\sum Tyit - (T1t = 1\sum Txit)'\beta\text{^}FE \quad (1)$$

So, as a result of the calculations, we have the following result (Table 4):

**Table 4. Individual effects of personnel transformation in competitive change management strategies in educational institutions as leaders of sustainable cluster development of innovation infrastructure, 2019-2023.**

| **Sumy National Agrarian University** | **a1** | **77.26** |
|---|---|---|
| National Transport University | a2 | 44.97 |
| Semyon Kuznets Kharkiv National University of Economics | a3 | 80.55 |
| Kyiv National University of Technologies and Design | a4 | 78.00 |
| Polesie National University | a5 | 44.56 |
| Poltava State Medical University | a6 | 73.38 |
| SSU "Sumy Professional College of SNAU" | a1 | 68.78 |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | a2 | 79.78 |
| Kharkiv Socio-Economic Vocational College | a3 | 76.52 |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | a4 | 43.93 |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | a5 | 62.98 |
| Professional Medical and Pharmaceutical College of PSMU | a6 | 61.06 |
| State educational institution "Sumy Interregional Higher Vocational School" | a1 | 22.86 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | a2 | 36.54 |
| Vocational and Technical Education Center No. 2, Kharkiv | a3 | 30.46 |
| Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art | a4 | 32.66 |
| Zhytomyr Professional Polytechnic Lyceum | a5 | 24.87 |
| Kremenchuk Medical College | a6 | 29.45 |

Thus, according to the coefficient of the individual effect of personnel transformation in competitive strategies of change management in educational institutions as leaders of sustainable cluster development of innovative infrastructure, the leader among higher education institutions is the Kharkiv National Economic University named after Semyon Kuznets (KHNEU named after S. Kuznets) 80.55 p.p., among colleges the Separate Structural Unit "Kyiv Transport and Economic Professional College" 79.78 p.p. and among lyceums and schools the State Educational Institution "Kyiv Center for Vocational and Technical Education" 36.54 p.p.. Although it should be noted the qualitative value of this coefficient in all studied educational institutions. Also, graphically, for comparison of the determined coefficients of the individual effect of educational institutions, they can be presented.

The next stage is forecasting. The author's own work is the forecasting of individual effects of personnel transformation in competitive strategies of change management in educational institutions as leaders of sustainable cluster development of innovative infrastructure using spatial data models for the next three years. To determine the effective indicator of the number of students in educational institutions, we use the coefficients a0, a1, and a2, which were calculated previously. As a result, the forecast values of the factors and the effective indicator in the cluster section of each educational institution for 2025-2027 were obtained (Table 5).

**Table 5. Forecasting factors and performance indicators of educational institutions, 2025-2027.**

| Higher education institutions | Years | Number of students in higher education institutions (higher education applicants), persons, Y | Share of doctors of sciences in the total teaching staff, % | Share of associate professors and candidates of sciences in the total teaching staff, % |
|---|---|---|---|---|
| Sumy National Agrarian University | 2025 | 11984 | 13.08 | 64.60 |
| | 2026 | 12786 | 13.17 | 64.71 |
| | 2027 | 13588 | 13.27 | 64.22 |
| National Transport University | 2025 | 6566 | 9.18 | 40.27 |
| | 2026 | 7012 | 9.32 | 40.64 |
| | 2027 | 7458 | 9.45 | 41.01 |
| Semyon Kuznets Kharkiv National University of Economics | 2025 | 8104 | 5.64 | 35.33 |
| | 2026 | 8179 | 5.77 | 35.40 |
| | 2027 | 8253 | 5.91 | 35.46 |
| Kyiv National University of Technologies and Design | 2025 | 12458 | 7.21 | 27.70 |
| | 2026 | 13104 | 7.26 | 27.90 |
| | 2027 | 13750 | 7.30 | 28.09 |
| Polesie National University | 2025 | 6892 | 7.45 | 28.64 |
| | 2026 | 7352 | 7.48 | 28.78 |
| | 2027 | 7811 | 7.52 | 28.91 |
| Poltava State Medical University | 2025 | 5603 | 14.21 | 64.28 |
| | 2026 | 5639 | 14.30 | 64.55 |
| | 2027 | 5734 | 14.77 | 64.63 |
| **College** | **Years** | **Number of students, persons. Y** | **Share of higher category teaching staff, candidates of sciences in the total teaching staff. %** | **Share of higher category teaching staff in the total teaching staff. %** |
| SSU "Sumy Professional College of SNAU" | 2025 | 757 | 7.39 | 24.36 |
| | 2026 | 789 | 7.67 | 24.39 |
| | 2027 | 822 | 7.95 | 24.43 |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | 2025 | 1229 | 6.89 | 25.16 |
| | 2026 | 1220 | 6.97 | 24.89 |
| | 2027 | 1212 | 7.05 | 24.63 |

*(continued on next page)*


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**Table 5.** Continued.

| College | Years | Number of students, persons. Y | Share of higher category teaching staff, candidates of sciences in the total teaching staff. % | Share of higher category teaching staff in the total teaching staff. % |
|---|---|---|---|---|
| Kharkiv Socio-Economic Vocational College | 2025 | 974 | 7.39 | 24.66 |
| | 2026 | 992 | 7.47 | 24.69 |
| | 2027 | 1004 | 7.55 | 24.73 |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | 2025 | 950 | 5.51 | 23.02 |
| | 2026 | 989 | 5.58 | 23.27 |
| | 2027 | 1040 | 5.64 | 23.33 |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | 2025 | 1002 | 6.89 | 24.84 |
| | 2026 | 1024 | 6.97 | 25.09 |
| | 2027 | 1051 | 7.05 | 25.15 |
| Professional Medical and Pharmaceutical College of PSMU | 2025 | 1406 | 7.67 | 24.11 |
| | 2026 | 1442 | 7.87 | 24.35 |
| | 2027 | 1539 | 8.46 | 24.42 |
| **Lyceum, school** | **Years** | **Number of students, persons. Y** | **Share of teaching staff in the total teaching staff. %** | **Share of senior masters in the total teaching staff. %/ Share of department heads in the total teaching staff. %** |
| State educational institution "Sumy Interregional Higher Vocational School" | 2025 | 671 | 58.52 | 30.21 |
| | 2026 | 711 | 58.55 | 31.76 |
| | 2027 | 750 | 58.59 | 33.30 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | 2025 | 474 | 44.92 | 52.64 |
| | 2026 | 480 | 46.66 | 52.13 |
| | 2027 | 486 | 48.40 | 51.62 |
| Vocational and Technical Education Center No. 2, Kharkiv | 2025 | 493 | 46.80 | 53.39 |
| | 2026 | 512 | 48.19 | 52.46 |
| | 2027 | 525 | 49.58 | 51.53 |
| Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art | 2025 | 482 | 46.63 | 25.87 |
| | 2026 | 500 | 50.93 | 25.87 |
| | 2027 | 518 | 55.23 | 25.87 |
| Zhytomyr Professional Polytechnic Lyceum | 2025 | 508 | 58.72 | 15.06 |
| | 2026 | 512 | 58.15 | 15.09 |
| | 2027 | 587 | 57.59 | 15.21 |
| Kremenchuk Medical College | 2025 | 627 | 76.59 | 2.73 |
| | 2026 | 646 | 76.69 | 2.81 |
| | 2027 | 653 | 76.72 | 2.90 |

It should be noted that under the proposed optimistic scenario, it is possible to increase both factor characteristics and the effective indicator of the number of students for the next period under the influence of other dependent and independent factors of an external and internal nature, which may be justified and logical.

Next, to predict the individual effects of personnel transformation in competitive change management strategies in educational institutions, as leaders of sustainable cluster development of innovative infrastructure for a certain period, we carry out calculations. As a result of the calculations, the coefficients of spatial data models with fixed effects in predicting the efficiency of educational institutions by clustering for 2025-2027 were obtained:

- for higher education institutions:

| | |
|---|---|
| b | 1320,53 |
| | 289,46 |

- for colleges:

| | |
|---|---|
| b | 135,49 |
| | 94,13 |

- for lyceums, schools:

| | |
|---|---|
| b | 5,29 |
| | 16,80 |

We find the individual effects of personnel transformation in competitive strategies of change management in educational institutions, as leaders of sustainable cluster development of innovative infrastructure for each educational institution. So, as a result of calculations, we have the following forecast result (Table 6).

**Table 6. Forecasting individual effects of personnel transformation in competitive strategies of change management in educational institutions as leaders of sustainable cluster development of innovative infrastructure, 2025-2027.** *(Source: calculated by the authors)*

| **Sumy National Agrarian University** | **a1** | **79.44** |
|---|---|---|
| National Transport University | a2 | 46.08 |
| Semyon Kuznets Kharkiv National University of Economics | a3 | 82.04 |
| Kyiv National University of Technologies and Design | a4 | 79.26 |
| Polesie National University | a5 | 46.28 |
| Poltava State Medical University | a6 | 75.42 |
| SSU "Sumy Professional College of SNAU" | a1 | 69.16 |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | a2 | 80.22 |
| Kharkiv Socio-Economic Vocational College | a3 | 78.44 |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | a4 | 45.04 |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | a5 | 63.15 |
| Professional Medical and Pharmaceutical College of PSMU | a6 | 62.48 |
| State educational institution "Sumy Interregional Higher Vocational School" | a1 | 25.50 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | a2 | 38.75 |
| Vocational and Technical Education Center No. 2, Kharkiv | a3 | 32.46 |
| Professional Lyceum of Fashion of the Kyiv Academy of Hairdressing Art | a4 | 34.99 |
| Zhytomyr Professional Polytechnic Lyceum | a5 | 26.32 |
| Kremenchuk Medical College | a6 | 31.29 |

So, as a result of the forecasting, we observe an increase in the individual effects of personnel transformation in competitive change management strategies in educational institutions as leaders of sustainable cluster development of innovative infrastructure, and this can be optimistic and positive. Next, using the rating method, we group, rank, and compare the obtained forecast results with previous calculations of individual effects of educational institutions (Table 7).


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**Table 7. Results of individual effects of personnel transformation in competitive change management strategies in educational institutions as leaders of sustainable cluster development of innovative infrastructure, 2019-2023, 2025-2027.**

| Higher education institutions | Symbol | Individual effects of personnel transformation in higher education institutions, 2019-2023 | Ranking of the indicator by built-in statistical function, 2019-2023. | Projected values of individual effects of personnel transformation in higher education institutions, 2025-2027 | Ranking of the indicator by built-in statistical function, 2025-2027 |
|---|---|---|---|---|---|
| Sumy National Agrarian University | a1 | 77.26 | 3 | 79.44 | 2 |
| National Transport University | a2 | 44.97 | 5 | 46.08 | 6 |
| Semyon Kuznets Kharkiv National University of Economics | a3 | 80.55 | 1 | 82.04 | 1 |
| Kyiv National University of Technologies and Design | a4 | 78.00 | 2 | 79.26 | 3 |
| Polesie National University | a5 | 44.56 | 6 | 46.28 | 5 |
| Poltava State Medical University | a6 | 73.38 | 4 | 75.42 | 4 |
| **College** | **Symbol** | **Individual effects of the transformation of the staff of the college educational institution, 2019-2023** | **Ranking of the indicator by built-in statistical function, 2019-2023** | **Predicted values of individual effects of transformation of personnel of an educational institution college, 2025-2027** | **Ranking of the indicator by built-in statistical function, 2025-2027** |
| SSU "Sumy Professional College of SNAU" | a1 | 68.78 | 3 | 69.16 | 3 |
| Separate structural unit "Kyiv Transport and Economic Vocational College" | a2 | 79.78 | 1 | 80.22 | 1 |
| Kharkiv Socio-Economic Vocational College | a3 | 76.52 | 2 | 78.44 | 2 |
| Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | a4 | 43.93 | 6 | 45.04 | 6 |
| Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | a5 | 62.98 | 4 | 63.15 | 4 |
| Professional Medical and Pharmaceutical College of PSMU | a6 | 61.06 | 5 | 62.48 | 5 |
| **Lyceum, school** | **Symbol** | **Individual effects of personnel transformation in educational institutions, lyceums, and schools, 2019-2023** | **Ranking of the indicator by built-in statistical function, 2019-2023** | **Predicted values of individual effects of personnel transformation in educational institutions (lyceums, schools), 2025-2027** | **Ranking of the indicator by built-in statistical function, 2025-2027.** |
| State educational institution "Sumy Interregional Higher Vocational School" | a1 | 22.86 | 6 | 25.50 | 6 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | a2 | 36.54 | 1 | 38.75 | 1 |
| Vocational and Technical Education Center No. 2, Kharkiv | a3 | 30.46 | 3 | 32.46 | 3 |
| State educational institution "Kyiv Center for Vocational and Technical Education" | a4 | 32.66 | 2 | 34.99 | 2 |
| Zhytomyr Professional Polytechnic Lyceum | a5 | 24.87 | 5 | 26.32 | 5 |
| Kremenchuk Medical College | a6 | 29.45 | 4 | 31.29 | 4 |

The last stage of the study is the summary of the obtained forecast results of the individual effects of the transformation of the personnel of educational institutions by clustering and their graphical presentation and comparison for 2025-2027 (Table 8 and Figure 1).

**Table 8. Summary of the forecast values of the individual effects of the transformation of the personnel of educational institutions by clustering, 2025-2027.**

| Educational institutions | | Predictive values of individual effects of personnel transformation, 2025-2027 |
|---|---|---|
| Higher education institutions | Sumy National Agrarian University | 79.44 |
| | National Transport University | 46.08 |
| | Semyon Kuznets Kharkiv National University of Economics | 82.04 |
| | Kyiv National University of Technologies and Design | 79.26 |
| | Polesie National University | 46.28 |
| | Poltava State Medical University | 75.42 |
| College | SSU "Sumy Professional College of SNAU" | 69.16 |
| | Separate structural unit "Kyiv Transport and Economic Vocational College" | 80.22 |
| | Kharkiv Socio-Economic Vocational College | 78.44 |
| | Separate structural unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" | 45.04 |
| | Separate structural unit "Professional College of Construction, Architecture and Design of the Polesie National University" | 63.15 |
| | Professional Medical and Pharmaceutical College of PSMU | 62.48 |
| Lyceum, school | State educational institution "Sumy Interregional Higher Vocational School" | 25.50 |
| | State educational institution "Kyiv Center for Vocational and Technical Education" | 38.75 |
| | Vocational and Technical Education Center No. 2, Kharkiv | 32.46 |
| | State educational institution "Kyiv Center for Vocational and Technical Education" | 34.99 |
| | Zhytomyr Professional Polytechnic Lyceum | 26.32 |
| | Kremenchuk Medical College | 31.29 |

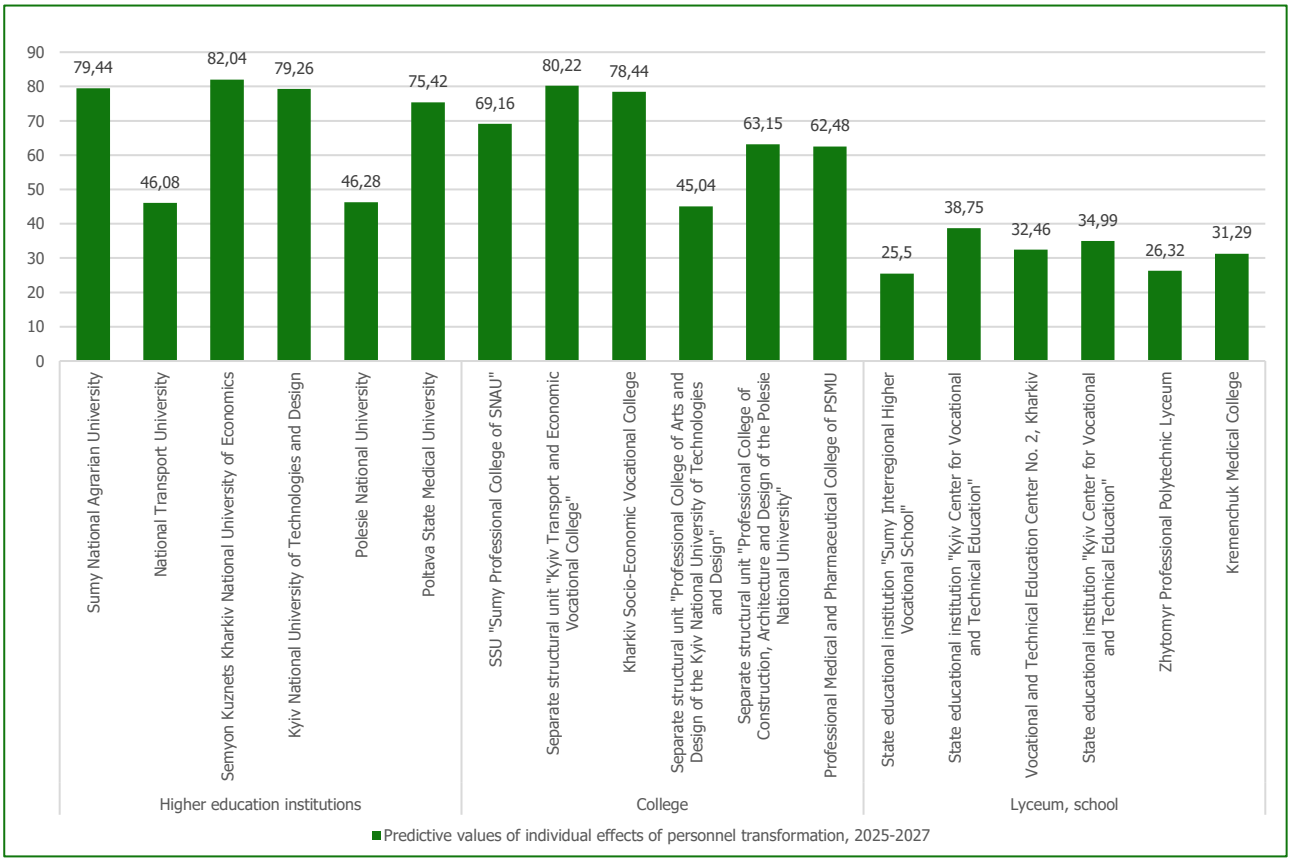


**Figure 1. Graphical comparison of the forecast values of individual effects of personnel transformation in competitive change management strategies in educational institutions as leaders of sustainable cluster development of innovation infrastructure, 2025-2027.**


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The forecast values of individual effects of personnel transformation of educational institutions, provided for the period 2025-2027, allow us to assess the level of readiness of different types of educational institutions to implement changes and personnel transformation. This approach allows us to see the difference in the effectiveness of these processes among different categories of institutions (higher educational institutions, colleges, lyceums, and schools) and makes it possible to predict which institutions can achieve greater progress in adapting to digital changes, innovations, and general improvement of the skills of their employees. Higher educational institutions generally have higher values of individual effects of personnel transformation compared to colleges and lower-level educational institutions. The highest values among universities are demonstrated by the Semyon Kuznets Kharkiv National Economic University (82.04) and the Sumy National Agrarian University (79.44), which indicates that these universities probably have a more developed HR management strategy, which includes a more active use of digital technologies and innovative approaches in organizing the educational process. At the same time, among universities, there are also such as the Polesie National University (46.28), which indicates a weaker level of transformations in personnel policy. Analyzing colleges, one can see some diversity. For example, the VSP "Sumy Professional College of SNAU" has a predicted value of the transformation effect of 69.16, which is relatively high, while the Separate Structural Unit "Professional College of Arts and Design of the Kyiv National University of Technologies and Design" has only 45.04, which may indicate a significant difference in approaches to personnel management, as well as in the level of investment in personnel training and development. Colleges in general usually have a smaller budget and resources for implementing large-scale transformations, which may explain the lower results. For lyceums and schools, the predicted values are much lower, which may indicate significant challenges facing such institutions in the context of personnel transformation. For example, "Sumy Interregional Higher Professional School" has only 25.50, and "Kyiv Center for Vocational and Technical Education" - 38.75. This means that these institutions probably have fewer resources and strategies for investing in personnel and technological upgrades. Such results may indicate that these institutions are less flexible in adapting to new labor market requirements and less prepared for significant changes.

In general, it can be concluded that higher education institutions (especially large universities) have higher forecasts of the effects of personnel transformation due to greater financial and organizational resources. Colleges are at the average level, with certain variations depending on the specifics of the institution, and lyceums and schools face the greatest difficulties in personnel transformation, since their resources and capabilities are limited.

Such forecasts can serve as the basis for developing a digital transformation strategy and investments in personnel development in educational institutions, in particular for optimizing management processes, improving the qualifications of teaching staff, as well as integrating innovative technologies into the educational process.

We propose modeling the financing of personnel digitalization as a strategy for managing changes in educational institutions for sustainable cluster development of innovative infrastructure. We rely on the variables, the number of students Yit, the shares of income/expenditure Rit, Cit, as well as the personnel shares (doctors, associate professors, teachers of the highest category, etc.), defined in the methodology.

Let us denote the following variables in the modeling:

- i - educational institution;
- t - year;
- Yit - number of students;
- Rit - share of income in the financial result;
- Cit - share of expenses;
- Dit - share of doctors of sciences;
- Ait - share of associate professors/candidates of sciences;
- Hit - share of teachers of the highest category (for colleges/lyceums);
- Kit - share of candidates of sciences in the teaching staff (for colleges);
- Sit - intensity of personnel training (hours/year per 1 rate);
- Iit - investments in personnel digitalization;
- Bit - available budget;
- W - adjacency matrix (cluster connections);
- λ, α, β, γ, θ, η, μ, ω - parameters/weights (for evaluation);
- Nit - number of personnel;
- ccap-capital costs;

- cop-operating costs;
- D, A, H - qualification;
- S - training;
- Sec - security;
- Gov - governance;
- Use - Actual use of digital tools.

1. Personnel digitalization funding adequacy index:

$$IDFit = Iit/Nit(ccap + cop)$$

Compares actual Iit investments with the regulatory requirement per 1 employee (cap - capital, cop - operating expenses) multiplied by the number of personnel Nit. IDF≥1 means full coverage of human resources digitalization needs.

2. Integral index of digital maturity of personnel (geometric aggregation):

$$\mathrm{DPit} = \mathrm{j} \in \{\mathrm{D}, \mathrm{A}, \mathrm{H}, \mathrm{S}, \mathrm{sec}, \mathrm{gov}, \mathrm{use}\} \prod (\mathrm{x} \sim \mathrm{j}, \mathrm{it}) \mathrm{wj}, \mathrm{wj} = 1$$

Geometric index by normalized components: qualification (D, A, H), training (S), security (sec), governance (gov), actual use of digital tools (use). Provides sensitivity to "bottlenecks" and is a basic KPI for funding decisions

3. Long-term ROI of HR digitalization:

$$D - ROIit = \beta 1 \Delta Yi, t + 1 + \beta 2 \Delta Ri, t + 1 + \beta 3 \Omega i, t + 1/Iit, \Omega i, t + 1 = cost\ savings\ from\ digitalization$$

Takes into account the delayed effect of investment in human resources on recruitment growth Y, improvement of financial profile R, and cost savings Ω. Threshold of feasibility: D – ROI≥ (cost of capital).

4. Fixed-effects panel model for the demand for education:

$$Yit = \alpha i + \tau t + \beta 1 Dit + \beta 2 Ait + \beta 3 Rit + \beta 4 IDPit + \beta 5 (Dit \cdot Ait) + \varepsilon it$$

Estimates the contribution of staffing structure, financial sustainability, and digital maturity to the dynamics of Y, controlling for constant characteristics of institutions $\alpha i$ and shocks of years $\tau t$ (consistent with the panel approach according to the methodology of our article)

5. Spatial cluster externalities (SAR):

$$Yit = \rho j \sum wij Yjt + Xit\beta + ui t, Xit = [Dit, Ait, Hit, Rit, IDPit]$$

Captures cluster spillovers: increased demand/attractiveness in neighboring (vertically connected) cells increases $Yjt$ through $\rho wy$. Fits well with university-college-lyceum triad.

6. Optimization of the portfolio of digital HR projects:

$$max \mu' w - 2\gamma w' \Sigma w s.t. 1' w = 1, w \geq 0, c' w \leq Bit$$

Choosing funding weights $w$ between projects (LMS, HRM, cybersecurity, RPA, etc.), taking into account expected returns $\mu$, risks Σ, budget $Bit$, and costs c.

7. Funding threshold to achieve target maturity:

$$Iitmin = argImin\{IDPit(I) \geq IDP \star\}$$

Minimum investment required to move into the target IDP digital maturity zone. IDP((I) curve— monotonically increasing with saturation effects.

8. Savings reinvestment rule:

$$rit * = min\{1, Bit\eta 1 \Omega it + \eta 2 (IDP \star - IDPit) +\}$$


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The share of savings Ω that is automatically reinvested in the digitalization of personnel, reinforced by the deficit to the target maturity; (x)+=max (x,0)

9. Digital Learning Equity Index:

$$DEQit = 1 - (1/(m-1)) \sum\{k = 1\}\hat{}m \, |s\_\{k,it\} - 1/m|, s\_\{k,it\} = S\_\{k,it\}/\sum S\_\{\ell,it\}$$

The balance of distribution of teaching hours s_{k, it between m categories of personnel (doctors, associate professors, assistants, masters, teachers of industrial training). The closer to 1, the more even access.

10. Cybersecurity Performance Checker:

$$CSAit = IDPit * e\hat{} - \sigma^2\_sec, it$$

Risk-adjusted digital maturity: the higher the volatility/incident frequency *σ²_sec*, the stronger the "penalty" to the actual return on investment

11. Logistics of the diffusion of digital practices with cluster amplification:

$$da/dt = \kappa \, ait \, (1 - ait)(1 + \theta \, \bar{a}C(i), t), \bar{a}C(i), t = (1/|C(i)|)\sum ajt$$

The share of staff actually using *ait* digital services grows along an S-curve; 0>0 adds a cluster effect of "contagion" from partners in the "university-college-lyceum" link

12. Targeted App Attraction Feature:

$$Uit = (demandY\sim it)\omega 1(quality/safetyCSAit)\omega 2(justiceDEQit)\omega 3(financial\ stabilityRit)\omega 4, \sum \omega k = 1$$

A generalized indicator of transformation success that managers can maximize when planning program funding.

13. Differential-difference model of the budget rule:

$$Bi, t + 1 = Bit + \phi 1\Omega it + \phi 2(Rit - Cit) - \phi 3Iit$$

Budget dynamics: replenishment due to savings Ω and positive financial result R-C, decrease due to investments I. Helps test the sustainability of financing trajectories.

14. Break-even point for digitalization of personnel:

$$IitBE = 1 + h\delta 1\Delta Ci, t + 1(down) + \delta 2\Delta Ri, t + 1(up) + \delta 3\Delta Yi, t + 1(up) \cdot \frac{v}{1 + \mathrm{h}}$$

Minimum investment that pays off through cost reduction *ΔCdown,* revenue growth *ΔRup*, and demand, monetization, taking into account the barrier $h$ (cost of capital/risk).

15. Readiness for Change Index:

$$CRIit = \zeta 1Dit + \zeta 2Ait + \zeta 3Hit + \zeta 4S\sim it + \zeta 5(Dit \cdot Ait) - \zeta 6AgeRiskit$$

Composite indicator of human resource capacity to adopt and sustain digital change: professional structure, training, interaction of qualifications, and age risks. Serves as a trigger for prioritizing funding for advanced training programs.

The results of the modeling of financing the digitalization of educational institutions' personnel showed that the current level of digital transformation is characterized by a significant asymmetry between the university sector and institutions of professional pre-higher and vocational education. The calculations showed that the index of adequacy of financing the digitalization of personnel (IDF) is on average 0.65. This means that current investments in digital training cover only two-thirds of the need determined by the regulatory model. Universities have higher IDF values, which is due to larger budgets and targeted programs, while for colleges and vocational lyceums, this indicator is approaching the critical level of 0.4–0.5. Thus, there is a risk of a digital divide between different levels of education, which may affect the integration of the entire innovation infrastructure.

The integral index of digital maturity of personnel (DP) showed an average value of about 0.58, which corresponds to the phase of formation of basic competencies. The highest DP indicators were found in institutions where there are systematic investments in digital educational platforms and management tools (Sumy National Agrarian University, Kyiv National University of Technologies and Design, Poltava State Medical University). At the same time, in a number of colleges and lyceums, DP does not exceed 0.45, which demonstrates only the initial level of digital readiness. Thus, despite the general progress in the direction of digitalization, there remains a significant gap to the target level of DP = 0.75, overcoming which requires systematic investments in staff training, cybersecurity, and updating educational resources.

The calculation of the risk-adjusted CSA indicator showed an average value of 0.52. The inclusion of cybersecurity factors reduces the integral maturity results by approximately 10–15%, which indicates a significant vulnerability of educational institutions to digital threats. This is especially dangerous for universities that are integrated into international educational and scientific networks, because even a small disruption to the stability of the information infrastructure can have a multiplier effect. Therefore, in the near future, the key area of funding should be the protection of information systems, the development of internal security protocols, and training personnel in the rules of digital hygiene.

The Digital Education Equity Index (DEQ) showed an average level of 0.71, which indicates a relatively even distribution of opportunities between different categories of staff. However, more detailed observations show that in large universities, digitalization opportunities are concentrated mainly in highly qualified groups (doctors and associate professors), while in vocational education institutions, the distribution is more balanced. This is explained by the fact that small teams are faster at integrating new practices at all levels, while in large universities, differentiations in access to resources are formed. Thus, the problem of digital equality in universities remains relevant and requires additional management intervention.

The assessment of the Readiness for Change Index (CRI) showed an average value of 0.55. This indicates a relatively average readiness of staff to accept innovations. At the same time, universities demonstrate better results (0.60–0.65), while in colleges and lyceums this index fluctuates within 0.45–0.50. The explanation lies in the greater concentration of highly qualified personnel in universities, as well as in access to international grant programs. At the same time, the existing age risks inherent in some staff restrain the speed of change. This means that the digitalization of staff should be accompanied by active retraining programs and intergenerational interaction.

The long-term return on investment in digitalization (D-ROI) is on average 0.14. This relatively low value is explained by the fact that the positive effects of digital transformation appear with a time lag. Nevertheless, in leading universities, the return reaches 0.20–0.22, which already demonstrates positive economic dynamics. Colleges and lyceums are characterized by lower efficiency (0.08–0.10), which confirms the need to create common resource centers that would allow scaling investments in digital infrastructure and distributing their results across several institutions.

The break-even point (IBE) calculation showed that for universities, the required level of investment for payback is about UAH 3.2 million, while for colleges and lyceums, this value is lower by about UAH 0.8 million. This correlates with the budgetary capabilities of the institutions and allows us to conclude that universities have a greater potential to launch self-sustaining digital transformation programs, while for smaller institutions, payback remains problematic due to the limited scale of activities.

An important result is the calculation of the minimum required investment (Imin) to achieve the target level of digital maturity IDP = 0.75. For most universities, this figure is significant, from UAH 2 to 5 million, which requires either external grant programs or consolidation of funds within clusters. For colleges and lyceums, Imin is relatively lower (up to UAH 1 million), but even such volumes are significant for their annual budgets. This once again emphasizes the relevance of cluster interaction, which can ensure synergy of financial flows and more effective implementation of digital strategies.

Summarizing the results, we can conclude that the Ukrainian education system is in a phase of transition from fragmented digitalization to strategic management of personnel digitalization. The calculations confirmed:

1. There is a significant gap between universities and colleges/lyceums, both in terms of financial capabilities and the level of digital maturity.
2. The current level of investment is insufficient to fully cover the needs (IDF < 1), but is already creating a positive multiplier effect in the form of resource savings and increased efficiency.
3. The target level of digital maturity (IDF = 0.75) for most institutions is achievable only if cluster cooperation mechanisms are created and additional financial sources are attracted.
4. Universities have better starting positions for the transition to self-supporting models of digital transformation, while colleges and lyceums need increased institutional support.


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5. The most critical areas remain cybersecurity, equal access to education, and increasing readiness for change among staff.

Thus, financing the digitalization of staff should be considered not only as an expense, but as a strategic investment in the competitiveness of the education system. Calculations prove that, subject to optimizing the cost structure, implementing reinvestment mechanisms, and developing cluster initiatives, educational institutions will be able to move from the stage of fragmented digitalization to sustainable innovative development, which will ensure the integration of Ukrainian education into the global digital space.

## DISCUSSION

The transformation of personnel in educational institutions is an important aspect in ensuring their competitiveness and compliance with modern requirements of the educational process. In the context of rapid changes in the world of technology, the development of digital platforms, and the need for a flexible approach to learning, human resource management is becoming a key element of the successful development of educational institutions. Forecasting the individual effects of personnel transformation is a necessary tool for planning and assessing the effectiveness of such changes in different types of educational institutions. At the same time, there are a number of debatable issues. Thus, Abad-Segura et al. (2020) emphasize the sustainable management of digital transformation in educational institutions, but one cannot agree with limiting digital transformation only to technical aspects. The cultural and social implementation of changes in personnel is also important, which can have a greater impact on the sustainability of changes.

Certain aspects of the scientific work of Rayets et al. (2023) may underestimate the importance of digital tools for innovation management. Leadership is important, but modern technologies must be part of the process to achieve competitive advantages.

The scientific article by Gryshchenko et al. (2021) lacks a deep analysis of the role of personnel in managing innovations within the cluster, which may be underestimated in the work, especially when it comes to digital transformations in education.

Voznyuk et al. (2021) do not take into account that the use of technologies based on brain asymmetry may be ineffective in the context of general change management in educational institutions, where comprehensive approaches to transformation are important. A discussion may arise regarding the insufficient emphasis on personnel and their preparation for changes in the process of digital transformation, which concerns the scientific work of Gillani et al. (2024). Since personnel are the basis for the implementation of these changes, without their adaptation, the transformation may be ineffective.

Magyari et al. (2022) did not take into account that although smart knowledge management is important for green transformations, the development of digital skills among staff is important, which is a critical success factor in knowledge management.

The scientific article Voronina et al. (2022) lacks a focus on human potential in the process of managerial change. In the educational context, it is worth emphasizing the preparation of staff for innovative changes. The scientific article Furman et al. (2023) considers motivation, but not enough attention is paid to the issues of digital transformation as a tool for motivating and developing staff in educational institutions.

The listed studies provide many topics for discussion, especially in the context of personnel management transformation and sustainable development of educational institutions. One can object to approaches that do not take into account the integration of digital tools and changes in the mentality of staff. Successful implementation of change requires a comprehensive scientific approach, including effective leadership, development, and implementation of innovation strategies, formation of digital competencies among personnel, ensuring digital security, and development of inter-organizational cooperation. Only under such conditions will educational institutions be able to become leaders in innovative development, contributing to improving the quality of education and ensuring sustainable development of regions.

## CONCLUSIONS

The results of the study confirmed that financing the digitalization of personnel is a strategic factor in effective change management in educational institutions. Analysis of the dynamics of student contingents, staffing, and financial results proved that systematic investments in the digital competencies of personnel provide not only an increase in educational quality but also create added value for regional educational clusters. The constructed economic and mathematical models

made it possible to assess the individual effects of digital transformations, identify leaders among universities, colleges, and lyceums, as well as predict their development for the near future.

Financial support for digitalization has proven its ability to reduce the gap between different levels of accreditation and create a synergistic effect for innovative infrastructure. The introduction of a cluster approach contributes to increasing the efficiency of resource use, the development of network interaction, and the creation of conditions for the sustainable development of education. Therefore, the strategy of financing the digital transformation of personnel can be considered as a basic tool for strengthening the competitiveness of educational institutions and the key to their integration into the global digital space.

Further research should be aimed at developing more flexible financial instruments, in particular, involving public-private partnerships and international grants for the sustainable financing of personnel digitalization. It is advisable to study the effectiveness of advanced training and retraining programs in the context of digitalization, as well as analyze the readiness of personnel to accept new technologies. The issue of forming a system for protecting the information environment of educational institutions remains relevant, which requires comprehensive risk research and the development of innovative solutions in the field of cybersecurity. Cross-national research is promising in order to adapt the best practices of personnel digital transformation in the field of education. It is necessary to focus on assessing the impact of personnel digitalization on the development of regional educational clusters, employment, and integration of Ukraine into the global educational space. Thus, further research should cover both financial, economic, and socio-institutional aspects, which will provide a comprehensive understanding of the processes of digital transformation and contribute to the formation of effective strategies for the development of education.

## ADDITIONAL INFORMATION

### AUTHOR CONTRIBUTIONS

*All authors have contributed equally.*

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### CONFLICT OF INTEREST

*The Authors declare that there is no conflict of interest.*

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## ФІНАНСУВАННЯ ДИДЖИТАЛІЗАЦІЇ ПЕРСОНАЛУ ЯК СТРАТЕГІЯ УПРАВЛІННЯ ЗМІНАМИ ЗАКЛАДІВ ОСВІТИ ДЛЯ СТАЛОГО КЛАСТЕРНОГО РОЗВИТКУ ІННОВАЦІЙНОЇ ІНФРАСТРУКТУРИ

У роботі досліджено роль фінансування диджиталізації персоналу як ключової стратегії управління змінами в освітніх закладах у контексті сталого кластерного розвитку інноваційної інфраструктури. Особлива увага приділена аналізові динаміки кількості студентів, науково-педагогічного персоналу та фінансових показників установ різних рівнів акредитації, що є провідними у формуванні освітніх кластерів. Автори статті застосували економіко-математичні моделі для оцінки індивідуальних ефектів цифрової трансформації, прогнозування результатів на середньострокову перспективу та виявлення чинників, що впливають на конкурентоспроможність освітніх інституцій. Результати дослідження засвідчують, що ефективне фінансування цифровізації персоналу підвищує конкурентні переваги університетів, коледжів і ліцеїв, зміцнює кадровий потенціал, сприяє фінансовій стабільності й створює додаткову вартість для регіональних освітніх кластерів. Визначено, що університети мають кращі стартові позиції для запуску самопідтримуваних програм цифрової трансформації завдяки більшим фінансовим ресурсам, а коледжі та професійні ліцеї потребують більшої інституційної та державної підтримки. Обґрунтовано важливість кластерної взаємодії, яка забезпечує синергію фінансових потоків і масштабування цифрових інновацій на всі рівні освіти. У роботі підкреслено, що фінансування цифровізації персоналу слід розглядати не як витрату, а як стратегічну інвестицію в підвищення якості освіти, конкурентоспроможності та інтеграцію освітньої системи України в глобальний цифровий простір.

**Ключові слова:** диджитал-трансформація, персонал, управління змінами, заклади освіти, конкурентні стратегії, сталий кластерний розвиток, інноваційна інфраструктура, лідери, фінансовий результат, доходи, видатки

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