Развитие системного мышления студентов аграрного вуза при изучении основ искусственного интеллекта в инженерной практике

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АННОТАЦИЯ

Проблема и цель. Модернизация высшего образования открывает перспективы использования сервисов на основе искусственного интеллекта при подготовке высококвалифицированных специалистов технического профиля для аграрного производства. Взаимодействие участников дидактического процесса в такой информационной среде обладает потенциалом в плане развития востребованных soft skills (управление временем, адаптивность, цифровая грамотность, критическое и системное мышление). *Цель исследования* – изучить особенности развития системного мышления студентов аграрного вуза при изучении основ искусственного интеллекта в инженерной практике.

Методы исследования. Эксперимент проведён на базе Российского государственного аграрного университета – МСХА им. К. А. Тимирязева. В нём участвует 88 студентов Института механики и энергетики имени В. П. Горячкина, программа подготовки: 35.03.06 Агроинженерия. Интеграция сервисов, функционирующих на базе искусственного интеллекта, в обучение студентов реализовано в рамках дисциплины «Основы систем искусственного интеллекта в инженерной практике». Для оценки уровня развития системного мышления агроинженеров используется авторская методика, в основе которой тест системного мышления SRT. При статистической обработке данных использован критерий χ^2-Пирсона.

Результаты. В исследовании описана деятельность агроинженеров, проводимая по следующему плану: «Введение», «Погружение в проблематику», «Применение искусственного интеллекта в инженерной практике», «Систематизация и закрепление», «Полевые испытания». Ключевые темы дисциплины: генеративные нейросети, компьютерные средства разработки и языки программирования, основы теории экспертных систем. Особенность работы: результаты каждого предыдущего этапа используются студентами при информационном взаимодействии на следующем. Выявлены статистически достоверные различия в качественных изменениях, произошедших в педагогической системе (χ^2 = 6.820; p < 0,05).

Заключение. Определены особенности информационного взаимодействия, влияющие на развитие системного мышления агроинженеров: межпредметное обучение; обеспечение условий для понимания студентами социальной важности профессии; развитие творческого отношения к труду; освоение научно-критической деятельности; учёт результатов с предыдущих этапов взаимодействия в работе над следующими.

КЛЮЧЕВЫЕ СЛОВА

обучение агроинженеров, информационная образовательная среда, система задач, генеративные нейросети, инструментальные средства разработки, теория экспертных систем

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Development of students' systems thinking when studying the basics of artificial intelligence in engineering practice at the agricultural university

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ABSTRACT

Problem and goal. Modernization of higher education opens up prospects for using services based on artificial intelligence for the training of highly qualified technical specialists for agricultural production. The interaction of participants in the didactic process in such an information environment has the potential to develop popular soft skills (time management, adaptability, digital literacy, critical and systems thinking). *The purpose of the study* is to study the features of the development of systems thinking of students of an agricultural university when studying the basics of artificial intelligence in engineering practice.

Research methods. The experiment was conducted at the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy. It involves 88 students of the Institute of Mechanics and Power Engineering named after V. P. Goryachkin, training program: 35.03.06 Agricultural engineering. The integration of services based on artificial intelligence into student training is implemented within the framework of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice". The authors used the SRT systems thinking test to assess the level of development of systems thinking of agricultural engineers. In the statistical processing of data, Pearson's chi-squared criterion was used.

Results. The study describes the activities of agricultural engineers, carried out according to the following plan: "Introduction", "Immersion in the problematic", "Application of artificial intelligence in engineering practice", "Systematization and consolidation", and "Field tests". Key topics of the discipline: generative neural networks, computer development tools, programming languages, and fundamentals of the theory of expert systems. Feature of the work: the results of each previous stage are used by students in information interaction at the next one. Statistically significant differences in the qualitative changes that occurred in the pedagogical system were revealed ($\chi^2 = 6.820$; $p < 0.05$).

Conclusion. The features of information interaction that influence the development of systems thinking of agricultural engineers are defined: interdisciplinary training, providing conditions for students to understand the social importance of the profession, developing a creative attitude to work, mastering scientific and critical activity, taking into account the results from previous stages of interaction in working on the next ones.

KEYWORDS

training of agricultural engineers, information educational environment, task system, generative neural networks, development tools, expert systems theory

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INTRODUCTION

1. UNESCO plays a key role in the dialogue and expansion of knowledge in the field of AI applicability for education [1]. UNESCO experts, who have been systematically dealing with relevant issues for a long time, published recommendations on the ethics of integrating AI technologies into teaching and research in November 2021 based on analytical work. These developments were improved in 2023 when a guide about generative AI usage in educational and scientific practice was published [2]. Analyzing the situation in Russia, we note that experts from the AIRI Institute of Artificial Intelligence point out that [3]: the use of AI fundamentals can significantly enrich various types of educational, research, and professional activities; computer development tools and AI programming languages determine a number of factors for increasing productivity, improving user service, and supporting personal development.

2. B. N. Oyman, and E. Bozkurt, analyzing research from international databases, note that after UNESCO defined systems thinking as a key competency for achieving sustainable development goals in 2015, scientists' interest in the development of human systems thinking in the educational space has increased [4]. N. L. Karavaev and E. V. Soboleva, also considering the potential of digital technologies for the development of systems and critical thinking of future engineers, give examples of tasks that contribute to the development of skills and abilities that form the basis of systems thinking of a student in the technical field of training [5].

3. FAO and UNESCO, working on a single task (achieving sustainable development goals), integrate their efforts in working on global problems in the field of education, culture, and the relationship between food and health [6]. The organizations are developing joint programs, and implementing educational projects that involve the use of innovations in the field of AI. Experts on the state of agriculture in the world determine that a food crisis and social explosion are inevitable if: countries do not radically change their agricultural technologies; educational programs in the field of training relevant specialists are not amended to take into account the new challenges and opportunities of AI [1]. In addition, one of the important areas of UNESCO and FAO activities in improving the practice of breeding work is the creation of automated and robotic devices that can increase productivity and minimize manual labor. The latter circumstance determines the importance of training agricultural engineers.

4. In 2023 (in the Forum on the Ethics of Artificial Intelligence "Generation GPT. Red Lines"), Timiryazev Academy joined the Code of Ethics in the Sphere of AI [7]. The practical implementation of disciplines in this area is carried out by the digital department of the academy simultaneously in several professional retraining programs. However, for the bachelor's level, such work is still only experimental (fragmentary). A. Mckim and B. McKendree determine that problems related to agriculture, food, and natural resources are becoming increasingly complex [8]. These circumstances increase the need to develop in students the readiness to resolve such problems, the ability to self-knowledge, and self-improvement. The authors identified significant relationships between metacognition and systems thinking, as well as systems thinking and the ability to solve the above problems. At the same time, for example, in the work of L. Tarkhova et al., it is already proven that interactive educational content of digital information and reference manuals, including elements of AI, contributes to the effective training of technical specialists for the agro-industrial complex [9]. Thus, there is an objective need for additional research into the system thinking development as one of the key universal competencies of a graduate ready for the challenges of Industry 5.0.

Research hypothesis: the use of AI-based technologies in teaching students will provide additional resources for the development of their systems thinking as one of the sought-after universal competencies of the agricultural engineer of the future if it 1) relies on the existing scientific and methodological potential of the agricultural university; 2) takes into account the specifics of their training; 3) reflects real achievements of science and technology in the plots of text problems, the topics of practice-oriented situations.

The purpose of the work is to study the features of the development of systems thinking of students of an agricultural university when studying the basics of artificial intelligence in engineering practice.

Research objectives:

- to clarify the problems and possibilities of using AI-based digital technologies in teaching students at an agricultural university;
- to describe the structure and content of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice" taking into account the specifics of student training;
- to clarify the features of the development of systems thinking of students of an agricultural university when studying the basics of artificial intelligence in engineering practice;
- to experimentally test the effectiveness of the proposed version of information interaction in the training of agricultural engineers;
- to identify factors influencing the level of development of skills and abilities that form the basis of systems thinking of a student of an agricultural university.

MATERIALS AND METHODS

In the presented study, AI is considered a process that imitates the activity of human consciousness in a broad sense. It is used in programs, applications, and various technical systems to expand their capabilities for agricultural engineering. An agricultural engineer is a university student who designs, develops, and implements various systems, equipment, and technologies in agricultural production. The authors interpret the systems thinking of an agricultural student as thinking when an agricultural engineer can model any process in his head and see the whole picture, analyze all output data, make a decision (carry out mathematical processing), know what to do so that the system returns to the desired state. Studying the basics of artificial intelligence involves the following key topics: introduction to AI theory, generative neural networks (NiceBot, ChatInfo, NeuroCanvas, AI Duet, Tripo3D, GPTExcel, etc.), neurobrowsers, IOctopus mind maps, LMSYS Chatbot Arena resource, computer development tools and programming languages (Prolog), basics of expert systems theory.

In identifying the features that determine the influence of studying the fundamentals of artificial intelligence on the development of systems thinking of students of an agricultural university, the experimental work was organized and conducted at the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy. 88 students from the third year were involved in it. Training program: 35.03.06 Agricultural engineering. The work was carried out as part of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice". The discipline is taught to students of this training profile in the 7th semester. The average age of students is 20 years (30% – female, 70% – male). To assess the components that form the basis of systems thinking of a student of an agricultural university, an original test is used, designed according to the type of the systems thinking test (SRT RUS) from the company "Personnel Assessment and HR Consulting. Business Psychologists (ex. SHL)". In our country, the Russian representative of SHL remained and users can still use the SHL assessment tools and tests, but under a different brand and name. The systems thinking test includes four types of tasks that assess individual components: identifying patterns in logical sequences; analyzing and identifying patterns in structural diagrams; understanding diagrams and process diagrams (cyclic diagrams); identifying relationships between elements in complex systems.

Each of the monitored components is related to the abilities stated by the authors above: modeling an integral process (diagram), analyzing different structures (data), making a decision, and identifying a set (connections and interrelations) of events. When formulating the tasks, we took into account the knowledge that students of the agricultural university previously received in the disciplines "Informatics and digital technologies" and "Engineering and Computer Graphics". The authors formulated two sets of test tasks. One set for testing before the experimental work (hereinafter referred to as the EW), the other – after the EW. The test materials meet the norms of the current federal standard for the area of training, the requirements of an agricultural university, and the content of the work program of the discipline. The test materials are the basis for determining the control and experimental groups. Each set contains 100 questions (25 questions for each type of task). The correct answer to the question was estimated at 1 point. Examples of questions are in the

Research Program. Thus, based on the results of the control test, students of an agricultural university could score from 0 to 100 points. Levels of systems thinking of agricultural engineers: "low" (from 0 to 34 points), "medium" (from 35 to 89 points), "high" (from 90 to 100 points).

The methodology for interpreting the levels is in the research results. Control and experimental groups were formed. Each of them included 44 agricultural engineers. In statistical data processing, the Pearson's chi-squared test was used.

LITERATURE REVIEW

The development of AI-based technologies, as defined by V. Ratten and P. Jones, inevitably leads to the emergence of new difficulties that cannot yet be resolved for the following reasons: lack of unity at different levels of government; incomplete legislative framework and regulations [10]. B. A. Levin et al. examine the situation with the development of the scientific community's ideas about artificial intelligence, and the possibilities of its application in engineering education [11]. The authors define the volume and content of training in the form of the basics of a specific area of AI science – decision support systems. M. I. Qureshi et al. note that over the past decade, digitalization trends have affected the overall structure of education, vocational training, and employment around the world [12]. To prove their hypothesis, the authors analyzed 47 studies from international databases. N. Rane analyzes 51 scientific articles in the field of application of augmented/virtual reality, simulation, Internet of things for higher education [13]. According to the author's conclusions, these technologies contribute to a deeper immersion in theoretical material, student involvement, interpersonal information interaction, cost and risk reduction, modeling of real practical scenarios, learning without time and place restrictions, development of algorithmization skills and study of technologies, their application for self-realization. E. B. Moraes et al. reveal how AI into the education system leads to significant changes. In particular, the authors note that traditional learning models are giving way to more personalized and adaptive ones [14]. The authors consider the possibilities of using machine learning algorithms and natural language processing to create personalized learning environments.

R. Chen and Y. Chen note that with the rapid development of artificial intelligence, the importance of assessing the impact of technical, and ethical challenges and risk factors to support decision-making in the digital educational space is increasing [15]. M. Rice et al. indicate that digital school teachers are faced with the task of being competent and evolving in the constantly changing information educational space [17]. The latter includes both machine learning programs and AI algorithms. The mentor is required to: not only apply generative AI in teaching; but also understand (use in teaching) reasonable ways to prevent their students from constantly turning to AI. M. Ghajargar identifies that theorists and methodologists in education are turning to generative AI to support such types of cognitive activity as the development of ideas and substantive concepts [18]. B. N. Oyman and E. Bozkurt reveal that the analysis of studies from international databases indicated an increasing interest in the development of human systems thinking in the educational space [4]. According to the authors, this is due to the fact that in 2015, UNESCO in its "Education 2030 Action Agenda" identified systems thinking as a key competency (along with 8 other skills) for achieving sustainable development goals. An analysis of sources allowed B. N. Oyman and E. Bozkurt to conclude that research in the field of systems thinking development is mainly conducted using examples of training in the natural sciences [4]. V. G. Maracha considers applied systems thinking as a process of collective problem-solving, including interaction and coordination [19]. According to N. V. Ronzhina, systems thinking includes the transition [20]: from observing events or phenomena to defining behavior patterns in the context of performing work functions; from choosing (among a set of actions) to creating effective and long-term solutions for global problems affecting professional activity. Among such problems are climate change and the environmental crisis, economic instability, digitalization of all sectors of the economy, and rapid technological progress. Of course, the presented interpretation of the definition of "systems thinking" is one of the few existing in domestic and foreign literature.

For example, in the work of V. V. Likholetov, the definition of this term is given as an understanding of reality that emphasizes the importance of interactions between parts of the system, rather than the actions of the parts themselves [21]. The author also notes that solving many industrial problems requires the use of a systems approach in the design and development of more efficient and environmentally friendly technologies and mechanisms.

E. Makarowa and E. Saenko determine the methodological dominant in the context of implementing integrated training for students of an agricultural university. It is a system of problem-based professionally oriented tasks [22]. Such a system of tasks aimed at solving specific agricultural engineering problems is compiled taking into account the specifics of training graduates who can adapt to rapidly changing conditions both in the labor market and in the profession. According to the authors, the selection of tools and methods for solving these problems should be carried out in a dialogue between the participants in the didactic process (both students and their teachers) considering knowledge of various academic disciplines in an agricultural university. N. Das notes that despite all the positive didactic opportunities, digital technologies in teaching students of an agricultural university have the following negative consequences: constant sitting at the computer causes back pain, radiation from the screen of devices causes eye irritation, headaches [23].

A. Awadalla reveals that the faculty and students of the Agricultural Department of Alexandria University positively evaluate the use of hybrid learning (including elements of traditional and e-learning) [24]. Y. Tsench determines that after the modernization of the Russian higher education system, those universities that trained only specialists for the agricultural sector ceased to exist as independent educational institutions. New trends determined the merger and integration of research institutions, and the creation of large federal research centers on their basis [25]. J. Soler Rovira et al. study the characteristics of the learning styles of students of an agricultural university. And identify the possibilities of using digital technologies to develop oral and written communication as the basis of soft skills [26]. Dr-R. Elmeanawy studies the possibilities of using e-learning (EL) for teaching agricultural sciences [27]. The author developed a questionnaire aimed at: identifying and analyzing problems associated with the inclusion of EL; assessing the quality of interaction between students and teachers; determining the participants' attitude in the didactic process towards EL; views of teachers and students on the applicability of EE for agricultural sciences.

L. Tarkhova et al. present a set-theoretic model and methods for developing and using in practice a set of digital information and reference manuals aimed at training engineering personnel for the agro-industrial sector [9]. A variant of structuring images (drawings of parts and products, diagrams, technical objects) and training management using multidimensional scenarios is described. The authors have proven that interactive educational content of digital information and reference manuals contributes to the effective training of technical specialists for the agro-industrial complex. E. V. Shchedrina and O. N. Ivashova describe the potential of services for generating text, images, spreadsheets, sound, and video in the training of agricultural engineers [28]. The authors, based on the analysis of their own accumulated experience, and the works of other university teachers, offer specific formulations of tasks, and educational / problem situations that take into account the specifics of training students of an agricultural university. E. V. Shchedrina and O. N. Ivashova in their study indicate that their developments require systematization, further clarification in the context of solving problems of ethics (copying and rewriting, information security, copyright protection), and technical innovations (disabling several functions, the emergence of new versions, the introduction of paid subscriptions) [28]. K. Alford et al. determine the need to develop systems thinking in colleges that graduate agricultural engineers [29]. The authors provide examples of how the use of modern technologies in the training of highly qualified specialists (in particular, in the field of electrical equipment and electrical technology), for example, in the process of solving problems of reducing the energy intensity of the economy (energy consumption per unit of GDP produced) allows to improve the quality of graduate training. Within the framework of the experiment, these empirical materials are confirmed by theoretical justifications.

E. Royse et al. indicate that there is a growing interest in interdisciplinary education that combines various concepts and disciplines [30]. Therefore, there is a need to assess students’ knowledge of these programs, as well as the educational practices implemented. The authors test a machine learning model for text classification to assess students’ systems thinking abilities. All texts were related to the triad "Food, energy, and water". It was necessary to answer two questions: can machine learning models be used to identify essential concepts in students’ responses; what do students know about the relationships between food, energy, and water. E. Royse et al. claim that their study represents one of the first attempts to assess the links between foundational concepts related to a particular discipline and students’ systems thinking abilities.

N. L. Karavaev and E. V. Soboleva attempt to substantiate the need to take into account the specifics of training future engineers when formulating tasks for developing their thinking [5]. For example, in the following formulation: "In the table "IT Company Employees'", using the auto filter, display information about programmers living in the city of Kirov OR Kazan, with a name starting with the letter "A", who do not have a phone number". Thus, here the student is required to work with the text of the task; select the initial data and those that need to be obtained; update the existing knowledge on the auto filter; from the existing set of actions (filling in cells, writing formulas, using the auto filter, etc.) select those that will allow you to achieve the result; evaluate the answer received (correctness, optimality of achievement, efficiency of the solution method). However, N. L. Karavaev, and E. V. Soboleva note in the conclusion that it is necessary to supplement the formulated examples, since in the texts of the tasks, firstly, the specifics of the student's training should be taken into account. And, secondly, to refine the proposed set so that it is a system of educational tasks [5].

M.-A. Lorenzo-Rial et al. also suggest using information technology to support the development of systems thinking [31]. They are proposed to be used to process and present real practical data and to perform conscious and verified actions in solving problems related to climate change. In this case, climate is considered a system of interrelations of natural, social, and economic aspects (at different geographical and temporal levels). G. H. López and A. Reyes determine that the challenges of modern engineering education actualize the need to develop students' skills and abilities that determine their ability (readiness) to see how all elements in any system are connected and influence each other [32]. That is, to introduce future engineers to a systems view of the world. The authors believe that higher education teachers should think about the need to teach systems thinking to future engineers and search for appropriate methods and tools.

The analysis revealed that: studying the fundamentals of artificial intelligence systems is an important area of informatization of education and achievement of SDGs; AI-based technologies have the didactic potential for developing systems thinking as one of the sought-after universal competencies of the agricultural engineer of the future; there are some objective difficulties in including disciplines that involve studying the fundamentals of artificial intelligence systems in the training of students at an agricultural university.

RESEARCH PROGRAM

At the first stage, an analysis of the literature, and experience of using AI in training specialists in technical specialties and agricultural engineers, in particular, was carried out. It was also revealed that providing support for the development of systems thinking is an important condition for preparing a highly qualified graduate of an agricultural university. At the same time, it was determined: the use of AI in training agricultural engineers should take into account the specifics of their training; when formulating plots of text problems for algorithmization and programming, in the subject of problematic and practice-oriented situations, real achievements of science and technology should be taken into account.

An original test was designed that takes into account the essence and structure of the systems thinking test (SRT RUS) from the company "Personnel Assessment and HR Consulting. Business Psychologists (ex.SHL)". In accordance with the SRT SHL RUS test, four types of problems were developed. Let us present examples of questions from the sets of tasks for the test (before and after the experimental work) for each type of problem. All questions are open-ended (4 answer options). 1 type of task to identify patterns in logical sequences:

1.1. What parts does a URL consist of?

1.2. The worker (X) relation says that X is a worker. The more(X, Y) relation says that worker X gets paid more than worker Y. What does the following query mean: worker(X), not (more(X, _))?

2 types of tasks to analyze and identify patterns in structural diagrams:

2.1. There is a conversion of the number 1101 from the binary to the decimal system. Agricultural engineers are offered several solution options in the form of infographics/solution diagrams. The task is to determine the correct solution.

2.2. There is an agricultural field divided into cells. A tractor needs to go from the upper left to the lower right. In this case, it is allowed to step from a cell to a cell on the right or below. How many different paths are there for the tractor?

3 types of tasks to identify relationships between elements in complex agricultural engineering systems:

3.1. How many different words (not necessarily meaningful) can be formed by rearranging the letters of the word "meaning"

3.2. There were three flowers on the window of the office of the company "Agrokomplekt" – geranium, crocus, and violet. Let's designate them with the letters G, C, and V. Every morning, the first agricultural engineer wiped the window and swapped the right flower and the central one. The second agricultural engineer watered the flowers every evening and swapped the left flower and the central one. Determine the order of the flowers after 100 days.

4 types of tasks to understand diagrams and schemes of agricultural engineering processes:

4.1. Which of the formulas shown in the diagrams can be written in cell D2 so that the diagram constructed after performing the calculations based on the values of the cell range A2:D2 matches the figure?

4.2. Let's assume that it is necessary to construct an air conditioner control algorithm based on fuzzy logic. Depending on the room temperature, it is necessary to determine the rotation speed of the fans. The algorithm will include the following stages: a) changing the truth functions for the right parts of the rules; b) calculating the values of the truth functions for the left parts of the rules; c) combining the truth functions for the right parts of the rules; d) determining the speed. It is necessary to arrange the stages in the correct order.

A total of 25 questions for each type according to the structure of the SRT RUS test. The correct answer to the question was estimated at 1 point. Based on the results of the author's test, the levels of training of agricultural engineers were determined. A control and experimental groups were formed. The goals, objectives, indicators for competencies, sections, topics, theoretical issues and practical tasks, classroom and extracurricular workload, methods, tools, and control were specified. Lists of primary and secondary literature were also formulated.

In the second stage of the study, agricultural engineers studied the materials of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice" according to the work program. When organizing the information interaction of students in the experimental group, mentors constantly took into account the specifics of their training, both in the plots of text problems and in the selection of AI tools for agricultural engineering projects. When formulating project topics, teachers focused on real achievements of science and technology.

In the third stage of the study, factors and features influencing the level of formation of the components that form the basis of systems thinking of students of an agricultural university were identified.

RESEARCH RESULTS

So, during the analysis of scientific and methodological literature and the current federal standard for the field of training, it was established that an agricultural engineer combines knowledge from the field of engineering and agriculture to create effective and sustainable agricultural systems. The goal of mastering the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice" is to develop competencies in agricultural engineers that ensure the ability to use AI capabilities for: selecting information resources and searching for information following the task; systematizing information obtained from various sources under the requirements and conditions of the task; selecting and systematizing information on the main parameters of technical and technological solutions for agricultural problems.

The "Introduction" stage. The main block of issues studied in the first introductory lecture: key areas of research in the field of AI. Tasks of image recognition, logical inference, knowledge modeling, translation, semantic analysis of language structures. Agricultural engineers established that the general tasks that artificial intelligence deals with include translation from one language to another, text recognition, etc. The participants in the experimental group directly specified that AI in agriculture allows for analyzing the state of the land, controlling the growth and development of plants, increasing productivity; maintaining favorable conditions for crops and animals, minimizing the negative impact on the environment, etc.

The "Immersion in the Problem" stage. Next, examples of the use of neural networks in the agricultural sector were considered. For example, a service for increasing the economic efficiency of crop production. The essence of the service is the development of an adaptive landscape farming strategy based on accurate soil and climate maps. In this case, computer vision technologies are used based on a specially trained neural network. Methodological recommendation 1 (for students in the experimental group). Ask students to create a table including 10 great discoveries in agricultural engineering over the past 5 years. Using the generative neural network resource, students in the experimental group developed a presentation dedicated to one of the top discoveries highlighted in the table. For example, using the Gamma service (https://gamma.app/ru).

Methodological recommendation 2. Additionally, ask students to analyze other applications for generating presentations and compare their functionality.

Methodological recommendation 3. Students should correct all inaccuracies and shortcomings in the presentation "manually".

Methodological recommendation 4. Ask students to design a mind map for AI in agricultural engineering using the "neuro paw" from the IOctopus service.

Stage "Main work on the use of AI in engineering practice". The software tools and methods used:

- at the stage of searching and recording the found information, calculations, visualization, and presentation of the results of analytical activities – services for searching for information on the Internet using (neuro browsers); text and graphic editors, spreadsheet processors, timelines, and mental maps (for example – IOctopus (https://mind-map-online.ru/), using the "neurolapka" tool);
- at the stage of transformative work with text, graphics, sound, and models – generative neural network services corresponding to each of the specified types of processed information;
- for working with large language models – the "Assistant. Animal Husbandry" model, the LMSYS Chatbot Arena resource (https://chat.lmsys.org/);
- programming language – Prolog;
- when studying the basics of expert assessments – knowledge engineering methods, the brainstorming method, and the Delphi expert assessment method.

"Systematization and consolidation" stage. Here are some examples of assignments from lectures and practical classes that were discussed in the control and experimental groups.

1. When working with large language models (LMSYS Chatbot Arena), students formulated queries to the service to explain concepts, names, and specific phrases. For example, "artificial neuron". The query can be formulated as follows: "Please explain the concept of an artificial neuron". Continue the dialogue and ask the next question, for example: "What is neural network training? How does this training happen"? Vote for the model whose explanation you liked the most. For students in the experimental group, there was a block of work called "Future Profession". One of the students made a query: "Who is an agricultural engineer"?

Continuing the dialogue, the mentor advised asking the following question, for example: "What are the main areas of activity of an agricultural engineer." Then: "Please tell me where an agricultural engineer works?" Then: "What skills and knowledge will I need to get the profession of an agricultural engineer". The student then independently continued this dialogue. Methodological recommendation 5. Invite the participants of the experimental group to independently write an essay on the topic "Appeal to an agricultural engineer" about the discipline "Fundamentals of artificial intelligence systems in engineering practice", their attitude to it, their impressions of its teaching, advice, and recommendations for studying this discipline (minimum – 1000 characters). The essay must include at least 10 of the following phrases and word combinations: technical solution, grant recipients, innovation, AI-based biotechnology, automation of routine processes, unmanned systems, virtual assistant for agribusiness, careless use, reasonable approach, Timiryazev Academy, numerous problems, ethical issues, wide opportunities.

The students of the experimental group also worked with the "Assistant. Animal Husbandry" model, which was developed at the Academy. It is used to analyze text information in the field of animal husbandry with the use of deep learning technologies. The program is based on a modified architecture of the BERT model, adapted to solving question-answer problems with an agricultural focus. Agricultural engineers performed additional training of the model on specialized data corpora containing information on animal health, living conditions, diet, and other aspects of animal husbandry.

2. Determine what rules are in Prolog. For example, by options: statements containing variables; true statements; and logical formulas that allow one fact to be derived from another. Or, as a modification of the task: what are facts in Prolog (statements that are true under certain conditions; statements that are known to be true; statements that contain variables).

3. There are three types of expert system development tools: a) expert system shells; b) programming languages; c) automated development tools. Arrange them in order to increase development efforts.

4. Write a Prolog program that determines the sum of the maximum and minimum values given by the three numbers A, B, and C. In the experimental group, this task was formulated as follows: "Find the weight of the 25HP 50HP Euro 5, Versatile RSM-2375, Rostselmash 2405 tractors. Write a Prolog program that determines the sum of the maximum and minimum values given by the weight values entered".

5. There are facts: a bear is big, an elephant is big, a cat is small, a bear is brown, a cat is black, an elephant is grey. You need to find out: who is dark and big? Task for the participants of the experimental group. Borisov, Kirillov, Danin, and Savin are engineers. One is an auto mechanic, another is an agricultural engineer, the third is a builder, and the fourth is a radio engineer. Borisov, who beats Danin at chess but loses to Savin, skis better than the engineer who is younger than him and goes to the theater more often than the engineer who is older than Kirillov. The agricultural engineer, who goes to the theater more often than the auto mechanic, but less often than the builder, is neither the youngest nor the oldest of the four. The builder, who skis worse than the radio engineer, usually loses to the auto mechanic in chess battles. The oldest of the engineers plays chess better than all of them and goes to the theater more often than all of them, and the youngest is the best skier. Name the profession of each of the engineers, if it is known that no two are alike in either sports or their commitment to the theater.

6. When developing expert systems, the participants of the control group received topics according to the options from the teacher. For example, an ES for assessing the technical condition of a dam, and an ES for choosing a job after graduating from university.

The participants of the experimental group were offered a direction and a topic for developing an ES. The agricultural engineers formulated the topic themselves. For example, an ES for processing input data of a breeding animal to conduct accurate diagnostics and support veterinary diagnosis for the Samarsky stud farm. Or, an ES for helping to choose a tractor on a farm using funds from the Agrostartup grant. Such a task was formulated because in practice the farmer bought a Belarus tractor, which caused interested agricultural engineers to want to verify the facts using AI.

The "Field Testing" stage. Students of the experimental group were also involved in a project implemented at the sites of the Russian State Agrarian University: "Artificial Intelligence Methods in Agricultural Engineering Problems". The project is supported by the AI laboratory, which develops and implements industry AI solutions based on the unique expert base of Timiryazev Academy. The goal of the project is to solve the problem of automating agricultural work to reduce manual labor costs and increase production efficiency. Participants identified the following values of the project: automation of agricultural work, reduction of labor costs, and increase in production efficiency. In other words, it is aimed at solving the problem of farmers associated with the need to perform labor-intensive operations manually, which reduces production efficiency and increases costs.

The product/solution will be a robotic complex that processes soil, sows, harvests, and performs other functions. The robot is controlled using special software that allows you to monitor its operation in real-time. The pattern recognition system determines which operations need to be performed on each section of the field. Currently, the product is at the specification stage. According to the plans of the project organizers, the finished product will receive all the necessary certificates by the country's legislation and international laws. The creation of the robot will not end there. Next comes the implementation and use.

The participants of the control group were not involved in the project. After studying the materials of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice", control testing was carried out again and the levels of development of the components that form the basis of the systems thinking of a student of an agricultural university were determined again.

High level – the agricultural engineer sees the final result of the implementation at the stage of information modeling (complex in data analysis and the formation of a concept for solving the problem). He carries out competent coordination of information resources from the field of agriculture. The student uses effective AI tools to search for and make quick decisions in difficult situations. The future specialist calculates faults without errors and understands their cause. He takes effective actions to eliminate faults to optimize the operation of the entire system and possibly other (similar in design and operation) systems.

Medium level – the agricultural engineer sees the final result of implementation at the stage of developing preliminary schemes and calculations (mathematical model). He coordinates information resources without significant errors. The student uses AI tools to search for and make quick decisions in complex situations but sometimes gets confused in assessing the effectiveness of the selected AI tool. The future specialist calculates faults without major errors and involves other colleagues to eliminate their cause. He takes actions to eliminate faults to optimize the operation of only the entire system. He does not predict the performance of other (similar) systems.

Low level – the agricultural engineer sees the final result of implementation only at the stage of development or testing. He coordinates information resources with significant errors when solving a problem in the agricultural industry. The student experiences significant difficulties using AI tools to search for and make decisions in complex situations. The future specialist only with the help of mentors calculates faults and takes actions to eliminate them to optimize the operation of the entire system. Often does not even understand the cause of the faults that have arisen, does not transfer the found methods for eliminating faults to the operation of other (similar) systems. Table 1 presents the results of the formation of systemic thinking of agricultural engineers before and after studying the materials of the discipline.

Table 1 The level of development of systemic thinking of agricultural engineers before and after studying the basics of AI in engineering practice

Level	Groups			
	Experimental (44 agricultural engineers)		Control (44 agricultural engineers)	
	Before the experiment	After the experiment	Before the experiment	After the experiment
High	6 (14%)	12 (27%)	6 (14%)	7 (16%)
Medium	18 (41%)	26 (59%)	19 (43%)	21 (48%)
Low	20 (45%)	6 (14%)	19 (43%)	16 (36%)

The accepted hypotheses are: H0: the level of systems thinking of the student in the experimental group is statistically equal to the level in the control group; H1: the level in the experimental group is higher than in the control group. For $\alpha = 0.05$, χ^2_{crit} is equal to 5.991. It is determined that $\chi^2_{obs.1} < \chi^2_{crit}$ (0.053 < 5.991), and $\chi^2_{obs.2} > \chi^2_{crit}$ (6.820> 5.991). Therefore, changes in the level of development of systems thinking of agricultural engineers are not random.

Let us analyze the dynamics of the levels of formation of the components that form the basis of systems thinking of a student of an agricultural university:

1. The number of agricultural engineers, whose level of systems thinking is defined as "high", in the experimental group increased by 13% (from 6 students of an agricultural university to 12). The dynamics in the control group for this level is 2% (1 agricultural engineer).

2. The number of students whose level of systems thinking is defined as "medium" increased by 5% in the control group. In the experimental group, the dynamics are more significant: 18%.

3. The number of students whose level of systems thinking is defined as "low" in each group has changed qualitatively. But in the control group, the number of participants with a "low" level decreased by 7%. In the experimental group – by 31%.

A comparison of the results shows that training agricultural engineers using the materials of the discipline "Fundamentals of Artificial Intelligence Systems in Engineering Practice" contributed to the development of their systems thinking by taking into account the key provisions of the research hypothesis.

DISCUSSION

The presented study is a variant of the development of UNESCO educational projects to introduce innovations from the field of AI to the agricultural sector [1]. In the future, they can potentially be used to train personnel capable of offering agro-engineering solutions in the fight against the global food crisis and social explosion. In other words, to contribute to the achievement of sustainable development goals. The authors' conclusions can also be used to improve the practice of breeding work, create automated and robotic devices, increase productivity, and minimize manual labor. That is, the authors' conclusions correspond to the key areas of joint activities of UNESCO and FAO [6]. The work takes into account the provisions adopted by Timiryazev Academy in 2023 within the framework of the Forum on the Ethics of Artificial Intelligence on the need to ensure security, increase the availability of information and computing resources for users, and improve the system of training specialized personnel. The study materials complement and develop the conclusions of E. V. Shchedrina, and O. N. Ivashova on the potential of services for generating text, images, spreadsheets, sound, and video for training agricultural engineers of the future [28]. The conclusions of K. Alford et al. on the fact that the development of systems thinking of agricultural engineers is an important educational task are taken into consideration [29]. And in solving this problem, according to L. Tarkhova et al., this study uses interactive educational content based on AI [9].

As areas for development and clarification of the results formulated in this work, we can propose:

- their testing for other areas of training. For example, 08.03.01 "Construction", profile "Digital technologies for examination of construction objects and real estate management";
- adding practical work of agricultural engineers with some software solutions developed under the auspices of the Foundation for Assistance to Innovations. For example, with an intelligent platform for recognizing plant diseases from images, capable of analyzing both agricultural and ornamental crops.

CONCLUSION

Thus, the results of the study allow us to assert that the study of the fundamentals of artificial intelligence in engineering practice by students of an agricultural university contributed to the development of their systems thinking due to the following factors: teaching based on the materials of the relevant discipline was based on the existing scientific and methodological potential of the agricultural university (accumulated experience, provisions of the Ethics Forum, the "Assistant. Animal Husbandry" model, expert bases of the AI Laboratory); information interaction in the experimental group took into account the specifics of training agricultural engineers; facts and data on real recent achievements in science and technology were used in the formulation of the system of tasks and topics of research projects.

The study describes the activities of agricultural engineers, carried out according to the following plan: "Introduction", "Immersion in the problematic", "Main work on the use of AI in engineering practice", "Systematization and consolidation", and "Field tests". The results of each previous stage were used by students when working on the next one. For example, data from the table on advanced discoveries in agricultural engineering were taken into account from the first stage when working with language data models, when developing a program in Prolog, and when designing an expert system. As features of information interaction that influence the development of systems thinking of agricultural engineers, we highlight the following:

- the knowledge received and acquired should be from the field of information technology, as well as economics, mechanics, hydraulics, electrical engineering, automation, descriptive geometry, and engineering physics;
- creating conditions for students to understand the social importance of the profession, develop a creative attitude to work, and master scientific and critical activity;
- ensuring free, equal, and unimpeded access to information and resources of the Russian State Agrarian University, compliance with the rules of ethics and safety in the field of AI;
- taking into account the results from previous stages of educational and cognitive activity in work on subsequent ones.

As difficulties in organizing students' information interaction in studying the basics of AI, contributing to the development of their systems thinking, we note: additional labor and time resources for modernization of discipline materials, coordination of resources of various university bases, different levels of professional interest of students and their involvement in work on agricultural engineering projects. The obtained results can be used to improve: the training of students of the agricultural university within the framework of systems development and implementation of industry AI projects created on the basis of Timiryazev Academy.

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