JEL Classification: A22; C13; I20; I21 **DOI**: https://doi.org/10.31521/modecon.V49(2025)-01

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Application of a Learning Management System for the Formation of Agroecological Competence of Future Engineers

Abstract. Introduction*. The modern agricultural sector requires future engineers not only deep technical knowledge, but also a well-established agroecological competence, which involves the integration of environmental principles into the professional activities of engineers, which will ensure their ability to develop and implement technologies aimed at preserving the environment and rational use of natural resources. One of the effective tools for the development of this competence is a learning management system, which provides the opportunity to create interactive educational materials, organize distance learning, monitor student success and stimulate their independent learning activities.*

Purpose. *The article describes the features of using a learning management system to form agroecological competence of future engineers.*

Results. *The main characteristics of agroecological competence of future engineers, which is formed by LMS tools, are outlined. The technology of using a learning management system to form agroecological competence of future engineers is presented, which includes the engineering and digital component of the use of LMS tools. The study outlines the means of training for the formation of these components of the outlined technology. An experimental study was conducted in which higher education students in engineering specialties used a learning management system to form agroecological competence. The results obtained before and after the experiment were checked using the Pearson statistical criterion. It was determined that higher education students who used the outlined technology have higher knowledge quality results.*

Conclusions. *The outlined technology for forming agroecological competence in the conditions of LMS of higher education institutions takes into account the specifics of the agricultural industry and contributes to the organic integration of classroom learning and the use of a digital learning environment in order to level today's educational challenges. The result of the proposed technology is the acquisition of high-quality knowledge and the formation of agroecological competence in the conditions of the learning management system of a higher education institution.*

Keywords: *higher education applicants in engineering specialties, learning management system, higher education institutions, agroecological competence.*

УДК 37.09-005.94

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[1]**Стаття надійшла до редакції**: 18.02.2025
Received: 18 February 2025

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Застосування системи управління навчанням для формування агроекологічної компетентності майбутніх інженерів

Анотація *Сучасний аграрний сектор вимагає від майбутніх інженерів не лише глибоких технічних знань, а й сформованої агроекологічної компетентності, що передбачає інтеграцію екологічних принципів у професійну діяльність інженерів, що забезпечить їхню здатність розробляти та впроваджувати технології, спрямовані на збереження довкілля та раціональне використання природних ресурсів. Одним із ефективних інструментів для розвитку цієї компетентності є система управління навчанням, яка надає можливість створювати інтерактивні навчальні матеріали, організовувати дистанційне навчання, здійснювати моніторинг успішності студентів та стимулювати їхню самостійну навчальну діяльність.*

У статті описано особливості застосування системи управління навчанням для формування агроекологічної компетентності майбутніх інженерів.

Окреслено основні характеристики агроекологічної компетентності майбутніх інженерів, яка формується засобами LMS. Представлена технологія застосування системи управління навчанням з метою формування агроекологічної компетентності майбутніх інженерів, яка включає інженерний та цифровий компонент застосування інструментів LMS. В дослідженні окреслено засоби навчання для формування цих компонентів окресленої технології. Здійснено експериментальне дослідження, в ході якого здобувачі вищої освіти інженерних спеціальностей застосовували систему управління навчанням для формування агроекологічної компетентності. Отримані результати до та після експерименту перевіряли за допомогою статистичного критерію Пірсона. Визначено, що здобувачі вищої освіти, які застосовували окреслену технологію, мають вищі результати якості знань.

Окреслена технологія формування агроекологічної компетентності в умовах LMS закладів вищої освіти враховує специфіку аграрної галузі та сприяє органічному інтегруванню аудиторного навчання та використання цифрового навчального середовища з метою нівелювання освітніх викликів сьогодення. Результатом запропонованої технології є набуття якісних знань та формування агроекологічної компетентності в умовах системи управління навчанням вищого навчального закладу.

Ключові слова*: здобувачі вищої освіти інженерних спеціальностей; система управління навчанням; заклади вищої освіти; агроекологічна компетентність.*

JEL Classification: *A22; C13; I20; I21.*

Formulation of the problem. In modern conditions, agricultural higher education institutions are faced with the need to implement innovative teaching methods that combine traditional approaches with the latest digital technologies. This contributes to the training of competitive specialists who are able to work effectively in conditions of constant technological changes and challenges facing the agricultural sector. The development of digital technologies significantly affects all spheres of life, including education. The introduction of digital tools in teaching engineering opens up new opportunities for optimizing the educational process, improving access to knowledge and improving the quality of specialist training. This is especially important for the agricultural sector, where modern technical solutions play a key role in increasing production efficiency, rational use of resources and ensuring sustainable development.

Modern challenges in the agricultural sector, in particular the need to maintain ecological balance, introduce sustainable technologies and increase production efficiency, require high-quality training of future engineers. The formation of agroecological competence is a key task of education, as it ensures the ability of future specialists to integrate environmental principles into their professional activities. The use of a learning management system (LMS) significantly increases the efficiency of this process due to access to interactive content, personalized learning with the ability to adapt courses to the individual needs of students, real-time monitoring and assessment of knowledge, which contributes to prompt feedback, the formation of digital competencies that are necessary for a modern agricultural engineer, and ensuring access to modern scientific data and innovative solutions in the field of agroecology. Thus, the implementation of LMS in the training of agricultural engineers allows you to improve the quality of education, make it more flexible, technological and focused on solving real environmental problems of the agricultural sector.

Analysis of recent research and publications. The main goal of modern education is to introduce new information technologies into the educational process and the management of educational institutions, to create free access to cultural, educational and scientific information [1]. Authors [2] describe the peculiarities informatization of education that contributes to the development of a system of continuous education, which provides for an individual learning trajectory. Access of higher education students to various sources of information develops critical thinking and independence, and ensures a creative approach to learning [3]. Integration of the content of the digital learning environment into the training of higher education students is an effective way to solve the problems of higher education associated with the pandemic and full-scale invasion [4].

Digital skills are based on the mastery of information and communication competencies, they are an important aspect in the acquisition of professional competencies

[5]. When designing the content of education, it is necessary to take into account the general principles of its construction and updating in accordance with the requirements of the time [6]. Studies [7], [8] indicate that the development and implementation of practice-oriented classes activates and stimulates students' cognitive interest in mastering the necessary general and professional competencies, which is also important when studying future engineers. Students need practice-oriented courses that not only provide information, but also facilitate further professional activity [9]. There are many digital learning tools for engineering education, such as virtual laboratories, training simulators, etc. [10]. The authors [11] note that cloud solutions can be used in engineering education for creating and visualizing technical objects, 3D modelling. However, the widespread distribution of interactive content on the Internet requires effective methods for integrating this type of content into LMS and coordinating it with the necessary competencies [12].

In the context of discussing the developed technology for creating educational content for courses in engineering disciplines into the conditions of LMS and its implementation in the educational process, it is necessary to note that the educational horizon has changed with the advent of open educational resources and modern learning tools [13], [14]. Empirical studies of the use of LMS for formation of professional competences, particularly in the context of engineering education [15], [16] outline the impact of the use of digital learning tools on a number of educational aspects, such as improving the quality of engineering knowledge, developing STEM skills, etc. The authors [17] note that elements of open educational resources can be adapted and combined to create new resources that better meet the specific needs of different types of users. In the course of studying the problem of introducing cloud technologies into the educational process in the conditions of the LMS of higher education institutions, the authors conclude that it is necessary to develop skills in using digital technologies [18]. Open digital resources should be developed for a specific purpose and be consistent with specialized thematic content [19].

The authors [20] emphasize the importance of implementing pedagogical models for managing students' educational and creative activities; such models improve the quality of professional and creative competence of future engineers of agro-industrial production. Researchers [21] emphasize the need for an organized and thoughtful approach to training, which allows future engineers to effectively solve environmental problems at different levels. Development of the creative potential of future engineers of an agricultural profile, which contributes to the formation of innovative thinking and the ability to make environmentally friendly decisions [22]. Courses aimed at increasing environmental awareness and competence of future specialists are integrated into the curricula of higher education institutions, which contributes to the formation of environmental consciousness and responsibility [23]. The learning management system forms systemic thinking in future engineers, which is key to making environmentally sound decisions in the agricultural sector [24]. Therefore, the use of learning management systems in combination with the integration of specialized courses contributes to the effective formation of agro-ecological competence in future engineers and ensuring high-quality management of the educational process.

Formulation of research goals. Development and experimental verification of the effectiveness of application of a learning management system for the formation of agroecological competence of future engineers.

Outline of the main research material. Agroecological competence of engineers is a set of knowledge, skills and value orientations that ensure the ability of specialists in the agricultural engineering profile to effectively develop, implement and operate technical solutions that contribute to the environmental sustainability of agricultural systems. It is important for the sustainable development of the agro-industrial complex and the harmonious combination of technical progress with environmental protection principles. It is based on the understanding of environmental processes in agricultural production, the ability to environmentally sound design and use of agricultural equipment, the ability to assess and minimize the negative impact of agricultural activities on the environment, the ability to implement energy-saving and environmentally friendly technologies in production. Fig.1 presents the application of a learning management system for the formation of agroecological competence of future engineers. Application of a learning management system for the formation of agroecological competence of future engineers consist of the two components: the engineering component and the digital component. At the first stage there are outlined the engineering component of the presented technology from the point of view of the engineering disciplines.

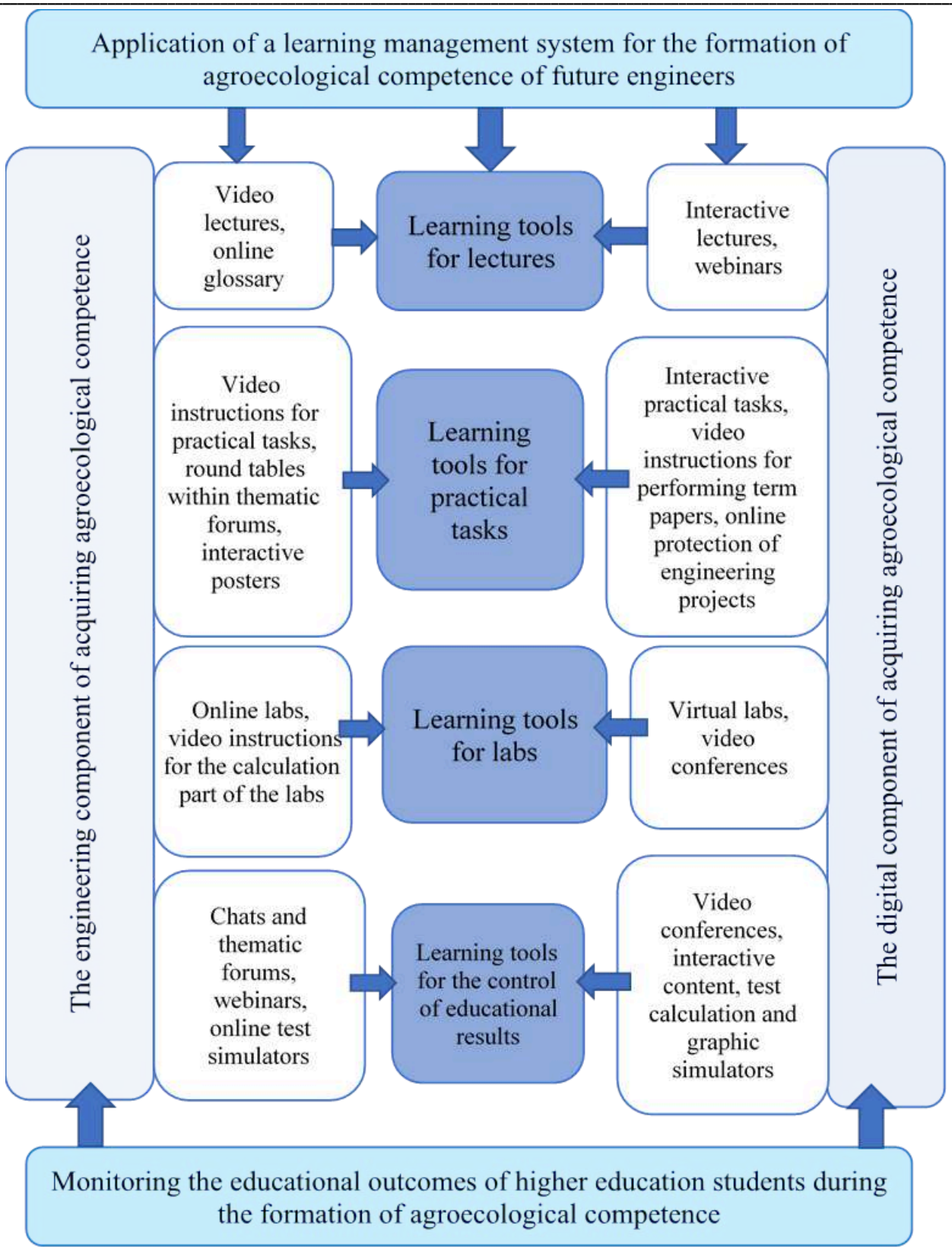

Figure 1 – **Application of a learning management system for the formation of agroecological competence of future engineers**

Source: authors' development

Engineering and computer graphics tasks should be aimed at solving specific problems that arise in the agricultural sector, for example, designing irrigation systems, developing plans for growing crops, modeling greenhouse structures, etc. Educational cases and projects should include situations from the agricultural sector, which allows students to use engineering graphics to solve real agro-technological problems. Future engineers also need to adapt graphic tasks to the specifics of animal and plant processing. This may include creating drawings of technological equipment, pipelines, developing layouts for equipment in production, as well as designing various components of production lines. The tasks and examples used in the course can be taken from real production, which will help students better understand how theoretical knowledge is applied in practice. Teaching engineering graphics to students of agricultural higher education institutions in a digital learning environment has its own specific features, which are determined both by the general requirements for engineering training.

The study of engineering graphics in a digital environment involves the active use of computer-aided design (CAD) programs, such as AutoCAD, SolidWorks, or software packages specific to the agricultural sector. This allows students to create and edit technical drawings, model parts and assemblies. The use of simulation programs allows students not only to design, but also to check the performance of structures in a virtual environment, which is especially important for agricultural machinery and equipment. Tasks for students should be adapted to the specifics of agricultural higher education institutions, for example, designing irrigation systems, structures for agricultural machinery or mechanisms for soil cultivation. This increases the relevance of training and prepares students for real challenges in their profession. Students should be able to create 3D models of specific objects, such as tractors, combines, greenhouses, automatic irrigation systems, etc.

Teaching mechanics of materials and constructions in a digital learning environment should take into account both the needs of higher education students and the capabilities of modern technologies. The teaching material should be adapted in such a way as to demonstrate its practical application. For example, attention should be paid to the mechanical properties of soils, the design of agricultural machinery, and the loads on agricultural machinery. Instead of abstract tasks, students are offered tasks related to real agro-technological scenarios, such as calculating the strength of parts of soil processing equipment.

Teaching technical and applied mechanics in a digital learning environment should be focused on the applied use of knowledge in the processes of processing livestock and crop production. This includes the analysis of mechanical processes in technological lines, such as grinding, transporting, mixing and pressing products. Educational materials should contain cases related to real production situations that demonstrate the application of the laws of mechanics in the processes of processing agricultural products. Teaching theoretical mechanics should take into account the specifics of agricultural higher education institutions, in particular, the use of examples and tasks related to agricultural machinery, greenhouse structures, irrigation systems and other objects of the agricultural sector. This allows students to better understand how theoretical knowledge is applied in practice in the specified field. Teachers can create tasks based on real problems and challenges that engineers face, so that the training is as applied and relevant as possible.

Teaching materials science in a digital learning environment has features that take into account the specifics of this discipline and the needs of agricultural education. For example, studying the properties of materials used in agricultural production, such as fertilizers, pesticides, and soil structures. The use of real agro-technological scenarios is used to demonstrate the quality and properties of materials that affect agricultural processes (for example, the choice of materials for irrigation systems or greenhouse structures). Special attention is paid to the properties of materials, such as the water-holding properties of soils, resistance to agrochemicals, and wear resistance of materials for agricultural equipment. The integration of local characteristics, such as soil types and climatic conditions, should be taken into account in the context of teaching materials science. It is also important to include information on materials used in the processing of livestock products, such as feed raw materials, protein additives, food additives, packaging, etc. This allows students to better understand the characteristics of materials in the context of their use. It is necessary to outline the use of modern examples and trends in processing of livestock products, including the latest technologies, innovative materials and methods that affect the quality of the final product. It is important to include examples and tasks that are directly related to the materials used in agricultural equipment. This will help students understand how the properties of materials affect the efficiency and durability of agricultural engineering systems. Another important aspect is the assessment of the properties of materials in specific conditions of the agricultural environment (the influence of moisture, aggressive chemical environments, mechanical loads).

Teaching the course “Details of Mashines” in a digital learning environment has specific features that must be taken into account to ensure high quality learning. The content must be adapted to the specifics of agricultural machinery. This includes the study of machine parts used in agricultural machines, such as tractors, combines, and other units. It is also necessary to emphasize the use of real examples and cases related to parts and mechanisms used in agro-industrial complexes.

Teaching the theory of mechanisms and machines in the conditions of LMS is related to both the nature of the discipline and the specifics of agricultural engineering. In a digital learning environment, it is important to use software products for modeling and simulating mechanisms and machines. This allows students to visualize how various mechanisms work in real agricultural production conditions. The inclusion of real-life cases from agricultural engineering, such as the design and optimization of agricultural machinery, helps students understand how theoretical knowledge is applied in practice. Virtual laboratories and mechanism simulators allow students to experiment with various structures and mechanisms without the need for physical models. This is especially useful in conditions of limited access to real laboratories or technical equipment. The use of digital tools to collect and analyze data, such as the results of experiments or production processes, helps students better understand the efficiency and productivity of various mechanisms. Teaching the theory of mechanisms and machines should take into account the specific features of agricultural machinery, such as work under heavy loads, contact with the soil, agroclimatic conditions, etc.

At the second stage there are outlined the engineering component of the presented technology from the point of view of the engineering disciplines. In the conditions of LMS, teaching of engineering subjects can be organized in a project format, where students perform complex tasks, such as developing technical documentation for agricultural equipment. This allows them to apply knowledge in practical settings. LMS provides the opportunity to create a portfolio of work where students store their drawings, models and other projects. This is useful for both assessment and future employment. Engineering subjects can be integrated with other disciplines, such as agronomy, ecology and agricultural management, which helps students understand how mechanical systems affect various aspects of agricultural production. The use of online tools for testing, assignments and assessing student progress can include automated tests that provide immediate feedback, as well as the ability to provide comments and recommendations for improving knowledge. Interactive 3D models and simulations allow students to study the design of machines and mechanisms, their interaction and functioning in real-world conditions. Teaching skills in working with modern computer-aided design (CAD) systems is an important element, as these systems are widely used in agricultural production for the design and construction of machine parts and mechanisms. Students can have constant access to online resources, including textbooks, video tutorials, interactive modules that explain the principles of engineering graphics, as well as the use of CAD programs. Using learning management platforms such as Moodle or Canvas to organize the learning process, upload learning materials, test knowledge and track student progress.

Virtual laboratories and simulations allow students to conduct research and test parts without physical access to real equipment. Interactive tasks and online workshops that include project creation, analysis and diagnostics help students understand the material more deeply. Using online collaboration platforms (e.g. Google Workspace, Microsoft Teams) allows students to work together on projects, share files and receive feedback from the teacher in real time. Regular webinars and consultations, during which the teacher can provide individual advice on completing graphic tasks, help students better assimilate the material. The use of online forums and chats to discuss course topics, solve problems and requests, which promotes active interaction between students and teachers. Regular virtual consultations and webinars allow teachers to provide feedback and assistance in real time.

The use of systems for automated assessment of tests and tasks allows students to receive results and feedback faster. The introduction of gamification elements, such as ratings, points and achievements, can increase students' motivation for active learning. Integration with real projects or the possibility of internships in agro-industrial companies can motivate students and provide them with practical experience. The digital environment allows students to work at their own pace, repeat the material or take additional courses for in-depth study of general technical disciplines.

Digital tools and technologies allow for a more interactive and personalized learning environment, which increases the efficiency of material assimilation. The use of 3D modeling, simulations, virtual laboratories and online workshops helps students to understand complex technical concepts more deeply. In the context of agricultural education, general technical disciplines need to be adapted to the specifics of agricultural machinery and technologies. It is important to use real examples from agricultural practice, which allows students to see the direct interdependence between technical knowledge and its practical application in agriculture. LMS provides an opportunity for flexible learning, allowing students to learn at their own pace and at a convenient time. It makes educational materials available at any time, which is especially important for dual education students who combine study with practice in the agricultural sector. The introduction of gamification elements and interactive learning methods increases student engagement, motivating them to actively study the material. Online forums, chats and video conferences contribute to the creation of a community of students who actively exchange experience and knowledge.

Teaching engineering subjects in the conditions of LMS faces certain challenges, such as the need for a high level of technical support, ensuring quality access to the Internet, and developing digital skills among teachers and students. The transition to digital learning requires teachers to constantly improve their skills in the use of digital technologies, distance learning methods, and the

development of digital learning materials, therefore, higher education institutions should support the professional development of teachers in this area. LMS allow for more effective adaptation of the learning process to the individual needs of students, enabling them to work with the material at a level that matches their knowledge and abilities. Digital learning requires students to have a high level of independence, self-discipline and responsibility for their learning. This contributes to the development of key skills, such as self-management and critical thinking, which are important for future specialists in the agricultural sector.

It is calculated the empirical value of Pearson's criterion χ2 at the beginning and at the end of the experiment in control and experimental groups. The amount of the 520 students of the control group took part in the experiment, as well as 520 students of the experimental group. Table 1 presents a statistical justification of the effectiveness of the formation of agroecological competence before conducting the experiment, based on the use of traditional forms of learning. Critical value for χ2 for levels of statistical significance ρ≤0.05 (5.993) and ρ≤0.01 (9.212).

Table 1 **Levels of quality of knowledge of higher education applicants during the formation of the agroecological competence in control (CG) and experimental (EG) groups at the beginning of the experiment**

Level	**EG, %**	**Empirical frequency n_i (EG)**	**CG, %**	**Empirical frequency n_{i1} (CG)**	(ni-ni1)^2	(ni-ni1)^2/ni1
A	4,42%	23	4,04%	21	4	0,19
B	5,00%	26	5,38%	28	4	0,14
C	15,38%	80	15,96%	83	9	0,11
D	27,88%	145	26,92%	140	25	0,18
E	27,69%	144	27,12%	141	9	0,06
FX	19,62%	102	20,58%	107	25	0,23
Total	100,00%	520	100,00%	520		**0,91**

Source: authors' development

As can be seen from Table 1, the value of χ2emp = 0.91 and χ2emp ≤ χ2crit. It was determined that the statistical differences between the control and experimental groups are small, it can be concluded that the formation of agroecological competence requires correction.

Table 2 presents the statistical justification of the effectiveness of the formation of agroecological competence after the experiment. Higher education students in the control group studied using traditional methods, while students in the experimental group studied using the proposed technology for the formation of agroecological competence using LMS.

Table 2 **Levels of quality of knowledge of higher education applicants during the formation of the agroecological competence in control (CG) and experimental (EG) groups at the end of the experiment**

Level	EG, %	Empirical frequency n_i (EG)	CG, %	Empirical frequency n_{i1} (CG)	(ni-ni1)^2	(ni-ni1)^2 /ni1
A	16,15%	84	7,88%	41	1849	45,10
B	19,42%	101	12,50%	65	1296	19,94
C	22,50%	117	16,73%	87	900	10,34
D	21,15%	110	25,00%	130	400	3,08
E	12,12%	63	21,15%	110	2209	20,08
FX	8,65%	45	16,73%	87	1764	20,28
Total	100,00%	520	100,00%	520		118,87

Source: authors' development

As can be seen from Table 2, the value of χ2emp = 118.87 and χ2emp ≥ χ2crit. It was determined that the statistical differences between the control and experimental groups have significant differences, based on the comparison of the hypotheses put forward, it can be concluded that the formation of agroecological competence for the experimental group, which studied according to the outlined pedagogical technology in LMS conditions, is effective.

Conclusions. The inclusion of new technologies in courses on engineering disciplines, such as automation of agricultural processes, precision farming systems, drones for monitoring crops, etc., is an important aspect of the digitalization of agricultural education. Combining classroom classes with courses in the conditions of LMS can be effective in ensuring a deeper understanding of the theoretical aspects of general technical disciplines. For example, theoretical classes can be conducted online, and laboratory work and practical tasks can be performed in the classroom. Organizing online consultations and discussions to solve problems and clarify material helps maintain a high level of engagement. Students may be offered project assignments that require independent research and development of solutions to real-world agricultural problems. This may include analyzing mechanisms, designing new machines, or improving existing technical solutions. Providing access to online resources such as scientific articles, technical documents, and video tutorials helps students expand their knowledge and supports their independent work.

Learning in the conditions of the LMS of a higher education institution is intended to support and supplement classroom forms of educational activity, such as lectures, practical, seminar and laboratory classes. Lectures during learning in the conditions of the digital learning environment of a higher education institution are accompanied by graphic and interactive content, experimental tasks and calculation projects. Quality control of learning involves modular control through testing in the conditions of the digital learning environment of a higher education institution and final control during the formation of agroecological competence.

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