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DIGITAL TRANSFORMATION OF HIGHER EDUCATION FOR ENVIRONMENTAL MANAGEMENT AND SUSTAINABLE DEVELOPMENT: AN INTERDISCIPLINARY APPROACH

Introduction. *The digital transformation of higher education has become a key factor in ensuring high-quality training of specialists in environmental management and sustainable development in response to contemporary global challenges. It has created new opportunities for modernizing educational processes, developing interdisciplinary competencies, and integrating innovative teaching methods.*

Problem Statement. *A detailed study focusing on the interest of educational process participants in interdisciplinary learning and their attitudes towards it is timely and relevant.*

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Purpose. *This study aims to identify the prerequisites for improving the management of higher education in ecology and sustainable development through digitalization and the implementation of an interdisciplinary approach.*

Materials and Methods. *The study has been based on the results of a cross-sectional survey of students from 11 higher education institutions in Ukraine conducted within the framework of the DAAD project Ukrainian-German Digital Teaching Network. Observation, comparison, analysis, synthesis, measurement, statistical data processing, and hierarchical cluster analysis have been employed to identify relationships among academic disciplines and determine their potential for interdisciplinary integration.*

Results. *The findings have shown that students have positively assessed the accessibility and flexibility of digital learning platforms. At the same time, the study has identified technical problems, insufficient digital competencies, and limited use of individual modern learning tools as the principal barriers to effective digital learning. Hierarchical cluster analysis has enabled the disciplines to be systematized into three interdisciplinary blocks integrating environmental, managerial, economic, and information-analytical components. The proposed approach has provided a basis for the modular design of educational programs and the development of integrated professional competencies.*

Conclusions. *The study has established that digitalization is not merely a technological tool but also an important factor in transforming educational content and developing interdisciplinary models of specialist training. The practical significance of the findings lies in the potential application of the proposed approaches to modernize educational programs, improve the efficiency of educational process management, and support progress toward the Sustainable Development Goals.*

Keywords: digitalization of education, management processes, interdisciplinary approach, modernization of educational infrastructure.

Economic growth cannot be achieved without simultaneously protecting and preserving the environment; otherwise, both society and individuals are exposed to significant risks. Given the environmental degradation and deterioration observed in Ukraine, which have been further exacerbated by the ongoing war, there is a pressing need to improve the effectiveness of environmental management and advance sustainable development. The hypothesis of this study is that these objectives can be achieved by improving the quality of professional training and transforming environmental education. Current labor market trends indicate a growing demand for specialists who can process digital data on environmental conditions, develop and implement environmental technologies, assess the impacts of climate change on the economy and society, and formulate policies for sustainable development [1]. Through both formal and non-formal education, Ukrainian higher education institutions have been continuously seeking opportunities to enhance the professional competencies of specialists capable of implementing innovative management solutions in environmental protection and sustainable development. The current system of environmental education in Ukraine requires modernization and digital transformation to improve its effectiveness. This transformation should include the development of academic partnerships that can expand opportunities for interdisciplinary learning and competency development, thereby supporting the achievement of the Sustainable Development Goals.

Having faced global challenges, such as the COVID-19 pandemic and military actions, Ukrainian universities are struggling to work under war conditions. This also includes military operations on a significant part of the territory, the search for new and innovative methods and models of digitalizing education and distance learning, and the study of their impact on the quality of training, which becomes urgent. The use of online technologies, including Massive Open Online Courses (MOOCs), has become an integral part of modern education. Therefore, understanding the prerequisites for implementing innovative digital technologies in environmental education and sustainable development is a pressing task that enables us

to identify modern approaches to online education, thereby improving the quality of learning in uncertain and risky conditions.

The aspects of sustainable management, in general, and ecological management, in particular, are reflected in many Sustainable Development Goals (SDG 17) [2]. Understanding the circular nature of the change process using different methodologies is impossible without all three components of sustainable development (SD) [3, 4]. Integration of the relevant components of the SDGs into the educational process is becoming an increasingly complex and demanding task at all levels — global, national, regional and local. The concept of NEST (Nature, Environment, Science and Technology) remains important for education [5].

2020 has become a key catalyst, prompting many company leaders to implement environmental, social, and governance (ESG) standards and certifications. ESG is becoming a long-term growth strategy for the company and protection against risks [6]. MNCs such as Alibaba, Microsoft, Google, Sony, Huawei known for their products and services, as well as the largest companies in the forest sector International Paper Co. Paper and Packaging, Oji Holdings Corp. Japan, Sumitomo Forestry Co Ltd., Stora Enso Oyj, UPM-Kymmene Corp., West Fraser Timber Co Ltd., use socially responsible projects consistent with core values, such as rural development or inclusive technologies. This indicates the importance and urgent need to train specialists competent not only in developing and implementing relevant standards, but also in communicating and managing the chain of cooperation [7—10].

Organization of the educational process in current conditions foresees the online teaching and learning using digital technologies and platforms, allowing students to gain knowledge and skills without physical presence at educational institution. Being active for decades, online teaching and learning have been individualized due to their flexibility in time and pace of mastering educational material [11]. Artificial intelligence algorithms for analyzing and forecasting student success, the possibility of creating individual educational trajectories, as well as the use of mobile digital devices become an essential complement [12]. However, the teaching and learning require students' self-discipline and self-management [13], proper technical support [14], initiative and teachers' digital skills [15, 16]. That is why both advantages and caveats that must be taken into account to ensure quality education via online courses.

Many scientists and professionals have studied the development of digital education. The prerequisites and current trends of the global digital transformation of education were studied by Rybchuk A. V., Zhurba I. E. and Protsyshyn O. R. [17]. They concluded that digital technologies play a crucial role in reforming and modernizing the global educational environment, transforming all types of information into digital form [17]. The main problems of using modern digital tools to transform education in conditions of crises and dangers and highlight key topics of ensuring high-quality distance education using digital means was studied by the team of authors led by Jan-Peter Mund, Evelyn Wallor and Yu. Nikitchenko [18].

The analysis of the international experience of developing IT education using the example of the EU, USA, China, Singapore, South Korea, India, and Malaysia in the context of sustainable digital development of education and society is carried out by the authors Seiko N., Ershov M.-O. [19].

As a tool for implementing flexible educational solutions, the digitalization of education and the use of distance learning formats open up new opportunities for developing interdisciplinary approaches, contributing to the formation of innovative competencies in teachers [20] and students [21].

The means for implementing interdisciplinary approaches, unfortunately, are still insufficient despite the goals set by Ukrainian education and the substantiation of the online learning format. This applies to both material and technical support and methodological tools providing high-quality training for students to solve complex problems in various fields of knowledge. As well it is rather challenging to incorporate all courses (as educational components) into educational programs [22]. In the

realities of Ukraine's military state, the personnel potential of individual HEIs is being reduced, which does not allow ensuring proper interdisciplinarity for educational programs [23]. In some places, the priorities of technical and pedagogical solutions may be devoid of innovation due to the lack of knowledge about modern digital tools by participants in the educational process, which prevents the full implementation of problem-based learning or effective interaction between teachers and students during distance learning [24].

The integration of the environmental component into curricula across various fields of knowledge has become a primary focus of interdisciplinary approaches in higher education, particularly in environmental management and sustainable development. This is due to the fact that environmental and quality education has become an integral part of sustainable development embedded in the content of the UN 2030 Agenda for Sustainable Development, launched in 2015 [25]. Modern environmental changes, such as global warming, biodiversity loss, soil degradation, and water resource disruption, have led to a review of traditional approaches in many educational programs. These challenges necessitate updated approaches to education, which encompass the practical aspects of sustainable natural resource use, methods for assessing the impact of human activity on the environment, and the development of strategies for its restoration and adaptation to climate change [26]. In parallel, the direct ecological specialization, basically perceived as a perspective for understanding the need for natural resources preservation and environment protection, is increasingly transforming into an interdisciplinary intersection of engineering, socio-economic sciences, information technologies, bioethics, and management. Ecological education goes beyond just environmental aspects. It includes the analysis of natural resources economic value, green technologies development, natural risks management, mathematical forecasting and of sustainable development modelling [27]. It is obvious that considering environmental problems through the prism of interaction of different spheres contributes to the training of professionals able to complete the tasks of environmental conservation in various dimensions.

V. M. Bogolyubov in his research has studied environmental education development in Ukraine. In the context of the professional competence formation for master's students in Ecology, the author has analyzed the problems of sustainable development of society [28]. T. V. Ivanova has considered environmental education a key factor in the sustainable development of the state [29].

The analysis of scholarly research papers in the field of distance teaching and learning and digitalization of higher education from different countries, including Ukraine, has indicated an increase in the level of application of innovative information technologies for training specialists and the growing interest of participants in the educational process in this topic. Understanding the prerequisites for the implementation of innovative digital technologies and methods aimed at improving the quality of managerial education in the field of ecology and sustainable development, detailed research is required focused on the interest and concern of educational process participants in interdisciplinary education.

The aim of the research is to determine the prerequisites for elaborating managerial processes in the field of ecology and sustainable development based on the analysis of the students' attitude to the modernization of the educational process and the organization of online learning. The identification of key factors influencing the implementation of innovative IT technologies and distance learning methods in the context of digitalizing higher education is a core issue of the study.

The research methods of are: observation (conducting a survey of applicants and stakeholders), comparison (identifying changes and features in responses of the survey), measurement (processing the collected data), abstraction (forming the proposals for the development of managerial directions in the field of ecology and sustainable development), analysis and synthesis (forming the prerequisites for research and conclusions).

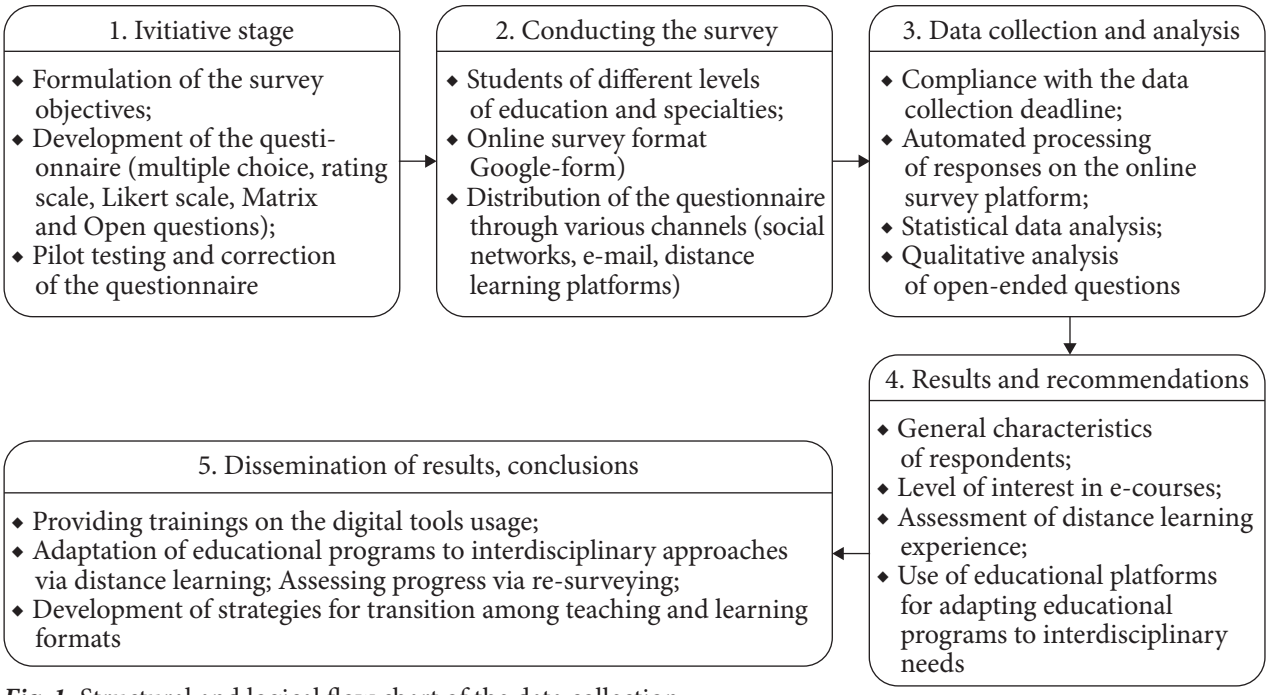


Fig. 1. Structural and logical flow chart of the data collection

The theory and methodology for developing questionnaires were based on the modern pace and time values of respondents. New trends and reports on the development of questionnaires were used, as well as the structure, optimal number of questions and timing to answer them [30, 31].

The survey results analysis with the subsequent development of strategies for the elaboration of educational programs was included in the research as integration of digitalization into interdisciplinary approaches and flexible transition among teaching and learning formats, depending on the conditions. This approach should be used as the basis for the formation of the competencies for future managers.

The stages of the research (data collection) are presented in Fig. 1.

Current methods and tools of distance teaching and learning became the initial part of the research conducted by collecting information via anonymous survey of university students. When performing the research tasks, the results of a single-phase survey of students conducted in 2024 within the framework of DAAD project "Ukrainian-German Digital Teaching Network" were used.

The purpose of the survey was to analyze the opinions of university students about the use of methods and technologies of online teaching and learning, digital content, the organization of distance education and the development of university digitalization, their readiness to change educational methods and transition to them. The structure of the questionnaire developed and offered to students included 26 target questions (close-ended and open format), representing such content categories as General information (HEI, level of education, specialty); Determining interest in online learning and electronic courses; Understanding the term "digitalization;" Analysis of the experience of distance learning and the use of digital tools; Assessment of the level of distance learning in Ukrainian universities; Advantages and challenges of different forms of learning; Proposals for improving the digitalization in education.

The survey sample consisted of 329 students from 11 higher education institutions in Ukraine.

Nearly half of the respondents were students at Yuriy Kondratyuk Poltava National Technical University (Poltava, Ukraine), accounting for 47.4% of the sample, followed by Ivan Boberskyj Lviv State University of Physical Culture (Lviv, Ukraine), at 12.5%, and National Transport University (Kyiv, Ukraine), at 10.0%. Students from the remaining institutions collectively accounted for 30.1% of the sample. The distribution of respondents by educational level was as follows: Bachelor's degree, 83.3%; Master's degree, 11.2%; and postgraduate studies, 5.5%.

The largest groups of respondents represented Specialty 101, "Ecology;" Specialty 072, "Finance, Banking and Insurance;" and Specialties 183, "Environmental Protection Technologies;" and 073, "Management." Specialties represented by 3.6—4.9% of respondents included 029, "Information, Library and Archival Studies;" 014, "Secondary Education;" 017, "Physical Culture and Sports;" 185, "Oil and Gas Engineering and Technologies;" and 081, "Law." Respondents from all other specialties individually accounted for between 0.3% and 2.7% of the sample.

Thus, among the entire set of specialties represented by the surveyed students, the following educational fields prevailed: "Natural Sciences" (26%), "Management and Administration" (25%), "Production and Technology" (16%), "Education"/"Pedagogy" (11%), "Culture and Art" (6%), which in total covered 84% of students.

Such a variety of educational programs is due to the active cooperation of universities within the framework of the implemented international project, which made it possible to consider the interests of students of technical, ecological, economic, IT and other profiles, as interdisciplinary approaches to teaching and learning. In addition, the combination of several educational fields in studying distance learning and digitalization issues within the educational process made it possible to monitor the needs of a wide range of students and to carry out an objective assessment of the integration of modern technologies into the educational process. The ecological component was tracked by reviewing the list of elective courses as part of the individual educational trajectory.

General trends in the students' choice of courses from different fields indicate their interest in those that are close to their major (Fig. 2).

We have observed that students in field 07, "Management and Administration," have most frequently selected courses with a managerial or business-oriented focus, including "CO_2 Management," "Competitiveness Management," and "Innovative Entrepreneurship." Students in field 10, "Natural Sciences," have actively selected courses related to environmental research, environmental modeling, and information technologies in ecology, including "System Analysis and Assessment of Environmental Quality," "Environmental Impact Assessment (Adaptive Ecosystem Management)," "Geo-Ecological Informatics," and "Methods of Processing Environmental Information."

Students in fields 18, "Production and Technology," 27, "Transport," and 17, "Electronics and Automation," have demonstrated a noticeable preference for technology-oriented environmental courses, including "Resource Potential of Solid Domestic Waste" and "Methods of Mathematical Modeling and Forecasting of the State of the Environment."

Students in fields 01, "Education/Pedagogy," and 08, "Law," although representing a minority of the respondents, have expressed interest across all courses. We suggest that this pattern may be explained by the fact that environmental and management topics represent additional competencies for these fields rather than the primary focus of professional training.

The analysis of individual courses has indicated that "CO_2 Management" and "Trade and Environmental Economics" have been the most attractive courses among students in fields 07, "Management and Administration," and 10, "Natural Sciences," and, to a lesser extent, among students in field 18, "Production and Technology," and other fields. This finding indicates growing interest in topics at the intersection of economics and environmental management, particularly CO_2 emissions trading and the financial dimensions of environmental protection.

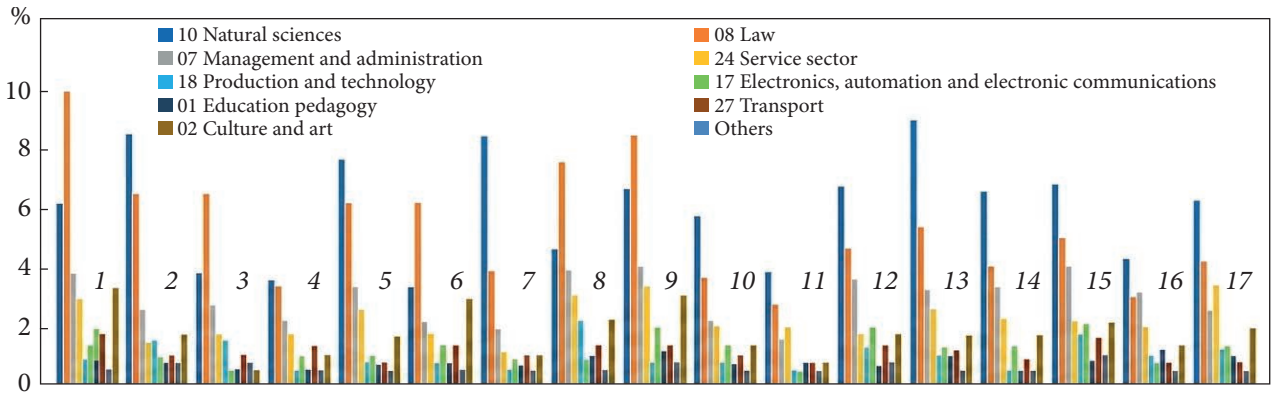


Fig. 2. Distribution of the students' choice of courses for distance learning according to their educational fields: *1* — CO_2 Management and Trade; *2* — System Analysis and Assessment of Environmental Quality; *3* — Corporate Social Responsibility; *4* — Resources Potential of Municipal Solid Waste; *5* — Environmental Economics; *6* — Competitiveness Management of the Enterprise; *7* — Environmental Impact Assessment (Adaptive Ecosystem Management); *8* — Innovative Entrepreneurship and Startup Management; *9* — Management of Research Projects; *10* — Methods of Environmental Information Processing; *11* — Methods of Mathematical Modelling and Forecasting the State of Environment; *12* — Organic Production Management; *13* — Problems of Environmental Education; *14* — Systemic Analysing the Protective Processes in Ecological Systems; *15* — Project Management; *16* — Geoecological Informatics; *17* — Natural Resource Management in the Context of European Integration

Students in field 07, "Management and Administration," have shown a stronger preference for courses such as "Management of Research Projects," "Competitiveness Management of the Enterprise," "Innovative Entrepreneurship," and "Startup Management." Representatives of field 10, "Natural Sciences," have also shown interest in these courses, possibly reflecting a desire to develop managerial competencies applicable to scientific and environmental startups.

The courses "Environmental Impact Assessment (Adaptive Ecosystem Management)" and "Methods of Environmental Information Processing" have proved particularly popular among students in fields 10, "Natural Sciences," and 07, "Management and Administration." This pattern indicates a strong interest among future specialists in competencies related to comprehensive environmental impact assessment and environmental data analysis.

The courses "Resource Potential of Municipal Solid Waste" and "Methods of Mathematical Modeling and Forecasting of the State of the Environment" have attracted notable interest from students in fields 10, "Natural Sciences," and 18, "Production and Technologies," as well as, to some extent, from students in field 17, "Electronics and Automation." This distribution indicates a discernible connection between students' academic fields and the technical and technological dimensions of environmental management.

Thus, the diagram presented in Fig. 2 illustrates that students from different specialties actively choose environmental and managerial courses, with the greatest interest shown by representatives of the "Management and Administration" and "Natural Sciences" directions. We suggest that the results can assist in optimizing the structure and content of distance learning courses, given the demand.

Cluster analysis (Single Linkage, Euclidean distance) was used to track how the 17 selected courses are grouped based on the similarity of their content and thematic focus, in particular from the point of view of ecology, management and economics. The resulting dendrogram shows that all courses are grouped into three main clusters (Fig. 3).

1. Management and assessment of environmental impact (CO_2 management, project manage-

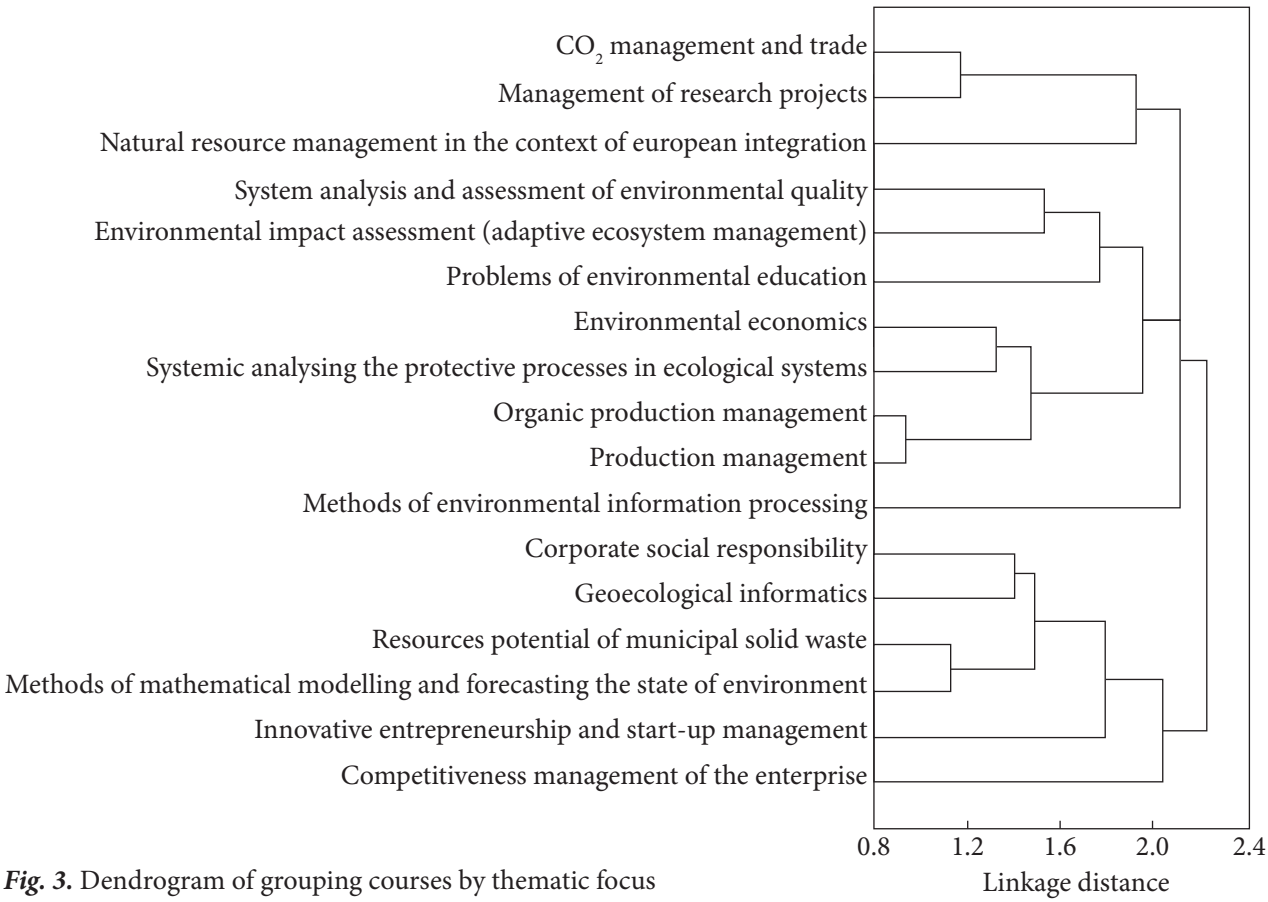


Fig. 3. Dendrogram of grouping courses by thematic focus

ment, natural resources, impact assessment, eco-education);

2. Economics, production, information processing and social responsibility (environmental economics, organic production, eco-data processing methods);

3. Resources, mathematical modelling and innovative entrepreneurship (solid waste, mathematical forecasting, startups, competitiveness).

The cluster of management and analytical-ecological aspects includes courses related to emission regulation (CO_2), project management, and use of natural resources in the context of European integration, assessment of environmental quality and impact, as well as environmental education. The main idea that connects the courses within the cluster is integrated management and assessment of the state of the environment in a global context.

The cluster of economic, production information and analytical courses combines subjects inclining to economic assessment, production management (in particular organic), the use of ecosystem analysis methods and corporate social responsibility. There are also technological and IT courses related to environmental data processing, geoinformation analysis and modelling of eco-processes.

The cluster of resources, mathematical modelling, and entrepreneurship combines courses with a high degree of technical and business-oriented components: waste potential management, mathematical modelling of ecological processes, innovative entrepreneurship, and competitiveness management.

Given this grouping, in the process of developing educational programs, we suggest the "module" sets of courses depending on students' professional or

research interests. For example, to form blocks of disciplines or profile specializations ("Environmental Management and Policy," "Economics and Information Systems in Ecology," "Innovation and Modelling in Environmental Entrepreneurship," etc.). The approach optimizes interdisciplinarity taking into account both the ecological and economic components, creating the potential for collaborations between managers and specialists in environmental modelling or environmental impact assessment. The introduction of innovative IT technologies and the digitalization of teaching and learning at universities are crucial in ensuring interdisciplinary approaches.

Analysis of the level of organization of distance teaching and learning at universities showed that 45.3% of students are satisfied with the accessibility and flexibility of training at their universities, moreover 31% are completely satisfied with the quality and format of online education. More than three-quarters of respondents (77.2%) determined that all educational materials and tasks are available on online platforms (e.g., Moodle, Google Class, Microsoft Teams, etc.). It should be considered that more than half (59%) of respondents were active users of online education, as all classes for them were held exclusively online (lectures and practicals). 38.3% of respondents noted that educational materials and tasks were sent by mail and/or via messenger (Viber, Telegram). Almost half of the respondents (45.9%) indicated that they are satisfied with the level of distance learning, 31.9% were very satisfied, 14.3% described their level of satisfaction as neutral, and only 5.2% were dissatisfied with the level of distance learning, feeling the lack of knowledge in the specialty.

During the survey, students were provided with a list of digital platforms and tools used by instructors in teaching different courses. According to the responses, instructors most frequently used tests and quizzes ("often": 34.2%), recordings of their own lectures (30.9%), educational videos available online (29.4%), and video instructions for practical classes (28.8%). For many of the listed digital tools, the most common responses were "rarely" and "do not know about it." Among these tools, Mentimeter had the lowest reported level of use, with 25.8% of students indicating "rarely" and 57.9% reporting that they did not know about the tool. Similarly, 28.8% and 50.9% of respondents, respectively, selected these options for Coursera, while 30.0% and 48.2%, respectively, did so for Google Earth. The results are presented in Fig. 4.

Regarding other digital platforms and tools used by teachers, students mentioned Zoom (14.6%), Moodle (6.4%), university website (4.6%), Google Meet (2.4%). Some teachers use Telegram, Youtube, Viber, Microsoft Teams, Google Classroom, Kahoot, etc.

Answers regarding challenges and/or obstacles in using digital tools in the study process are presented in Table.

The most common answers for students, according to the results, were "periodically" and "never," with the highest rate of "periodically" for the criterion "Technical problems' (62.3%). For the same criterion, the majority of answers were "often" compared to the other criteria.

The majority of respondents (78.7%) indicated that they do not require additional training or seminars on using digital tools for learning. And their suggestions for improving digital skills included:

1. Conducting training for teachers and students for better understanding of digital tools (4.6%), including organizing trainings (9.4%) and seminars (2.4%) on the use of digital tools for teaching and learning including working groups, webinars (1.2%), video lessons (2.1%), involving well-known experts in the field of digital technologies as guest lecturers (2.1%), advanced training courses on the use of digital tools in the educational process (4.3%); active using of informal teaching and learning tools and methods for students (online courses, for example, Prometeus) (3.6%).

2. Creating online communities and forums allowing teachers and students to share their experience using digital tools (3%).

3. Development of specialized educational resources (5.2%), manuals (1.5%), and software for digital education (2.1%), assisting students and teachers in mastering digital tools principles.

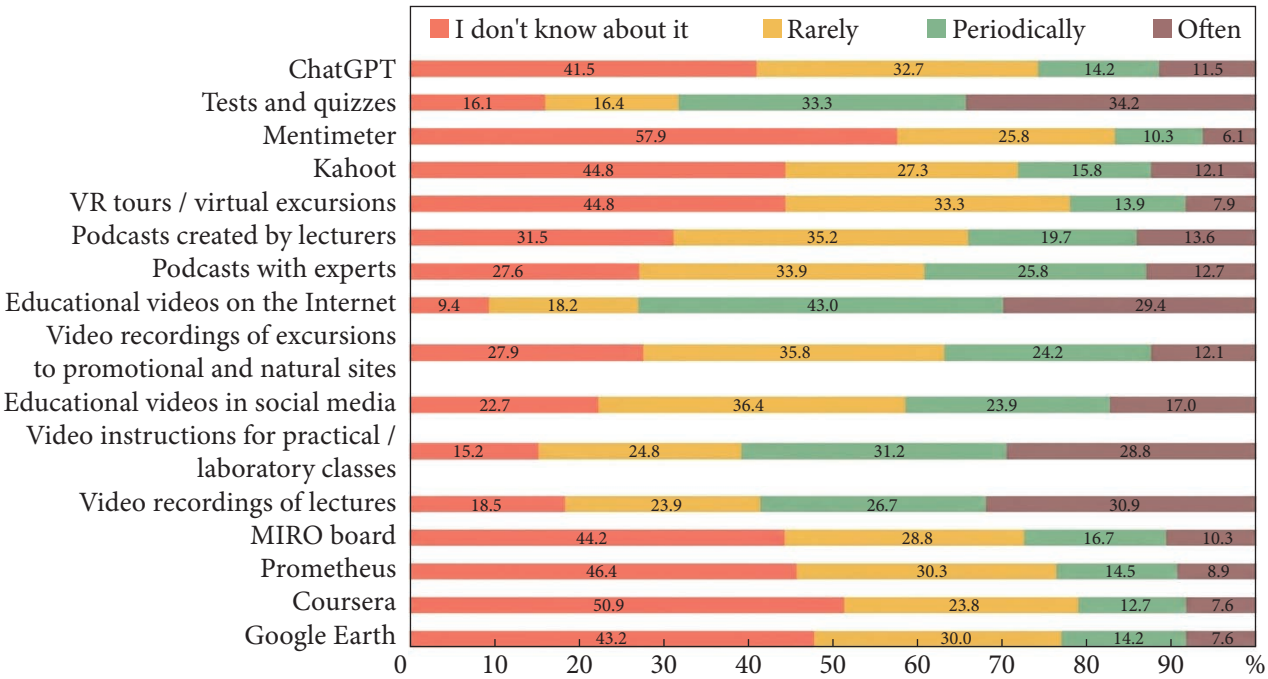


Fig. 4. Digital platforms and tools used by teachers in their courses

4. Practical classes with students at the university using digital tools (2.4%); training of teachers (2.7%).

According to 63.5% of the surveyed students, the technical infrastructure and logistical support available at their universities — including Internet

Challenges and/or Obstacles in Using Digital Tools in the Study Process

Challenge description	Often	Periodically	Never
Lack of /limited access to necessary online resources and tools	7.6	37.4	55.0
Technical problems (software failures, Internet connection problems, incompatibility with devices)	15.8	62.3	21.9
Difficulties in learning and using new tools (e.g., due to their complexity and limitations in use)	8.2	41.0	50.8
Insufficient level of proficiency and insufficient skills to effectively use digital tools	6.7	29.5	63.8
Lack of time to master and use digital tools	10.9	41.3	47.7
Internal resistance (unwillingness) to master and use new technologies	7.0	32.8	60.2
Insufficient motivation to master available tools due to the inexpediency of their use	10.6	31.6	57.8
The use of digital tools may raise questions about the security and confidentiality of personal data	10.9	29.8	59.3
Low quality of digital content (“childish” and/or non-professional tasks, illogical tasks and tests, content that does not correspond to the content of the discipline/specialty, etc.)	7.6	24.6	67.8

access, computer laboratories, and digital technologies — have enabled the use of digital tools for in-person teaching and learning. Another 30.7% of respondents have indicated that the available infrastructure has only partially enabled such use, whereas 5.8% have reported that it has not enabled it. Technical problems with the Internet connection or technical support at the university are a potential challenge for the use of digital tools in traditional learning (51.7%). However, students believe that the shift to distance learning can improve educational outcomes (may improve — 34%, partially improve — 48.3%, does not improve — 17.6%).

Students' views on the potential of digitalization to improve the quality of higher education in Ukrainian universities have been particularly informative. Overall, 12.5% of respondents have indicated that digitalization would improve the quality of education, although they have not provided specific reasons for this assessment. Another 10.0% have found it difficult to answer the question, while 2.4% have indicated that digitalization would not improve the quality of education.

The ways that digitalization can improve the quality of education in Ukrainian higher education institutions, according to the respondents, are:

1) increase in the accessibility of education (9.4%) regardless of the place of residence and despite the limitations of the physical capabilities (1.8%); convenience of learning via gadgets (3%); the ability to combine study with work (1.5%); effective time management (3%); increase of success (1.8%) and development of social, technical, communicative, etc. skills (1.5%);

2) increase in the flexibility of learning (1.2%) and its pace (1.2%), as well as the communication with teachers (1.8%);

3) providing access to high-quality educational content (10.9%) through online resources and electronic platforms: online libraries, electronic textbooks and scientific databases providing students and teachers with access to the updated research and materials for processing at a convenient time; expanding the possibilities of distance learning and the use of innovative and interactive methods (4.6%), involving students in active participation, introducing innovative technologies to improve practical training;

4) promoting the personalization of learning (2.1%), allowing materials to be adapted to the individual needs, which increases the involvement of a larger number of students in the educational process (1.5%); increasing students' interest and motivation for learning (1.2%); increasing the efficiency of the educational process and stimulating innovation and creativity among students and teachers (1.2%);

5) expanding students' opportunities (2.4%); improving knowledge and skills (1.8%); self-development (3%); mastering, processing and analysis of information (2.1%); better preparation for the digital age (2.7%) and for the future profession (2.1%);

6) strengthening international cooperation (2.1%) and the exchange of knowledge and experience through joint projects and programs, which contribute to the development of the international community in education.

Prospects for further research are related to expanding the sample by including a larger number of higher education institutions, educational programs and regions and conducting repeated waves of surveys to track changes in students' attitudes towards digital learning, deepening the assessment of the effectiveness of the use of digital tools and platforms (including MOOCs) through the analysis of academic achievements, the formation of competencies and the level of involvement, as well as validating the resulting typology of disciplines by applying alternative metrics/grouping algorithms and expert verification of content blocks. A separate direction may be the development and pilot testing of modular interdisciplinary trajectories for training specialists in ecology and sustainable development, with further assessment of their impact on the quality of training, academic load, and student satisfaction, as well as the analysis of organizational and technical factors that determine the effectiveness of the digitalization of the educational process.

The study has found that digital technologies in Ukrainian higher education, particularly in ecology and sustainable development, are perceived

by students as a necessary tool for increasing the accessibility and flexibility of learning. The survey results have indicated that the majority of students have a positive assessment of the organization of distance learning and the availability of materials on online platforms. At the same time, the use of individual tools (in particular, platforms such as Coursera, etc.) remains limited, which indicates the unevenness of digital practices and the need for targeted pedagogical design and support.

Key barriers to digitalization that directly affect the quality of specialist training have been identified. Students have most frequently reported technical problems, including software failures, Internet connectivity issues, and device incompatibility, as well as periodic difficulties in mastering new digital tools and insufficient time to develop proficiency in their use. These findings indicate that digital transformation should be accompanied not only by the implementation of digital platforms but also by the development of digital competencies and appropriate organizational support.

The analysis of content similarity among the disciplines has established the feasibility of grouping them into three interdisciplinary blocks, thereby creating a basis for the modular design of educational programs that takes into account students' professional and research interests and strengthens the integration of environmental, managerial, and economic competencies.

The prerequisites for the effective implementation of online technologies in the training of specialists in ecology and sustainable development have included the technical accessibility and stability of the digital environment, the development of digital competencies among participants in the educational process, methodologically sound course design, and institutional mechanisms for support and quality assurance.

The scientific novelty of the study is the development of an integrated analytical procedure that combines students' assessments of digital learning with content-based grouping of academic disciplines, thereby establishing interdisciplinary blocks as a basis for evidence-based curriculum modernization. The study has introduced a cluster-based approach to structuring interdisciplinary courses in environmental management education, empirically assessed students' readiness for digital and interdisciplinary learning under crisis conditions, and demonstrated that digitalization can serve as a driver of curriculum integration rather than merely as a technical tool.

The practical significance of the results lies in the fact that the identified prerequisites and proposed modular approach to grouping disciplines can be used for: (i) optimizing the structure of distance-learning courses in accordance with student demand; (ii) prioritizing digitalization measures, particularly those aimed at improving technical reliability and strengthening digital competencies; and (iii) modernizing educational programs through the integration of environmental, managerial, and economic components.

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ЦИФРОВА ТРАНСФОРМАЦІЯ ВИЩОЇ ОСВІТИ ДЛЯ ЕКОЛОГІЧНОГО УПРАВЛІННЯ ТА СТАЛОГО РОЗВИТКУ: МІЖДИСЦИПЛІНАРНИЙ ПІДХІД

Вступ. Цифрова трансформація вищої освіти є одним із ключових чинників забезпечення якісної підготовки фахівців у сфері екологічного управління та сталого розвитку в умовах сучасних глобальних викликів. Вона створює передумови для модернізації освітнього процесу, розвитку міждисциплінарних компетентностей та інтеграції інноваційних методів навчання.

Проблематика. Актуальним є детальне дослідження, зосереджене на зацікавленості та ставленні учасників освітнього процесу до міждисциплінарного навчання.09:42.

Мета. Визначення передумов удосконалення управління освітою у сфері сталого розвитку на основі цифровізації та впровадження міждисциплінарного підходу.

Матеріали й методи. Дослідження базується на результатах одноетапного анкетування студентів 11 закладів вищої освіти України, проведеного в межах проєкту *DAAD* «*Ukrainian-German Digital Teaching Network*». Використано методи спостереження, порівняння, аналізу, синтезу, вимірювання, статистичної обробки даних та ієрархічного кластерного аналізу для визначення змістових взаємозв'язків між навчальними дисциплінами.

Результати. Встановлено, що студенти позитивно оцінюють доступність і гнучкість цифрових платформ, водночас серед основних бар'єрів визначено технічні проблеми, недостатній рівень цифрових компетентностей та обмежене використання окремих сучасних інструментів навчання. Кластерний аналіз дозволив систематизувати дисципліни у три міждисциплінарні блоки, що поєднують екологічні, управлінські, економічні та інформаційно-аналітичні компоненти. Запропонований підхід створює основу для модульного проєктування освітніх програм і формування комплексних професійних компетентностей.

Висновки. Доведено, що цифровізація є не лише технологічним інструментом, а й чинником трансформації змісту освіти та розвитку міждисциплінарних моделей підготовки фахівців. Практичне значення результатів полягає у можливості використання запропонованих підходів для модернізації освітніх програм, підвищення ефективності управління освітнім процесом та підтримки досягнення Цілей сталого розвитку.

Ключові слова: цифровізація освіти, управлінські процеси, міждисциплінарність, модернізація навчальної інфраструктури.