

Pedagogical technologies for teaching environmental engineering in the online learning system of higher education institution

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Abstract. The article outlines the pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions. There are proposed ways of developing educational technologies for teaching environmental engineering: active and collaborative learning, individualisation of training, use of video and audio materials, using electronic tools for evaluation of educational results, development of digital literacy, implementation of interactive online courses and professional communication and mentoring. There are presented the use of these technologies in the different aspects of environmental engineering, such as analysing water quality parameters, soil quality assessment, studying waste management practices, and studying the integration of renewable energy into the practice through virtual labs, online tests, video lectures, and collaborative projects. The proposed pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions were tested in the educational process. The Student's t-test was used for statistical calculation of the obtained experimental data. At the end of the experiment, there is a statistically significant difference between the mean values of the experimental and control groups. It can be claimed that the use of pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions is perspective.

Keywords: professional training · environment engineering · online learning environment

1 Introduction

In today's world, where electronic technologies permeate all spheres of life, education is also affected by these changes. In recent years, the field of environmental engineering has gained paramount importance as societies grapple with pressing environmental challenges such as climate change, pollution, and resource depletion. As a result, there is an increasing demand for skilled professionals in this domain who possess both theoretical knowledge and practical expertise to address complex environmental issues.

With the rise of online learning systems in higher education institutions, there is a need to translate the environmental engineering curriculum effectively into the digital realm. This necessitates the utilisation of pedagogical technologies that not only replicate traditional classroom experiences but also leverage the unique capabilities of online platforms to enhance learning outcomes.

Environmental engineering is a branch of engineering that focuses on the application of scientific and engineering principles to protect and improve the quality of the environment. Environmental engineering plays a crucial role in addressing various challenges faced by engineers. The intersection of environmental engineering is essential for sustainable and efficient practices. Design and optimisation of irrigation systems ensure efficient water use and involve technologies such as drip irrigation, precision irrigation, and soil moisture sensors to minimise water wastage. Monitoring and improving water quality for irrigation purposes is critical. Environmental engineering specialists can assess water sources, implement water treatment processes, and manage water pollution to safeguard crops and the environment. Environmental engineering principles can also be applied to design erosion control measures, such as terracing, cover cropping, and contour ploughing, to prevent soil erosion and maintain soil fertility. Engineers may collaborate with knowledge in environmental engineering to remediate contaminated soils. Techniques such as phytoremediation and bioremediation can be employed to restore soil health.

The specialists mentioned above can assist in the development of sustainable waste management practices, including composting and anaerobic digestion, to convert waste into valuable resources like organic fertilisers and biogas. Proper treatment of runoff and effluents is crucial to preventing water pollution and designing systems to treat and manage wastewater. Engineers use knowledge of engineering ecology to implement renewable energy solutions on farms, such as solar and wind power, to reduce reliance on non-renewable energy sources and mitigate environmental impacts.

Environmental engineering can contribute to the development of climate-resilient practices. This may involve designing systems that can withstand extreme weather events, implementing climate-smart agriculture, and promoting sustainable land use. Conduction assessments to evaluate the potential environmental impacts of projects help in making informed decisions and implementing measures to minimise adverse effects. Contribution to the development and implementation of sensor technologies in precision agriculture involves using data from various sensors to optimise resource use, monitor crop health, and improve

overall farm efficiency. By integrating environmental engineering principles into modern practices, engineers can contribute to more sustainable and environmentally friendly farming systems. This interdisciplinary approach is crucial for addressing the complex challenges posed by the intersection of technologies and the environment.

2 Related work

The integration of modern technologies in education has been a strategic priority for many universities in recent years [11]. Online learning environments, in particular, have shown promise as frameworks to support both distance and blended learning modalities [10]. However, research suggests that students often engage with technologies beyond those officially provided by their institutions [19]. This highlights the need for educators to carefully consider how they can effectively leverage technology to enhance learning.

One key aspect of technology-enhanced learning is the use of video content. Yoon et al. [26] outlined principles and strategies to optimise video-based learning, while Kanivets et al. [16] described the use of a mobile application to support remote laboratory work. The interactive potential of video is further explored by Holovnia et al. [14], who investigated how student response systems can facilitate engagement during online lectures.

Collaborative learning is another critical component of effective online education. Munoz-Carril et al. [21] analysed factors influencing students' perceived impact and satisfaction in Computer Supported Collaborative Learning environments. Han et al. [13] and Schwarz et al. [23] demonstrated how learning analytics dashboards and teacher monitoring tools can provide adaptive support for real-time collaboration. Koszalka et al. [17] explored the role of preparatory activities in fostering deep learning in asynchronous online discussions. However, Lyu et al. [20] noted that engineering students often struggle with effective collaboration, suggesting a need for further research in this area.

Personalisation and self-regulation are also key considerations in online learning. Bogachkov et al. [3] discussed the importance of flexible, individualised learning paths. Nastas and Vember [22] investigated the design of quality cloud-based multimedia resources, while Slutskyi [24] highlighted the effectiveness of combining video and audio materials on global educational platforms. Bolshanina et al. [4] reported on the use of a blended learning model in chemistry education for engineers. Feldman-Maggor et al. [9] demonstrated the value of optional assignments and learning analytics for predicting student success in online chemistry courses.

The use of interactive and adaptive technologies is particularly relevant in engineering education. Vlasenko et al. [25] provided guidelines for the UI/UX design of educational online courses. Zaika et al. [28] compared online tools for creating math tests. Dotsenko et al. [8] presented a technology for developing educational content for open digital resources in technical disciplines. Batsurovska et al. [1, 2] discussed the organisational and pedagogical conditions for training

engineers in a competence-oriented online environment, emphasising the importance of practical skills development.

Several studies have focused specifically on applications of technology in agricultural and environmental engineering education. Zabolotska et al. [27] highlighted the role of digital competencies for teachers in transforming the educational environment. Dotsenko [7] investigated the use of online learning platforms in electrical engineering education. Kushwah and Chowdhury [18] explored the scope of nanotechnology in agricultural engineering, while Górnicki [12] provided an overview of computer science applications in this field. Civeira et al. [5] analysed the objectives of agricultural engineering training programs, and Jin et al. [15] proposed teaching reforms based on engineering education accreditation standards.

However, the analysis of pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions was not the specific subject of the research. In the conditions of the online learning system of a university, where technologies become an integral part of professional activity, pedagogical technologies of professional training of engineers require adaptation and use of new approaches. The use of electronic means and resources in the educational process can significantly increase the effectiveness of education, promote the development of practical skills, and prepare students for the modern requirements of the profession.

3 Research aims and questions

The research aim is to investigate the impact of specific pedagogical technologies on student learning in an online environmental engineering course.

The research questions are:

1. How do active and collaborative learning strategies influence student achievement in an online environmental engineering course compared to traditional instructional methods?
2. What is the effect of integrating audio-visual materials and interactive online tools on student engagement and performance in this context?
3. To what extent can digital literacy development and professional communication opportunities enhance the quality of student work in environmental engineering projects conducted online?

4 Methods

The following research methods are used in the article:

- systematic observation of the learning process and the use of online learning system in the professional training of engineers;
- experiment, where some groups of students use certain pedagogical technologies in the online learning system of universities and others – traditional methods, to compare their effectiveness and results;

- statistical methods to process and analyse data obtained from experiments.

The research was conducted over an 18-week semester within the online learning system of two higher education institutions in Ukraine: Mykolayiv National Agrarian University and the Academy of Labour, Social Relations and Tourism.

The study involved a total of 53 undergraduate students enrolled in an environmental engineering course. The experimental group consisted of 27 third-year students from the “Agricultural Engineering” speciality at Mykolayiv National Agrarian University. In comparison, the control group comprised 26 students from the “Professional Education” speciality at the Academy of Labour, Social Relations and Tourism. All participants were recruited through convenience sampling based on their enrollment in the targeted course sections. Informed consent was obtained from all students prior to data collection, and the Institutional Review Boards approved the study procedures at both participating universities.

In the experimental group, the online course was delivered using a range of pedagogical technologies, including:

- active and collaborative learning strategies, such as practical tasks, group projects, and virtual laboratories;
- individualised learning paths, allowing students to choose materials and pace;
- integration of video lectures and multimedia content;
- electronic assessment tools, such as online tests and quizzes with immediate feedback;
- development of digital literacy skills through specialised training;
- interactive online modules and simulations;
- facilitation of professional communication and mentoring via forums and webinars.

In contrast, the control group received instruction using a more traditional online format, primarily consisting of synchronous lectures and practical assignments without additional technological enhancements.

The study was carried out over an 18-week semester. During this period, the experimental group engaged with the aforementioned pedagogical technologies, while the control group learned using traditional methods. At the end of the semester, quantitative data on student achievement was collected in the form of final course grades. These grades were based on a 100-point scale and reflected students’ cumulative performance on various assignments, projects, and exams throughout the semester.

To compare the learning outcomes between the experimental and control groups, an independent samples t-test was conducted using the final course grades as the dependent variable. This statistical analysis allowed for the determination of whether the difference in mean grades between the two groups was statistically significant. The assumptions of normality and homogeneity of variance were checked prior to running the t-test. All statistical analyses were performed manually, with a significance level of $\alpha = 0.05$.

The research findings are reported in a manner that protects the identity of participants and ensures their privacy. No personally identifiable information is included in the manuscript or any published materials resulting from this study.

5 Pedagogical technologies for teaching environmental engineering in the online learning system of higher education institution

Pedagogical technologies for the professional training of engineers in the online learning system play an essential role in ensuring quality education and the development of students' competencies. The university's online learning system provides many opportunities for implementing innovative approaches to the educational process, activating students' independent work, and providing access to up-to-date information. The following pedagogical technologies can be used for the successful implementation of professional training of engineers in this learning system.

5.1 Active learning

Students are offered practical tasks, projects and research aimed at developing their professional skills. They can work with e-learning resources, simulation programs and virtual laboratories to gain hands-on experience in solving real-world engineering problems. Engineers can actively learn environmental engineering online through various methods and platforms. Active learning involves engaging students in activities that encourage critical thinking, problem-solving, and application of knowledge. It is possible to utilise virtual simulations and labs that replicate environmental engineering scenarios. This allows students to experiment with different variables, make observations, and draw conclusions. Platforms like Labster, ChemCollective, or PhET Interactive Simulations offer a range of virtual experiments related to environmental engineering.

There are some examples of this type of task for engineers in the context of environmental engineering.

- To make the soil quality assessment, it is possible to conduct virtual tests for soil pH, texture, and nutrient content and simulate the impact of different fertilisers on soil quality.
- Analysing water quality parameters can be conducted through virtual tests for water pH, turbidity, and nutrient content and simulation of the effects of agricultural runoff on water quality.
- Understanding the impact of environmental factors on crop growth can be conducted by analysing the influence of temperature, precipitation, and soil quality on crop yield.
- Study waste management practices by simulating the composting process for agricultural waste and analysing the environmental impact of different waste management strategies.

These labs can provide engineers with a hands-on and interactive learning experience, allowing them to explore and understand various aspects of environmental engineering.

In the case of active learning there also can be used the following resources: environmental impact reports, research papers on water management, air pollution control, waste management, etc. and government regulations and guidelines (e.g., EPA guidelines, UNEP reports). Students work in groups to analyse real-world environmental case studies, discuss solutions, and present findings and teams of students are given open-ended problems (e.g., designing a sustainable water treatment system) and work together to propose solutions in the context of case-based and problem-based learning.

5.2 Collaborative learning

The use of online learning systems enables students to communicate and collaborate with colleagues, learn from each other and solve problems in groups. This promotes the development of communication skills, leadership and cooperation, which are important aspects of the professional activity of engineers. They were also offered to take part in the development of engineering projects that required the execution of drawings and calculations. It is necessary to present real-world case studies related to environmental challenges, ask students to analyse the cases, identify problems, and propose solutions. Encouraging collaborative problem-solving can be led through online discussion forums or group projects. Platforms like Google Workspace or Microsoft Teams can facilitate collaborative work. Online collaborative projects require students to work together on solving environmental challenges. This could involve designing sustainable practices, developing water management plans, or proposing innovations. We are using collaborative tools like Google Docs, Trello, or Slack to facilitate communication and project management.

In the context of environmental engineering, collaborative projects can be conducted to design and analyse aquaponics systems for sustainable agriculture by outlining the interactions between fish and plant components in the system. Also, studying the integration of renewable energy into modern practices can be done by calculating solar and wind energy to power agricultural operations and analysing the economic and environmental benefits of integrating renewable energy. There can be plenty of resources for collaborative projects: local ecosystems, rivers, or industrial sites; monitoring tools (e.g., water quality meters, air pollution sensors); and GIS (Geographic Information System) data. Also, students visit local ecosystems or industrial sites in teams to observe and collect data, then collaborate on analysing the environmental impact and partner with local communities to collect data on environmental factors like pollution, water quality, and waste management, facilitating a collaborative approach to real-world problem-solving. Cloud-based tools like Google Docs, Miro, and Microsoft Teams, as well as simulation software such as SWMM (Storm Water Management Model), EPANET for water distribution, and MATLAB for environmental modelling, are useful collaborative software tools. Students use cloud platforms

to co-author reports, share datasets, and develop collective environmental models or solutions. Teams work together on shared documents and simulation tools to design environmental systems like wastewater treatment plants or energy-efficient buildings.

5.3 Individualization of training

The online learning system of the university allows students to choose learning materials and learning speed according to their needs and pace of mastering the material. The use of personalised learning platforms, interactive exercises and tests helps students focus on specific aspects of their studies and progress at their own pace. Develop a comprehensive library of resources, including articles, videos, and research papers, allowing learners to explore topics of personal interest. The incorporation of real-world case studies relevant to engineering and environmental issues encourages learners to apply theoretical concepts to practical situations, fostering a deeper understanding, including multimedia elements, simulations, and hands-on activities that cater to diverse learning styles.

Tools like Knewton and Smart Sparrow adapt course content in real time based on individual student performance. In environmental engineering, adaptive learning systems can modify the difficulty of questions, projects, and exercises to suit the learner's proficiency. Learners advance based on their ability to master a skill or competency. Environmental engineering courses can be broken into modules (e.g., water treatment and solid waste management), with assessments used to ensure competency before moving on.

5.4 Use of video and audio materials

Video and audio materials can be effective means of training engineers. They allow you to demonstrate real examples, processes and technologies, which contributes to a better understanding of the material and stimulates interest in learning. Each part of the video lecture requires an answer to a question; after it is correctly provided, the completed material is considered to be passed. Platforms like Coursera, edX, and Udemy offer online courses on environmental engineering. These courses often include video lectures, simulations, and practical demonstrations.

For example, video and virtual models of greenhouse gas emissions can help students understand the sources and mitigation of greenhouse gas emissions and explore virtual technologies for reducing them. Modelling the process of environmental impact assessment and researching strategies to minimise the ecological footprint will lead to the analysis of the technology of adaptation to climate change by modelling the impact of climate change on crop production.

Tutors can create educational videos using simulation and modelling software like MATLAB, AutoCAD, EPANET, and ANSYS Fluent. It is necessary to record or create video demonstrations of simulations (e.g., fluid dynamics in pipelines, air dispersion models) for use in classrooms or presentations and use

screencasting tools like OBS Studio or Camtasia to capture real-time simulation processes, combined with voice-over explanations.

5.5 Evaluation using electronic tools

The use of electronic assessment tools, such as online tests, provides a quick and convenient assessment of student knowledge. Such tools can also provide students with immediate feedback on their performance and help identify areas of weakness for further improvement. In the context of evaluation, an electronic journal of evaluations was used for each of the disciplines of the curriculum for the preparation of the specified group of students. Developing online quizzes or self-assessment tools to help students reinforce their understanding of environmental engineering concepts.

Platforms like Kahoot! or Quizizz can make the assessment process more interactive. Platforms like Moodle, Canvas, and Blackboard offer tools for creating quizzes, assignments, and discussions that can help assess students' grasp of environmental engineering concepts. Online assessment tools such as Google Forms and SurveyMonkey are helpful for creating quizzes and surveys that can be easily shared and analysed.

5.6 Development of digital literacy

The training of engineers in the conditions of an online learning system involves the development of digital literacy, that is, the ability to work with electronic resources, analyse and interpret data, and effectively use information technologies. Special educational courses and training can be held for this purpose. Students in each of the disciplines are provided with an electronic glossary for studying and checking engineering terminology as part of online courses. It was also suggested that online calculators be used to perform the elements of practical work in specialised disciplines that require preliminary general technical calculations.

Implementing digital literacy in environmental engineering is essential to address complex environmental challenges through technology, data analysis, and communication. Digital literacy in this field involves integrating various tools and approaches to enhance problem-solving, data management, and decision-making. There are some techniques commonly used in environmental engineering to foster digital literacy: spatial data collection and analysis for environmental modelling, mapping pollution, natural resource management, and land use planning; remote sensing and satellite image processing are used for environmental monitoring. Software such as ArcGIS, QGIS (open source), and Google Earth Engine are commonly used in environmental engineering.

5.7 Implementation of interactive online courses

The development and use of interactive online courses in environmental engineering can help students independently master the material and navigate the

course. New interactive platforms can become a powerful tool for training engineers. These can include online courses, webinars, interactive tutorials, and assignments that allow students to communicate, exchange ideas, and collaborate in real-time. Conduct live online lectures using platforms like Zoom or Microsoft Teams and integrate interactive elements such as polls, quizzes, or open-ended questions to gauge understanding and encourage participation. Using polling tools like Mentimeter or Poll Everywhere to create interactive sessions can also be helpful in the context of the implementation of interactive forms of study.

There are plenty of courses in environmental engineering on learning platforms, such as ESRI's online training courses, Coursera (GIS specialisation), and Khan Academy (basics of GIS). Also, valuable tools for the outlined specific are EPA's resources for environmental models, Udemy, or other platforms offering specialised courses on modelling.

5.8 Professional communication and mentoring

The electronic environment can facilitate professional communication and mentoring of students with teachers and practitioners. This may include online consultations, webinars, open lectures, and opportunities for students to interact with professionals in their field. Virtual field trips to engineering sites can be conducted using video, 360-degree images, or live streaming to give students a sense of real-world applications.

The invitation of guest speakers, such as professionals or researchers in environmental engineering, can be made through online presentations. It is essential to have an effective feedback system that allows students to receive feedback and evaluations of their work in order to improve. This may include assessing the level of mastery of the material, reviewing projects, and providing feedback to teachers and peers. Conduction workshops on specific environmental engineering topics can be useful tools in professional discussions, as well as invitation experts to deliver online sessions or use pre-recorded content, encouraging participation through live sessions or discussion forums.

Social networks can also be an effective means of communication, collaboration, and knowledge exchange between students, teachers, and specialists. The creation of joint groups, forums, chats, and discussions can contribute to the active exchange of ideas, the development of critical thinking, and the provision of learning support. Online discussion forums can be created where students can discuss current environmental issues, share relevant articles, and engage in conversations related to the course material. Platforms like Discourse or Moodle forums can support asynchronous discussions.

Taking into account the peculiarities of teaching environmental engineering in higher education institutions and the possibilities of the online learning system, pedagogical technologies should contribute not only to the assimilation of theoretical knowledge but also to the development of practical skills, critical thinking, creative approach and problem thinking. It is important to stimulate the independent work of students and active participation in projects and research activities.

All pedagogical technologies must be supported by appropriate technical means and infrastructure that provides access to electronic resources, the possibility of interaction and communication, and also ensures the security and protection of information.

The implementation of pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions requires constant improvement and adaptation to modern technological and educational trends. It is important to create a favourable educational atmosphere that encourages students to be active, self-developing and professional growth. The electronic environment can stimulate students to develop self-organisation, independent work, and the ability to manage their learning. They can be able to plan their schedule, set goals, complete tasks at their own pace, and create learning portfolios to track their progress. All these areas can contribute to improving the quality of professional training in environmental engineering in the online learning system.

6 Results

In order to determine the effectiveness of teaching environmental engineering in the online learning system, the semester score of the students was recorded, and the following data was used (table 1).

Table 1. Semester scores of environmental engineering students.

Group	Semester score	Average score
Experimental ($n=27$)	73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99	85.5
Control ($n=26$)	62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71	67.615

The average value of the experimental group (27 persons) is 85.5, and the average value of the control group (26 persons) is 67.615.

It was calculated the statistical significance using the Student's t-test [6].

The null hypothesis (H_0) was formulated: "The average values in the control and experimental groups are equal".

The alternative hypothesis (H_1) was formulated: "The average values in the control and experimental groups differ."

The standard deviation of the experimental group is 10.388, and that of the control group is 4.396.

The obtained value of the t-statistic (11.356) can be compared with the critical value of t for the corresponding level of significance and degrees of freedom.

Since both groups have 26 and 27 observations, respectively, in the experiment, we are interested in the critical value of t for 51 degrees of freedom ($26 + 27 - 2$).

The table of critical values of t-statistics for a two-sided test at a significance level of 0.05 and 51 degrees of freedom found the critical value of $t = 2.011$. Since the obtained value of the t-statistic (11.356) exceeds the critical value of t (2.011), there can be rejected the null hypothesis (H_0) and the alternative hypothesis (H_1) show that the average values in the control and experimental groups differ statistically significantly.

So, based on the t-test results, it can be claimed that there is a statistically significant difference between the mean values of the experimental and control groups.

7 Discussion

The present study investigated the impact of pedagogical technologies on student learning in an online environmental engineering course. The findings offer valuable insights into effective strategies for designing and delivering virtual instruction in this field.

The first research question explored the influence of active and collaborative learning strategies on student achievement compared to traditional online teaching methods. The results showed that students in the experimental group who engaged with these strategies significantly outperformed their peers in the control group. This aligns with previous research highlighting the benefits of active learning in engineering education [7, 20].

The second research question focused on the effects of integrating audio-visual materials and interactive online tools on student engagement and performance. The use of video lectures, multimedia content, and simulations emerged as a key theme, with students expressing appreciation for the variety and interactivity of these resources. This corroborates earlier studies on the effectiveness of video-based learning [26] and the value of virtual laboratories in engineering education [16]. Moreover, the significant difference in achievement between the experimental and control groups suggests that these technologies can directly enhance academic outcomes when used strategically.

The third research question addressed the role of digital literacy development and professional communication opportunities in the quality of student work. The integration of specialised training and mentoring sessions was identified as a beneficial aspect of the experimental course design. This finding resonates with research emphasising the importance of developing digital competencies for both students and teachers in transforming the educational environment [27]. Additionally, the use of forums and webinars to facilitate professional communication aligns with best practices for fostering authentic learning experiences in online settings [10].

Beyond the specific research questions, several other findings from this study contribute to the growing body of literature on online engineering education. The personalised learning paths and self-paced options emerged as a key advantage of the experimental course design, echoing earlier work on the importance of flexibility and individualisation in virtual learning [3, 9]. The use of electronic

assessment tools and authentic tasks also aligns with best practices for providing timely feedback and preparing students for real-world applications [8, 25].

8 Conclusion

Digital technologies and electronic resources have great potential for improving the quality of engineer training and developing their professional skills. Environmental engineering training in the online learning system of higher education institutions has certain features due to the need to develop engineering thinking, perform a large number of calculations, work with design and modelling programs, and carry out engineering projects.

Pedagogical technologies such as the use of active and collaborative learning, individualisation of learning, the use of audio and video materials, assessment using electronic means, development of digital literacy, implementation of interactive online courses and professional communication and mentoring are described in the point of view of the teaching environmental engineering in the online learning system of higher education institutions.

One key aspect is active learning, which requires students to participate actively in the educational process. In the context of teaching environmental engineering, this can be achieved through interactive tasks, simulations, and virtual laboratories where students can experiment and gain practical experience.

Students can interact with tutors and colleagues through virtual platforms, exchange ideas and experiences, and collaborate on projects. This promotes joint learning, collaboration, and the sharing of ideas, which expands students' ability to solve complex tasks and stimulates their creative potential.

Completing interactive tasks by the student at his own pace and passing online tests that require the development of engineering skills, performing calculations and working with drawings contribute to the acquisition of professional competencies. Video materials contribute to the visibility of the presentation of material, which is important when studying the principle of operation of machines and mechanisms. The development of digital literacy, working with modelling and design programs, and the use of online calculators to determine some aspects of general technical disciplines contribute to improving the learning of professional disciplines. Innovative interactive platforms have the potential to be an effective tool in the context of teaching environmental engineering. These can include interactive tutorials, webinars, online courses, and homework that enables real-time communication, idea sharing, and teamwork among students. It is necessary to offer students a sense of real-world applicability; virtual field tours to environmental engineering locations can be undertaken via live streaming, 360-degree photos, or video. Online presentations can be used to host guests, such as environmental engineering experts or researchers.

Pedagogical technologies for teaching environmental engineering in the online learning system of higher education institutions are constantly developing and adapting to new trends in the field of technology and education. With the help of innovative approaches and the use of modern electronic resources, it is possible

to create an effective learning system that promotes a deep understanding of the material, the development of critical thinking and practical skills of future engineers in the context of learning environmental engineering. Integrating a mix of these pedagogical technologies can create a dynamic and engaging online learning environment.

An experiment was conducted on the use of the indicated pedagogical technologies by students. Based on the results of the t-test, it can be claimed that the use of outlined pedagogical technologies for teaching environmental engineering in the online learning system of agricultural universities is effective.

Prospects for further developments in teaching environmental engineering in the online learning system of higher education institutions is great and presents a number of new opportunities. First, it is the expansion of the use of virtual and augmented reality, which can give students a unique opportunity to interact with real situations, creating an immersive learning experience. This contributes to a deeper understanding of the processes and the performance of virtual experiments and, in the end, a better assimilation of the material. Another prospect for further exploration is research in the direction of the development of interactive educational platforms. New interactive platforms can become a powerful tool for training engineers. These can include online courses, webinars, interactive tutorials, and assignments that allow students to communicate, exchange ideas, and collaborate in real-time.

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