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Modern Strategies for Educating Natural Science Students in Higher Education

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Abstract

The training of higher education applicants in natural sciences in today's conditions is based on implementing the achievements of scientific and technological progress, the digitalisation of education, and the principles of interdisciplinary, and it focuses on sustainable development. The study proposes introducing technology to implement innovative approaches to the training of higher education students in natural sciences. The experimental work was carried out based on Master's degree students majoring in "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" and "Secondary Education. Geography". Criteria for evaluating the implementation of technology for introducing innovative approaches to the training of higher education students in natural sciences have been developed to conduct a survey of teachers to determine the input and output indicators of the levels of training of higher education students in natural sciences. Three levels of training for applicants for higher education in natural sciences have been developed: high, medium and low. The effectiveness of training of higher education students majoring in "Educational, Pedagogical Sciences and "Secondary Education. Geography" is based on self-assessment results by the outlined levels and learning outcomes. A statistical test of learning outcomes was also carried out using Pearson's criterion. It has been determined that applying innovative approaches to the training of higher education students in natural sciences ensures the formation of professionals with a high level of competitiveness and the ability to solve the problems of sustainable development and natural challenges of today.

Keywords: Higher Education Students, Innovative Pedagogical Approaches, Methods of Teaching Geography, Modern Teaching Technologies, Natural Sciences Majors.

Introduction

The challenges of today, caused by the need to increase the level of competitiveness of specialists, the introduction of digital technologies, and the need for interdisciplinary approaches, require transformational processes in the higher education system. Solving environmental and natural problems necessitates highly qualified personnel, which is relevant in terms of training specialists in the field of natural sciences. Applying innovative approaches to the training of higher education students in natural sciences contributes to the formation of creativity, interdisciplinary and critical thinking for the further application of knowledge in their future professional activities. It also increases the requirements for professional competences and involvement in educational and research activities. There is a gap between labour market requirements and the professional training of higher education students, but there is a demand for qualified personnel. Developing energy-saving technologies, sustainable development, and introducing environmental technologies are also relevant areas of scientific and technological progress. Therefore, developing and implementing innovative approaches to training higher education students in natural sciences can overcome these problems. The study is devoted to evaluating the effectiveness of innovative approaches to training higher education students in natural sciences. Several authors explore innovative approaches to the training of higher education students. Creating personalised educational trajectories entails using analytics, which is especially relevant for students studying

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technical, natural and engineering sciences according to the curriculum (1, 2). Scientists consider the possibility of self-selecting educational content by higher education students and using virtual laboratories to form professional competences (3, 4). The optimisation of the educational and pedagogical process using means is based on developing interdisciplinary approaches and using data analytics and innovative approaches in pedagogy (5, 6). Outlining the principles of environmental technologies is an important aspect of science teachers' in-service training. These approaches develop the application of knowledge acquired in the context of theoretical training in the practical activities of teachers specialising in the training of teachers in the field of natural sciences (7, 8). The involvement of specialised software to provide and analyse data on geographic information systems is a step towards developing interdisciplinary approaches to learning and teaching (9, 10). The article is devoted to implementing an innovative teaching approach that uses massive open online courses (MOOCs) to integrate these courses into curricula (11, 12). The development of critical thinking skills in natural sciences students is carried out through problem-based learning methods and practical methods (12, 13). The article analyses the effectiveness of practical learning for higher education students of engineering specialities (14). Interactive learning technologies involve higher education students deepening knowledge, creating independent learning paths and improving overall educational outcomes (15, 16).

The study focuses on the development of innovative courses based on machine learning (17). A methodology for creating massive open-distance courses has been developed, and the effectiveness of their use and positive feedback from higher education students has been proven (18). The article describes students' perceptions of using voice assistants when searching for information. The study was conducted based on students of technical specialities at the University of Applied Sciences in Zagreb (19). The study outlines the formation of a geographical environment within the framework of smartphone-based virtual reality for a geography course (20). In the context of the literature analysis, it has been determined that the use of digitalisation strategies and research skills of professional competences. The aim of the article is to outline the modern strategies for educating natural science students in higher education, implement it into the educational process and to evaluate the effectiveness of its implementation.

Methodology

In the course of the study the methods of questioning teachers, conducting a pedagogical experiment and statistical evaluation of learning outcomes were used. It was carried out by conducting teacher self-assessment and statistical comparison of learning outcomes of higher education students. The study was conducted at Pavlo Tychyna Uman State Pedagogical University and Zaporizhzhia National University during the academic year 2022–2023.The first part of the pedagogical experiment assessed the effectiveness of innovative approaches. It was carried out based on a survey of teachers of the specialties "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" and "Secondary Education. Geography." A total of 32 teachers took part in the survey. During the implementation of the second part of the experimental work, the training results of higher education students in the specified specialities were compared. In total, 166 higher education students took part in the experiment, forming a control group (CG) (83 people), which studied natural sciences according to the traditional teaching technology provided by the educational programme and an experimental group (EG) (83 people), which used innovative approaches outlined in the technology proposed by the authors to study the disciplines provided by the educational programme (Appendix A).

Results

The study focuses on developing, implementing, and evaluating the effectiveness of applying innovative approaches to training higher education students in natural sciences. It was conducted among Master's degree students specialising in "Educational and Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" (EPP) and "Secondary Education. Geography" (SEG). The speciality "Educational and Pedagogical Sciences" and the educational programme "Higher Education

Pedagogy" aim to train highly qualified, competitive teachers who can effectively solve current problems, complex research and innovation tasks, which involves practical educational, scientific, methodological and managerial activities; conducting psychological and pedagogical research. During the training of higher education applicants in the speciality "Secondary Education. Geography", the formation of general and professional competences in the field of geography knowledge and methods of teaching geographical disciplines is carried out, which will allow free access to employment in pedagogical institutions of specialised secondary education of academic and professional orientation, vocational, vocational-technical or professional higher education.

Taking into account the peculiarities of training of higher education applicants in these specialities, Figure 1 presents the technology of introducing innovative approaches, which has the main generalised stages, such as the integration of digital technologies, focus on practice and competence development, the use of research methods and interdisciplinary pedagogical approaches, and the means of teaching for the specialities are distinguished according to their problems and peculiarities.

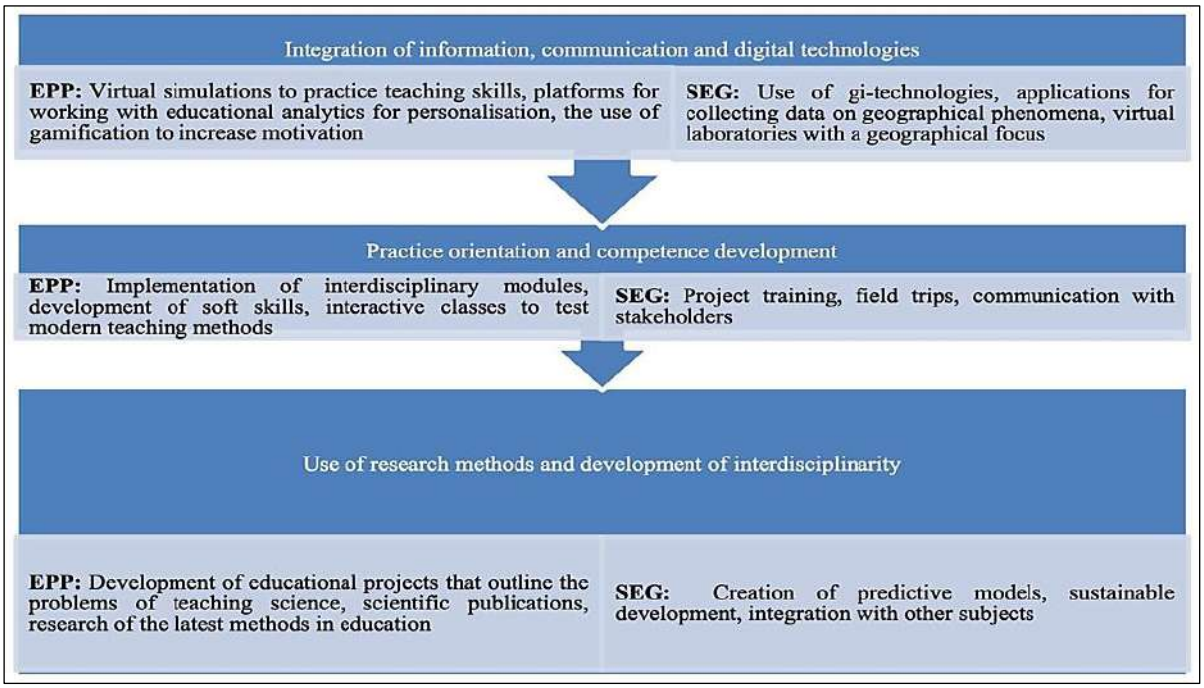

Figure 1: Technology of Implementation of Innovative Approaches to the Training of Higher Education Applicants in Natural Sciences (On the Example of the Specialities "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" (EPP), "Secondary Education. Geography" (SEG)

When implementing the outlined stages of their training by the proposed technology, applicants for higher education in the speciality "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" use a wide range of teaching tools, including platforms with the ability to simulate classrooms and to practice teaching skills, educational resources for modelling educational analytics to implement personalised learning paths in the context of professional activities. For Master's degree students, it is also important to publish, work on projects that outline the problems of applying pedagogical approaches to teaching science, and research innovative teaching methods.

Master's students majoring in Secondary Education. Geography" within the framework of the outlined pedagogical technology should focus on using geographic information technologies, applications for analysing geographic data, and interactive virtual laboratories. Also, important aspects in implementing the outlined technology for higher education students in this speciality are interdisciplinary, teaching based on the principles of sustainable development, creating predictive models and project-based learning, organising

practical research, and communicating with stakeholders.

A survey was conducted among the lecturers of the specified specialisations. The questionnaire was developed based on four criteria: improving the overall level of competence acquisition (OC), developing professional-pedagogical competences (PC), enhancing research skills (RS), and utilising an interdisciplinary approach (IA). The collected data were assessed on a scale from 0 to 100 points. The effectiveness level of innovative approaches in training higher education students could be classified as low, medium, or high. Table 1 outlines the levels of effectiveness in applying innovative approaches to training higher education students in natural sciences.

Table 1: Levels of Effectiveness of Innovative Approaches to Training Higher Education Students in Natural Sciences

Level	Criterion	Indicator
Low	OC	Difficulties in understanding pedagogical and natural science concepts
	PC	Minimal use of modern pedagogical methods
	RS	Carrying out simple research with the help of a mentor
	IA	A narrow range of focus during research
Medium	OC	Limited use of professional case evaluation methods
	PC	Ability to teach science classes with the help of mentors
	RS	Application of standard analytical methods
	IA	Focusing on basic disciplines when conducting interdisciplinary research
High	OC	Ability to implement experimental work in the professional field
	PC	Demonstration of independence in designing educational processes, application of modern methods
	RS	Conducting research, applying innovative methods of designing pedagogical processes
	IA	Implementation of knowledge from related disciplines to develop original approaches

Table 2: Evaluation of the Effectiveness of Training of Higher Education Students in Natural Sciences Based on the Results of Self-assessment

	To implement innovative approaches				After implementing innovative approaches			
Criterion/ Level	**LL**	**ML**	**HL**	**Average**	**LL**	**ML**	**HL**	**Average**
OC	26,25	59,42	71,16	52,28	33,28	66,18	95,26	64,91
PC	23,84	55,68	70,52	50,01	32,16	65,82	92,26	63,41
RS	22,84	58,71	69,52	50,36	33,62	65,12	96,52	65,09
IA	21,52	54,62	67,92	48,02	33,92	64,32	94,82	64,35
Average	23,61	57,11	69,78	50,17	33,25	65,36	94,72	64,44

The first stage of the pedagogical experiment was the self-assessment of the application of the technology to introduce innovative approaches to the training, which is presented in Table 2.

Table 2 shows the following conventions: OC, PC, RS, IA – criteria for assessing the effectiveness of innovative approaches to training higher education applicants in natural sciences; LL, ML, HL – low, medium, and high levels of effectiveness of innovative approaches to training higher education applicants in natural sciences.

Figure 2 shows the visualisation of the effectiveness of training according to the self-assessment results by the outlined levels in percentage terms.

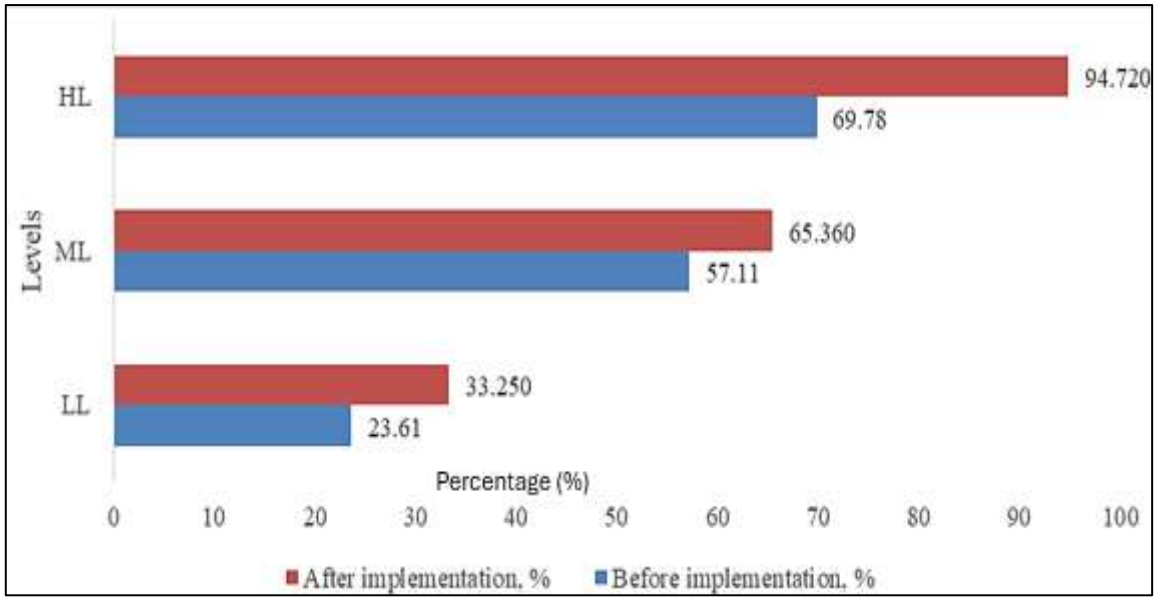

Figure 2: Effectiveness of Training of Higher Education Applicants Majoring in "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" and "Secondary Education. Geography" According to the Results of Self-assessment by the Outlined Levels

The effectiveness of training of higher education students majoring in EPP and SEG by the outlined levels increases after using the proposed innovative approaches. The low-level indicators increase by 10 points, the medium-level indicators increase by 8 points, and the high-level indicators increase by 25 points, indicating a stable increase at the low and medium levels and significant efficiency in applying the outlined innovative approaches for high-level students.

The second stage of the pedagogical experiment was to evaluate the effectiveness of innovative approaches to training higher education students in natural sciences based on learning outcomes. The analysis of learning outcomes also revealed a positive increase in indicators when applying the proposed technology for training higher education applicants in natural sciences. In this part of the study, low-level indicators correspond to grades D and E of the ECTS scale, medium-level indicators – to grades B and C, high-level indicators – to grades A, and unsatisfactory levels – to grades FX. The assessment of learning outcomes was conducted during 2023–2024 for Master's degree students majoring in "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" and "Secondary Education. Geography".

To statistically test the impact of innovative approaches on the training of higher education students in natural sciences, Pearson's criterion χ^2 was applied. If χ^2 is less than the critical value, then the impact of the use of pedagogical technology on learning outcomes is insignificant. If χ^2 is greater than the critical value, then the use of pedagogical technology to implement innovative approaches significantly impacts learning outcomes.

Tables 3 and 4 present the learning outcomes of higher education students in natural sciences before and after implementing innovative training approaches, respectively, before and after the experiment. The following notations are used in Tables 3 and 4: EF (EG, CG), the number of students – empirical frequency of grades obtained by higher education students in the control and experimental groups. The degree of freedom for this sample is v=5, and the critical values of χ^2 for v=5 are ($\rho(0.05) \geq 11.09$; $\rho(0.01) \geq 15.089$).

Table 3: Learning Outcomes of Higher Education Students in Natural Sciences Before the Introduction of Innovative Training Approaches

Level	EG, %	EF_{EG}, number of students	CG, %	EF_{CG}, number of students	$(EF_{EG} - EF_{CG})^2$	$(EF_{EG} - EF_{CG})^2 / EF_{CG}$
High level	6,02%	5	7,23%	6	1	0,17

Medium level	24,10%	20	26,51%	22	4	0,18
Low level	46,99%	39	44,58%	37	4	0,11
Unsatisfactory level	22,89%	19	21,69%	18	1	0,06
Total amount	100,00%	83	100,00%	83		0,51

The results of training higher education students in natural sciences before introducing innovative approaches to training indicate a large percentage of low-level indicators in both the CG and EG. Indicators of unsatisfactory and medium levels have an average percentage of empirical frequency for higher education students in both the groups. The value of χ^2 is less than critical, which indicates an insignificant statistical distribution in the control and experimental groups.

Table 4: Learning Outcomes of Higher Education Students in Natural Sciences After the Introduction of Innovative Training Approaches

Level	EG, %	EF_{EG}, number of students	CG, %	EF_{CG}, number of students	$(EF_{EG} - EF_{CG})^2$	$(EF_{EG} - EF_{CG})^2 / EF_{CG}$
High level	19,28%	16	7,23%	6	100	16,67
Intermediate level	46,99%	39	26,51%	22	289	13,14
Low level	25,30%	21	46,99%	39	324	8,31
Unsatisfactory level	8,43%	7	19,28%	16	81	5,06
Total amount	100,00%	83	100,00%	83		43,17

The results of training higher education applicants in natural sciences after introducing innovative approaches to training indicate a large percentage of high- and medium-level indicators in the EG and a high percentage of low and unsatisfactory indicators in the CG. The value of χ^2 is higher than the critical one, which indicates the effectiveness of applying innovative approaches to training higher education students in natural sciences.

Figure 3 presents a comparative analysis of the levels of learning of higher education students in natural sciences before and after implementing the proposed pedagogical technology.

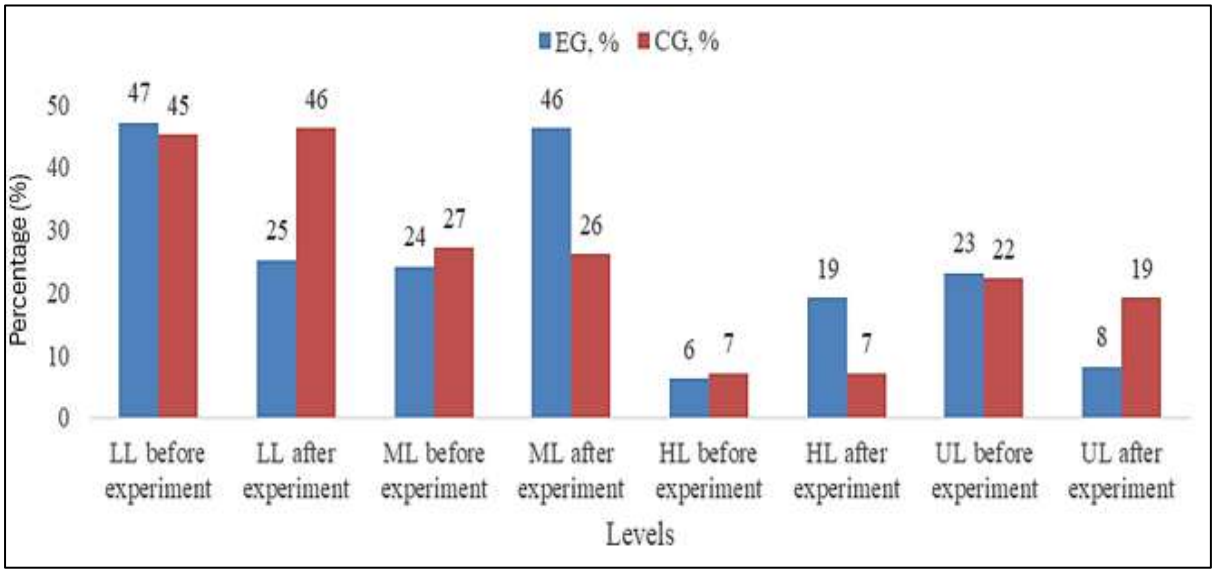

Figure 3: Comparison of Learning Levels of Higher Education Students in Natural Sciences Before and After Implementing the Proposed Pedagogical Technology in Percentage Terms

As can be seen from Figure 3, after the experiment, the percentage of higher education students with an unsatisfactory level (UL) of knowledge decreased by almost 3 times, and the low level (LL) indicators also fell by almost half after introducing the technology. It is also worth noting that the number of medium-level students (ML) has almost doubled, and the number of high-level students (HL) has also almost tripled. The increase in the percentage of students of high and medium levels

and the decrease in the percentage of low and unsatisfactory levels indicate the effectiveness of applying the outlined innovative approaches to training higher education students in natural sciences.

Discussion

The motivational factors for attending MINT (mathematics, informatics, natural sciences and technology) classes are identified. This course is introduced at the University of Vienna at the faculties of business analytics, data science and digital humanities as part of master's programmes. The article presents analytics comparing the motivation of higher education students to attend such courses with different indicators, such as gender, level of training, and social status. It is determined that the various learning opportunities offered in this course meet students' individual needs, which increases the accessibility of the field of science (21). The paper deals with integrating engineering and natural sciences in German educational institutions. This approach helps to create interdisciplinary links and increase motivation and understanding of the development path from basic research to a ready-made technical solution. Students were encouraged to understand the methodology and content aspects of current technical and scientific research in a prepared learning environment (22). The use of machine learning techniques and expert knowledge was analysed to offer an optimal choice of courses, considering the student's skills (student profile) and the profiles of the courses offered at the university. This approach has been validated for computer science courses at the Faculty of Science, University of Peradeniya, Sri Lanka (23). It can be concluded that it is important to integrate technology, sustainable development, and digitalisation approaches, which is important in terms of today's challenges in the context of training higher education students in natural sciences.

The current situation and problems of blended learning and information and communication technologies at a general education university are investigated. College students are satisfied with blended learning, but there are problems with the misuse of technology and lack of knowledge. Researchers have recommended that teacher guidance, redesigning learning resources, and strengthening knowledge consolidation through technology can improve the blended learning environment (24). Developing argumentation skills is fundamental for engineering students, allowing them to identify assumptions and draw conclusions about observed phenomena. The article investigates the strategy of confirmation – justification – application of the laws of physics to build arguments about a specific engineering system by higher education students. The effectiveness of implementing this technology through the media and communication environment is indicated (25). The development of sustainability education is key for students of engineering colleges, particularly for developing their non-technical literacy. Using the example of students of the Faculty of Communication Engineering at the North China University of Technology (NCUT), the article explores methods for assessing the effects of sustainability education. It was found that students' concept of sustainability has shown a noticeable improvement compared to the commercial mainstream student survey. At the same time, for engineering students, the explanation of sustainability concepts should focus on professional characteristics, which are more conducive to improving performance (26). However, it should be noted that the balance between the use of technology and the use of field-based learning approaches, problem-based learning and project-based learning in the modern context should be aimed at developing the latter, as the training of higher education students in natural sciences should be based on practice. Technology can be an effective tool for data processing. It has been identified that resources that enable students to apply artificial intelligence and NLP, especially in science, remain limited (27). Spatial and temporal dynamics limit the field practice environment in geography, so getting an in-depth effect of situational learning is impossible. A 3D model for virtual modelling of marine geomorphological evolution is presented and a supporting platform for geographical field practice is developed using 3D GIS technology (28). Currently, the development of innovative technologies is a powerful tool in modern education, but it is necessary to select the most effective ones among a large number of these

interactive, visual and virtual tools, which is the task for research and teaching staff.

The article presents the experience of enriching students' curriculum through educational underwater drones within the project "Citizen Science: Measurement and Observation of the Sea" framework. The data collected can be helpful to meteorologists, marine biologists, ecologists, and other scientists in their research (29). An example of using software and pedagogical tools to fulfil all types of students' workload in studying specific professional disciplines is presented. The study's results can be used in the educational process to form information and professional competences of future specialists (30). Also, when introducing innovative approaches to the training of higher education students in natural sciences, attention should be paid to the organic integration of these approaches into the curriculum and educational programmes of the specialities.

During the discussion, it was determined that the integration of sustainable development techniques and approaches, practical orientation, prudent choice of digitalised educational tools, and their organic integration into academic disciplines are key approaches to applying innovations in the training of higher education students in natural sciences. In future studies, it is advisable to use probabilistic methods of selecting respondents to increase the representativeness of the sample, as well as conduct research on more heterogeneous subsamples. In addition, it is worth expanding the methodology by combining quantitative and qualitative approaches, which will allow a better understanding of the nature of the identified relationships. Also promising is the conduct of longitudinal studies to analyse changes over time.

Conclusion

The challenges of today, such as globalisation processes and the need to introduce modern technologies and trends towards sustainable development, have led to the need to introduce innovative approaches to the training of higher education applicants in natural sciences. The article presents the technology of introducing innovative approaches to the training of higher education applicants, which is developed for the specialities "Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagogy)" and "Secondary Education. Geography". It consists of three main stages: integration of information and communication and digital technologies, focus on practice and competence development, use of research methods and development of interdisciplinary. By the outlined technology, the article describes which innovative approaches can be most effective for the specialities that participated in the study. Three levels of effectiveness of innovative approaches to the training of higher education students in natural sciences have been developed, which are formed based on evaluation criteria: acquisition of general and professional competences, interdisciplinary approach and development and research skills.

An experiment was conducted to evaluate the effectiveness of training of higher education applicants in natural sciences based on the results of self-assessment by teaching staff of educational institutions and statistical evaluation of learning outcomes. Determination of qualitative and quantitative indicators for the application of innovative approaches to the training of higher education students in natural sciences showed a high increase in the performance of higher education students of high and medium levels and a decrease in the total number of low-level students who, thanks to the application of the outlined technology, receive high-level points. Applying innovative approaches to training higher education students in natural sciences ensures readiness for the challenges of modernity and high professional training of specialists.

Abbreviations

CG: control group, EG: experimental group, EPP: Educational, Pedagogical Sciences (Educational Programme: Higher Education Pedagog), IA: interdisciplinary approach, LL, ML, HL: low, medium, and high levels, MINT: mathematics, informatics, natural sciences and technology, MOOCs: massive open online courses, NCUT**:** North China University of Technology, OC: competence acquisition, PC: professional-pedagogical competences, RS: research skills, SEG: Secondary Education. Geography.

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Author Contributions

Ruslana Vlasenko: Conceptualization, Methodology, Writing – Original Draft, Writing – Reviewing and Editing, Preparation, Formal Analysis, Oksana Ivantsiv: Methodology, Writing – Original Draft, Writing – Reviewing and Editing, Supervision, Project Administration, Formal Analysis, Viktoriia Rudchenko: Data Curation, Formal Analysis, Visualization, Resources, Tetiana Kolechyntseva: Supervision, Project Administrati-on, Resources, Oksana Herasymenko: Methodology, Preparation, Formal Analysis, Resources, Visualization.

Conflict of Interest

The authors declared that there are no conflicts of interest regarding the publication of this manuscript.

Ethics Approval

Not Applicable.

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Appendix A

Evaluation of the level of effectiveness of innovative approaches to the training of higher education students in natural sciences

Evaluate the level of effectiveness of innovative approaches to the training of higher education students in natural sciences according to the criteria. Indicate the result on a 100-point scale in the appropriate column, where 0-33 – low-level indicators, 34-66 – medium level indicators, and 67-100 – high-level indicators. The low level (LL) of the effectiveness of innovative approaches to the training of higher education students in natural sciences is characterised by a limited understanding of concepts and methods, limited independence in research, difficulty in applying knowledge to real professional situations, and lack of interdisciplinary. The medium level (ML) ensures technology adaptation to learning processes, requires mentor support, uses standard analysis methods, and focuses on core disciplines. High level (HL) corresponds to the ability to develop and implement innovative pedagogical methods, conduct research and integrate their developments into the educational process.

An example of filling out a questionnaire to assess the level of effectiveness of innovative approaches to the training of higher education students in natural sciences

Criteria	To use innovative approaches			After using innovative approaches		
	LL	ML	HL	LL	ML	HL
Increasing the overall level of competence acquisition	21					97
Formation of professional and pedagogical competences		45			66	
Development of research skills	11				67	
Using an interdisciplinary approach			77			99

The Pearson chi-square test is used to test the statistical relationship (or independence) between two qualitative (categorical) variables. It determines whether the actual frequency distribution differs from that expected under conditions of independence of the variables. The sample is random and the observations are independent of each other. Participation in the study was voluntary, and all respondents were informed about the purpose of the survey and had the opportunity to refuse participation at any stage. Confidentiality of personal data was ensured, and the results were presented in an anonymized form. Thus, the ethical principles of conducting social research were observed.