RedFame

Journal of Education and Training Studies
Vol. 14, No. 2; April 2026
ISSN 2324-805X E-ISSN 2324-8068
Published by Redfame Publishing
URL: http://jets.redfame.com

Use of Innovative Educational Technologies Based on Artificial Intelligence to Train Specialists in Higher Education Institutions for the Implementation of Sustainable Development Goals

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Received: December 18, 2025 Accepted: January 31, 2026 Online Published: February 12, 2026

doi:10.11114/jets.v14i2.8293 URL: https://doi.org/10.11114/jets.v14i2.8293

Abstract

In view of comprehensive access to information and the expansion of the impact of artificial intelligence (AI), there is a need for a deep rethinking of the role of higher education in achieving the sustainable development goals (SDGs) of humanity. The aim of the study is to determine the impact of innovative AI-based educational technologies on the development of key competencies for sustainable development in higher school students. The study employed empirical research methods. The content analysis using the MeetGeek tool revealed the teachers' key concerns related to the use of AI in educational activities. The survey assessed the impact of AI tools on the quality of the educational process and the development of key sustainability competencies. Case analysis contributed to the identification and systematization of effective pedagogical approaches. Statistical analysis provided comprehensive processing and interpretation of the obtained data. A total of 217 teachers of the humanities of higher education institutions (HEIs) of Ukraine participated in the survey. The results showed that AI-based educational technologies contribute to improving the quality of learning. The respondents highlighted the interactivity, flexibility, and practical orientation of learning using AI tools as key advantages of their integration into the educational process. Of them, 68.1% of teachers agreed that AI-assisted learning promotes the development of key sustainability competencies. Critical thinking (78.7%), Systems Thinking (75.5%), and the Integrated Problem-Solving (72.7%) are most affected. Anticipatory Thinking (69.1%), Strategic Thinking (66.4%), and Collaborative Ability (64.0%) are moderately affected. The student's value orientation (60.8%), self-awareness and reflexivity (57.5%) are least affected. The results of the study showed that AI-based educational practices should be organized using scientifically based methods of developing thinking and innovative pedagogical approaches. Special emphasis should be placed on the implementation of continuous problem-oriented project-based learning approaches that support the principles of sustainable development, ethical, socially oriented and critical thinking.

Keywords: sustainable development, technical learning, social change, artificial intelligence, sustainable competence, pedagogy methods

1. Introduction

1.1 Introduce the Problem

The concept of sustainable development determines the strategic direction of the evolution of human civilization and the formation of a model of managed global progress. Its effective implementation is a key prerequisite for the

preservation and progress of world civilization in the third millennium (Voronina et al., 2024). According to UNESCO recommendations (UNESCO, 2017), the integration of knowledge, values, and attitudes for ethical and responsible actions is a way to achieve the SDGs both on a national and global scale (Díaz-Torres & Díaz-Torres, 2025).

From a social perspective, education is a fundamental institution that performs a key function in the formation and development of the humanistic essence of man (Yuldashev, Khomiachenko &Yuldashev, 2022). The priority task of HEIs is to create the necessary conditions and circumstances for the development of students' professional qualities, skills, and abilities necessary for the creation of a qualitatively new social space. It is the educational system in which the comprehensive development of future specialists takes place with the use of innovative digital tools, with the implementation of effective pedagogical approaches and methods, which lays the foundation for the future development of regions, countries of the world, and the world space as a whole (Knysh et al., 2023). The priority is to reorient training programmes for specialists from today's issues to long-term planning and solving future challenges related to sustainable development. This requires the use of an integrated, interdisciplinary, and collective approach that flexibly operates with educational goals and methods of their implementation. Ensuring a comprehensive approach to the development of professional skills and sustainability competencies will contribute to the formation of a more equitable and innovative workforce, capable of using technology to achieve a positive social effect (Sejdiu & Sejdiu, 2025).

Rapid digital progress and the associated development of educational technologies have radically changed approaches to learning and teaching in higher school. Modern HEIs strive to provide training for highly qualified specialists with developed professional competencies who are in demand in the labour market, as the young generation Z requires non-standard approaches to organizing the educational process. One of the possible ways to achieve these goals is the digital transformation of the educational environment of a HEI, which is a platform for the development of modern methods and innovations (Henseruk et al., 2020). AI-based educational innovations strengthen the popularity and priority of personalized approaches to learning, and generative functions guarantee the adaptability of educational content to the requirements and capabilities of each student. Learning with the use of AI opens up expanded prospects in the field of sustainable development by forming innovative problem-solving skills and creating sustainable solutions for the future. As Filho, et al. (2025) stated, integration of AI-based digital tools in education for sustainable development develops students' skills and abilities to solve complex global problems with the help of innovative technologies. Bollaert (2025) emphasizes that the experience of using AI for educational purposes actualizes the importance of unique human transversal competencies. These include critical and analytical thinking, the ability to solve problems and make decisions, as well as creativity and empathy. However, the introduction of digital innovations into educational contexts requires fundamental changes in the development and implementation of the educational process. An important stage of these changes is the awareness of the opportunities and risks associated with the integration of technological innovations. Besides, it is important to justify the feasibility of using technologies, taking into account their effectiveness for the implementation of SDGs. The issue of developing optimal educational strategies for the coordinated and effective use of digital tools remains unresolved. Another important task is the search for pedagogical approaches aimed at developing key 21st-century competencies. In this regard, the aim of this study is to determine the role of innovative AI-based educational technologies in the development of key sustainability competencies in higher school students.

The aim of the study was achieved through the fulfilment of the following research objectives:

- Outline the prospects and risks of integrating AI into educational contexts;

- Determine the attitude of teachers of Ukrainian HEIs to the use of AI tools in educational activities;

- Determine the possibilities of AI in improving the quality of education based on the results of teachers' survey;

- Determine the impact of educational practices using AI tools on the development of key competencies of sustainable development.

The following hypotheses were advanced:

1. Learning using AI tools improves the quality of education.

2. The use of AI tools in the educational process contributes to the development of students' sustainability competencies.

3. The synergy of digital solutions, modern pedagogical approaches, and sustainable development narratives contributes to the development of students' thinking aimed at solving the 21st-century problems.

The scientific novelty of the study lies in establishing a conceptual connection between the functional capabilities of AI, modern teaching methods and sustainable development competencies. For the first time, the possibilities of using AI as a tool for the targeted development of competencies in the field of sustainable development have been substantiated. In

particular, the impact of the functional capabilities of AI on the development of systems thinking, predictive thinking, value orientation, strategic thinking, the ability to cooperate, critical thinking, self-awareness and reflexivity, and the ability to integrate problem solving have been investigated. Additional pedagogical methods for supporting the effectiveness of learning using AI have been identified. In particular, the impact of pedagogical methods on the formation of competencies in the field of sustainable development has been investigated.

1.2 Literature Review

Dynamic trends in testing and implementing AI tools in educational environments are accompanied by theoretical and practical discussions about the opportunities and risks of AI in achieving educational goals. Some researchers consider AI as a tool for increasing teaching efficiency and optimizing pedagogical activities. Others highlight the risks and threats of using AI in the educational process. In particular, Mallillin, et al. (2025) argue that the integration of AI into educational processes is accompanied by the development of innovative pedagogical methods, which leads to transformation and the formation of new trends in teaching. According to Haq (2025), AI technologies open up new opportunities for implementing quality learning through personalization, automation, analytical and generative functions. As McDonald, et al. (2025) argue, generative AI is a catalyst for changing assessment methods that acquire the properties of environmental friendliness and justice, legality, and ethics. According to Pachava, et al. (2025), AI systems contribute to the development of individual, adaptive curricula, strengthen the role of teachers as mentors. According to Kim (2025), AI tools cover a wide range of opportunities in the field of education. They provide effective analytics of educational data and mediation between users and educational resources. Such technologies also contribute to overcoming cognitive, linguistic and social barriers in the learning process. Indeed, AI is able to transform education, shift the focus of attention to the students and the effectiveness of their learning, change the teachers' role. Scientific researches highlights the potential of AI in improving the organization of the educational process, its optimization, and modernization. However, the issues of contextual integration of AI into educational processes for the development of key 21st century skills require more in-depth research.

Vieriu and Petrea (2025) argue that the key problems of integrating AI into education are data privacy risks and academic dishonesty. They also highlight over-reliance on AI in students and a decrease in critical thinking skills. According to Gerlich (2025), students' over-reliance on AI tools can negatively affect critical thinking skills. According to Zhu, Sun and Yang (2025), the integration of AI into education carries certain risks. These include the homogenization of student development and teaching, the crisis of the teaching profession, the alienation of the teacher-student relationship, deviation from educational goals, and academic misconduct. According to Bollaert (2025), the integration of AI into educational activities should be carefully planned and effectively organized, taking into account all risks and opportunities. It is important for AI users to realize that functionally AI-based systems are not adapted to promote effective learning. They are not able to be guided by advanced pedagogical practices, such as the implementation of active learning. There is also a limitation on the ability to build an effective system of cognitive load management and the formation of criteria and directions for professional growth. Analysis of scientific researches on the risks and opportunities of using AI in the educational process showed that scientists mostly study the impact of AI on the technological and organizational aspects of learning. The risk of AI's impact on critical thinking and the issue of homogenization of the educational process, which hinders the development of students' innovative abilities, are becoming more relevant. Therefore, additional researches is needed on approaches to integrating AI into pedagogical teaching methods to realize the implicit impact of educational initiatives on the development of students' critical and innovative thinking. So, both curricula and the teachers' functions need to be revised and adapted to the conditions of digital learning and learning supported by AI tools. In addition, there is an additional need to develop innovative learning concepts in which AI acts as an auxiliary tool that encourages students to engage in innovative search, critical and analytical thinking.

The issue of AI use related to the low level of digital competence of participants in the educational process was covered in the studies of Zou, et al. (2025), Vieriu, and Petrea (2025). As Zou et al. (2025) argue, digital learning supported by modern technologies such as AI virtual reality (VR) and collaborative platforms, has a significant impact on students. It significantly increases their motivation and success. However, there is a serious problem despite the fact that digital learning platforms make education more flexible, exciting, and personalized. It is the lack of teachers with the necessary digital experience and skills to work with digital tools. Many teachers lack technical skills and knowledge in the field of digital pedagogy. They also lack AI literacy to effectively conduct the educational process and achieve key educational goals. As Vieriu and Petrea (2025) argue, it is necessary to ensure comprehensive training of participants in the educational process for the effective integration of AI into education. The results of the study by Ebom-Jebose (2025) confirmed that the development of digital skills is critically important for achieving the goals of sustainable development. Their continuous improvement also contributes to reducing unemployment in the digital economy. As Jafarov (2025) argues, the formation of synergy between theoretical knowledge and practical skills in educational

contexts is crucial. This ensures the readiness of the workforce for the rapidly changing labour market. Scientific researches raises the issue of insufficient digital readiness of participants in the educational process to implement effective digital learning with AI tools. However, the issue of implementing managerial and organizational initiatives to integrate digital solutions into the educational environment is not sufficiently covered. There are no centralized, clear and effective mechanisms for implementing AI into the educational processes of higher education institutions. Therefore, the issue of organizing educational processes with AI tools, personnel, legal and material aspects of integrating digital solutions into pedagogical activities, both centrally and individually, require more thorough research.

The issues of ethics and conscious use of AI in pedagogy were considered in the studies of Woo and Cho (2025), Temper, et al. (2025). According to Woo and Cho (2025), educational interactions with AI should be implemented with the application of a critical attitude and ethical norms. As Temper, et al. (2025) noted, the targeted development of students' skills in the responsible and ethical use of AI is critically important for their future professional lives. At the same time, a risk-oriented approach to the use of AI increases awareness and a clear understanding that the consequences must be taken into account and cannot be ignored. Despite the current awareness of ethical issues related to the use of AI, scientific research has not sufficiently addressed the ethical aspects of the contextual integration of AI into educational and pedagogical activities. The latent impact of AI on students' cognitive development and value orientation also requires detailed research.

So, modern AI tools are integrated into the higher education system, creating new models of management and organization of the educational process, modernizing pedagogical approaches and teaching methods. According to Aguado-Garcı et al. (2025), the use of AI in education is at an early stage of development. Despite its potential, it can optimize the management and organizational aspects of educational activities. AI is also capable of improving the quality of teaching and learning. According to Zou et al. (2025), there is a significant gap between the theoretical advantages of digital integration and the practical realities that participants in the educational process encounter when interacting with AI tools. Therefore, the practical aspects of interaction with educational AI tools require further research. In addition, the analysis of academic research revealed the relevance of issues of ethics, sustainable development, and conscious use of AI. However, approaches to integrating the principles of sustainable development into educational practices are not sufficiently covered. The issue of competence development and integration of pedagogical methods and approaches into the context of digital education also requires more thorough research. In addition, the conceptual connection between AI functionality, pedagogical approaches, and competencies in the field of sustainable development is not sufficiently elucidated in scientific research. The methodology for forming modern competencies for sustainable development in the conditions of an AI educational environment requires more detailed research.

2. Method

2.1 Research Design

The research was conducted as part of the training course Digital AI Literacy towards Sustainable Development, which lasted three months — from August to November 2025. The course was organized and moderated by 4 teachers from the Department of Pedagogy and Methods of Primary and Preschool Education at the Faculty of Pedagogy and Psychology, Ternopil Volodymyr Hnatyuk National Pedagogical University. The training was aimed at developing skills for effective interaction with technologies and integrating them into the educational process. The training of teachers was conducted on practical cases thematically aimed at solving sustainable development problems. Interaction with a number of digital tools based on AI was organized during the training process, in particular:

1. Tools for learning and content creation (ChatGPT, Claude, Gemini, Canva Magic Write, Adobe Firefly, Runway ML).

2. Tools for assessment and testing (Quizlet AI, Kahoot! AI, ClassPoint AI, Socrative, Edpuzzle AI, Formative).

3. Distance learning platforms (Moodle with AI modules, OpenAI API integration)

4. Tools for academic and pedagogical research (Scite.ai, Semantic Scholar AI, Research Rabbit, Notion AI, ChatDOC, Perplexity AI)

The research design involved the implementation of four stages, each having a clearly defined goal and objective, which allowed for consistency and depth of analysis. The first stage of the study was implemented before the start of the training course (August 2025), the second, third and fourth — after the completion of the training (October 2025). The training was conducted online on the Prometheus platform. The group discussion was conducted on the Zoom platform, the data was processed using a content analysis tool, which made it possible to identify key statements for further assessment by the respondents. The research procedure is presented in Figure 1.

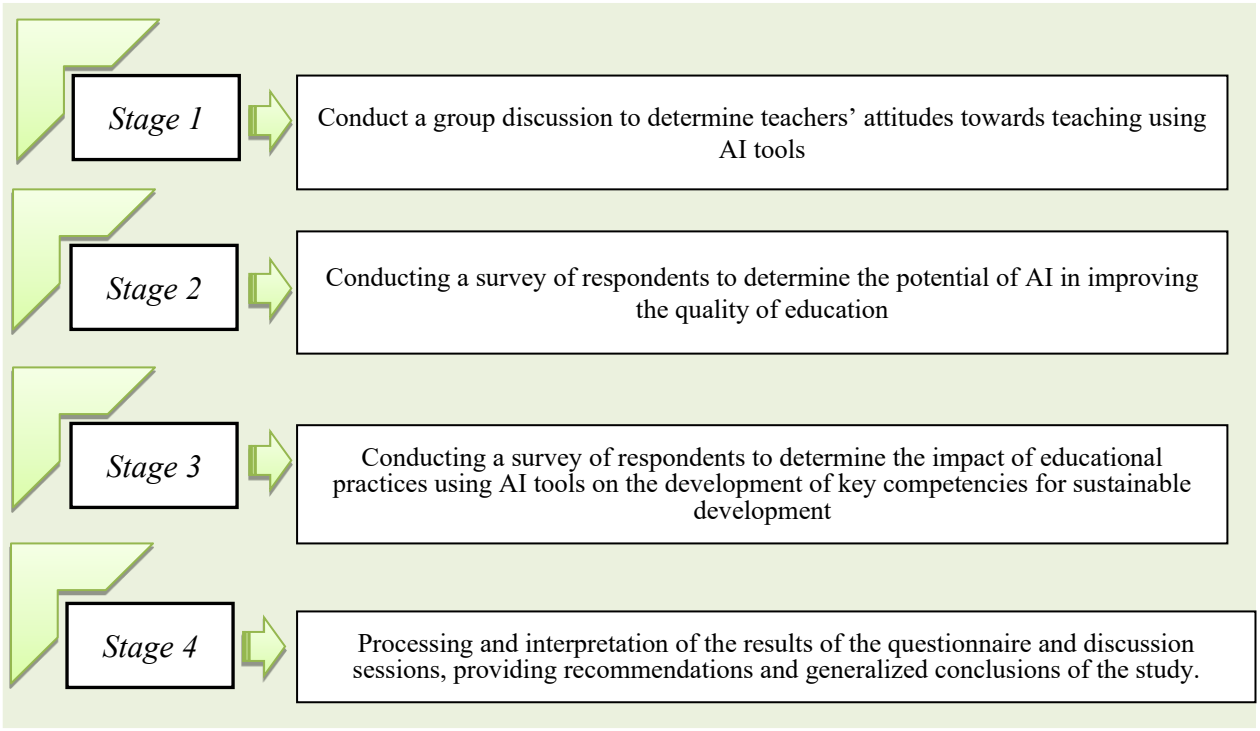


Figure 1. Research design

Source: developed by the authors

2.2 Research Sample

The study involved 217 educators from Ukrainian higher education institutions. The sample included teachers of humanities specialties - philologists, psychologists, sociologists and teachers of pedagogical disciplines (Table 1). The study was conducted in compliance with ethical principles, in particular voluntary participation, informed consent, and anonymity of respondents. The inclusion criterion in the study was training in the course Digital AI Literacy towards Sustainable Development.

Table 1. Research sample

Number of respondents (persons)	HEIs	Teaching experience
27	Kyiv National University of Trade and Economics (Kyiv)	3-12 years
12	State University of Information and Communication Technologies (Kyiv)	5-17 years
7	Sigmund Freud University Ukraine (Kyiv)	3-9 years
24	Drohobych Ivan Franko State Pedagogical University (Drohobych)	2-12 years
17	Lviv Polytechnic National University (Lviv)	3-19 years
15	Lviv State University of Life Safety (Lviv)	3-8 years
29	Kamianets-Podilskyi Ivan Ohiienko National University (Kamianets-Podilskyi)	2-11 years
26	Khmelnytskyi National University	3-13 years
13	Augustyn Voloshyn Carpathian University (Uzhzhorod)	4-16 years
17	Yurii Fedkovych Chernivtsi National University (Chernivtsi)	3-17 years
14	T.H. Shevchenko National University "Chernihiv Collegium" (Chernihiv)	4-8 years
16	West Ukrainian National University	3-18 years
Total respondents: 217 people		Average teaching experience: 2-19 years

Source: developed by the authors

When studying the impact of AI on the development of key sustainability competencies, 8 competencies presented by UNESCO (2017) were analysed. These include: systems and anticipatory thinking, value orientation, strategic thinking and the collaborative ability, critical thinking, self-awareness, and reflexivity, as well as the integrated problem-solving.

2.3 Methods

The study employed the following empirical methods:

- A survey was used to determine the impact of AI tools on improving the quality of learning, as well as the impact of AI training on the development of key sustainability competencies. The survey of study participants was conducted online using the Google Forms service. The assessment was carried out using a 5-point Likert scale.

The reliability of the questionnaires was checked using the Cronbach's alpha coefficient, which showed high internal consistency of its parts. The values were 0.85 for Determining the Potential of AI in Improving the Quality of Education and 0.83 for Determining the Impact of Training using AI Tools on the Development of Key Sustainability competencies (Table 2). The construct validity of the survey was ensured by the correspondence of its questions to the theoretically defined components of competencies and was confirmed by expert assessment and pilot testing on a target group of participants.

Table 2. Results of the reliability of the questionnaires using the Cronbach's alpha coefficient

Questionnaire	Number of items	Cronbach's alpha coefficient (α)	Reliability level
Determining the potential of AI in improving the quality of education	10	0.85	Good reliability
Determining the impact of learning using AI tools on the development of key sustainability competencies	8	0.83	Good reliability
Overall reliability of questionnaires	18	0.84	Good reliability

Source: developed by the authors

- The content analysis using the MeetGeek tool revealed the key teachers' concerns related to the use of AI in educational activities. The first survey involved respondents' assessment of statements regarding the risks of AI in education. Respondents selected from 11 statements those that most fully reflected their concerns regarding the use of AI in education. The second survey was aimed at assessing the impact of AI-based educational tools on the quality of learning. The questionnaire consisted of 10 statements. The third survey was conducted to assess the impact of training using AI tools on the training sustainability competencies. The questionnaire included 8 competences for impact assessment. The questionnaires underwent statistical testing, which showed that the results of the survey can be considered reliable and reproducible. The study used the factor-correlation modeling method, which combined structural analysis, the expert assessment method, and Pearson correlation analysis to identify the strength and direction of the relationships between pedagogical methods and sustainable development competencies.

- Case study and statistical analysis were used to identify and arrange effective pedagogical approaches, and also provided comprehensive processing and interpretation of the obtained data using SPSS software.

3. Results

The first stage of the study was to determine the teachers' attitudes towards teaching using AI tools. The group discussion revealed the key teachers' concerns related to the use of AI in education. The results of teachers' assessment of the risks of using AI in education are presented in Table 3.

Table 3. Main teachers' concerns related to the use of AI in education

Pedagogical risks associated with the use of AI	The threat is significant and has a real impact on the educational process
Undermining the concept of anthropocentric education, in which the goal of education is not only to transfer knowledge, but also to ensure the comprehensive development of the student's personality	76%
Levelling the creative, empathetic, and ethical aspects of education in the digital educational environment	84%
Exclusion of teachers from the decision-making process, levelling the importance of the teacher's professional experience in assessing the quality of student training	81%
Reducing the importance of the teacher's personal interaction as a source of knowledge with students, the value of their creative pedagogical approaches in building the students' competence	89%
Excessive students' dependence on the cognitive functions of AI systems when performing educational tasks leads to a decrease in the level of intellectual load and independent mental activity	94%
Excessive dependence on AI inhibits the development of students' thinking and makes learning superficial	91%
Blurring the boundaries between conscious learning and algorithmic assistance, which calls into question the effectiveness of learning and levels the value of academic performance	93%
Difficulty in achieving the principle of inclusiveness, which ensures that all participants in the academic community receive the support and resources necessary for teaching and learning in a digital environment	95%
Concerns about the confidentiality and security of student and teacher data. The need for significant investments in a secure and safe infrastructure	96%
Difficulty in achieving the necessary development of digital and AI skills among all participants in the educational process, without which digital learning generates imbalance, and inequality of opportunities	91%
Ensuring the integrity and comprehensiveness of educational programmes is a difficult task, as the development of AI systems for their effective integration requires significant managerial and organizational resources	86%
Lack of designed systematicity, strategic planning and scientifically sound strategies for implementing AI in the system of training higher school students	96%

Source: developed by the authors

So, the key concerns of educators were related to the change in traditional teaching methods, the quality of training of specialists in the digital environment, the lack of experience in interacting with AI systems, confidentiality and ethical issues, as well as organizational and technical difficulties. The training course completion was followed by a survey. The teachers assessed the potential of AI in improving the quality of education. The results of the survey are presented in Figure 2.

The results of the post-course survey showed a fairly high level of confidence among teachers in the potential of AI to improve the quality of education. Most respondents rated its impact as noticeable or significant, but not decisive. On average, more than 70% of respondents believed that the use of AI contributes to improving the quality of education by improving educational practices and increasing teaching efficiency.

The highest positive impact was recorded in the segment of AI capabilities to ensure flexibility and dynamism of the educational process (74% noted a noticeable impact, 17% - strong). The respondents also rated the segment of AI capabilities in implementing applied interactive learning experiences in authentic environments and AI-simulated realistic learning scenarios with high scores (70% and 18%). According to respondents, automation, optimization and standardization of administrative tasks contribute to high-quality learning (68% and 17%). High scores were received by the segment of AI capabilities related to ensuring the continuity of education and learning throughout life (68% noticeable, 13% strong impact). A high positive effect was also noted in the segment of knowledge assessment. According to respondents, increasing transparency and objectivity iassessing educational achievements using data analytics can improve its quality (61% of respondents noted a noticeable impact and 21% - strong). High scores were also given to the possibilities of personalizing learning and adapting it to the individual students' needs (65% and 12%). According to 16%, AI has a strong impact on the realization of independent students' learning in the digital environment by providing individual curricula and recommendations adapted to the users' wishes and requests. Lower scores were recorded in the areas of: overcoming language barriers (49% noticeable, 9% strong impact) and educational barriers for students with disabilities (47% and 8%). Relatively low scores were given to the area of democratization of education (56% and 11%).

In general, the respondents indicated interactivity, flexibility, and practical orientation of learning using AI tools as the main advantages of their integration into the educational process and determining factors of quality assurance. However, there was no general agreement among teachers that AI capabilities are decisive for improving the quality of learning.

At the next stage of the study, the impact of AI training on the development of key students' sustainability competencies was studied. Such competencies as systemic and anticipatory thinking, value orientation, strategic and critical thinking, ability to cooperate, self-awareness, and reflexivity were assessed. The results of the questionnaire are presented in Table 4 and Figure 3.

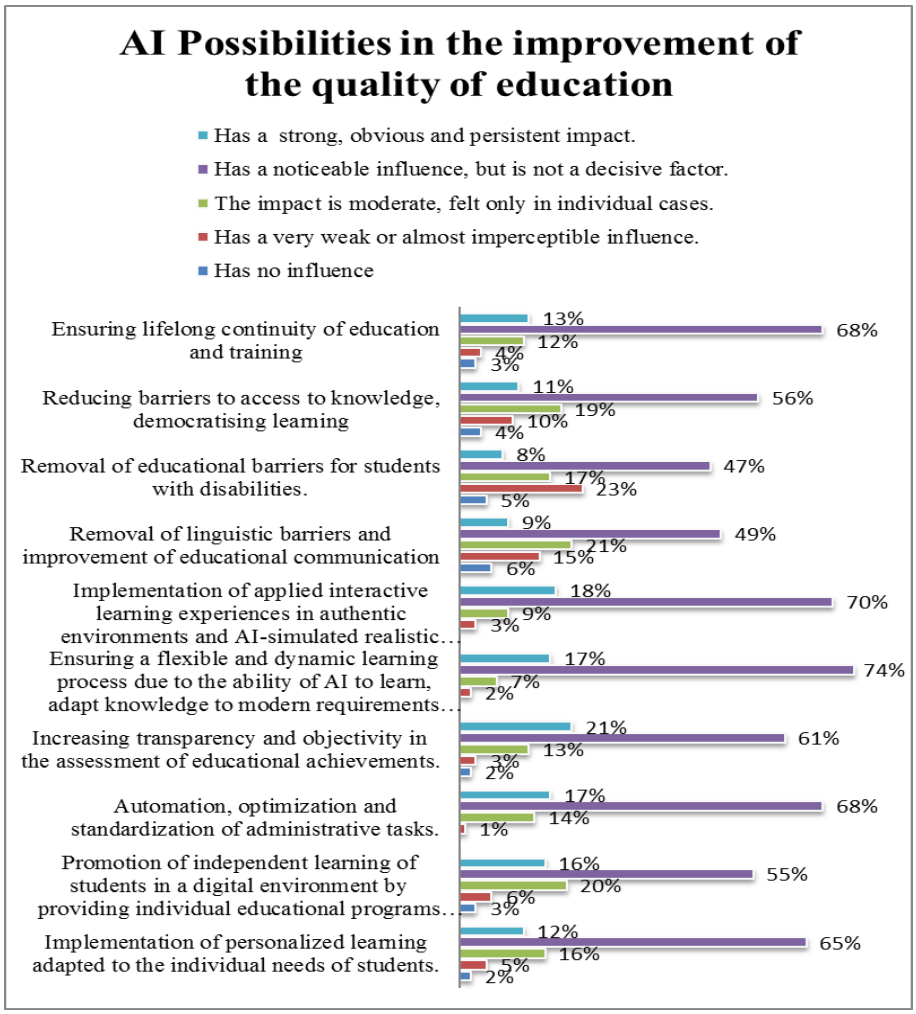


Figure 2. AI's potential to improve the quality of education

Source: developed by the authors

Table 4. Results of the assessment of the impact of AI on the development of key sustainability competencies

Competence	Scale (n=217) (number of respondents / % of total number) 1 No impact	2 Minor impact	3 Partial impact	4 Noticeable but limited impact	5 Pronounced and persistent impact
	(number of respondents / % of total number)				
Systems Thinking	3.2%	4.6%	6.9%	9.7%	75.5%
Anticipatory Thinking	5.1%	8.3%	7.4%	10.1%	69.1%
Value Orientation	11.1%	13.4%	8.8%	6.0%	60.8%
Strategic Thinking	7.4%	8.3%	10.1%	7.8%	66.4%
Collaborative Ability	8.3%	10.6%	9.7%	7.4%	64.0%
Critical Thinking	2.3%	4.2%	5.1%	9.7%	78.7%
Self-Awareness and Reflexivity	13.4%	12.4%	10.6%	6.5%	57.2%
Integrated Problem-Solving	3.7%	6.9%	8.8%	7.8%	72.7%
Average	6.8%	8.6%	8.4%	8.1%	68.1%

Source: developed by the authors

The results of the survey of teachers showed that targeted teaching practices using AI tools can have a qualitative impact on the preparation of higher school students for achieving the SDGs. In general, 68.1% of respondents agreed that teaching with AI has a pronounced and sustainable impact on the development of key sustainability competencies. Another 8.1% of respondents believed that the impact was noticeable but limited, while 8.4% of teachers noted that the impact was partial. The rest 8.6% assessed it as insignificant, and 6.8% 8.4% of the surveyed teachers indicated that there was no impact.

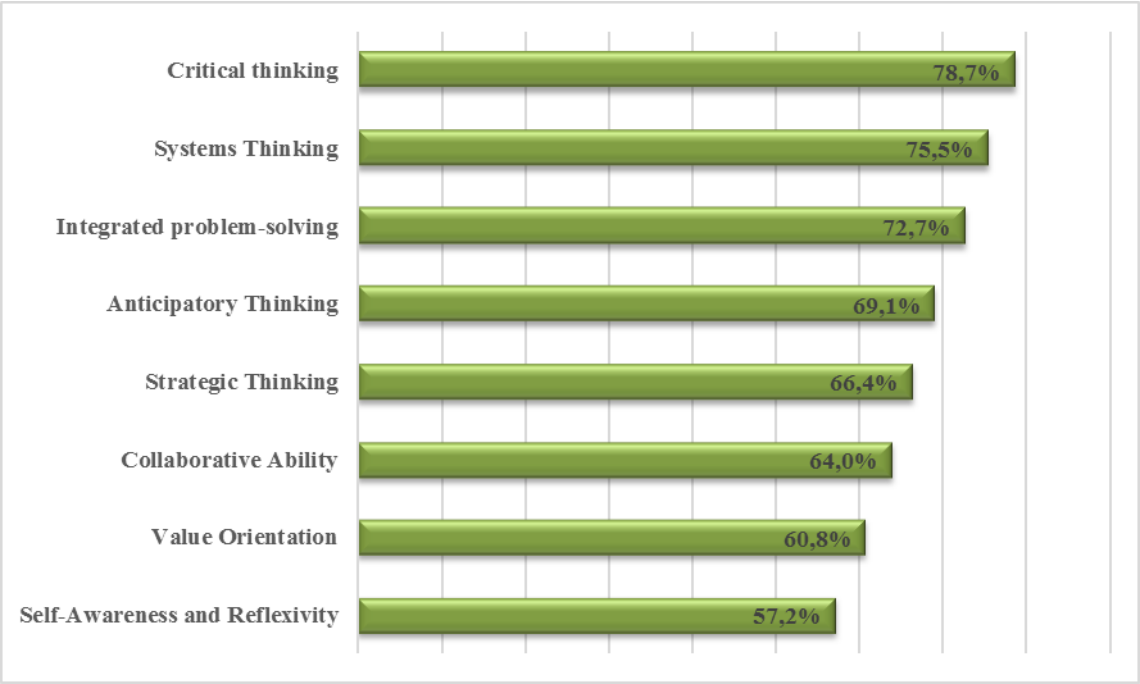


Figure 3. The impact of training using AI tools on the development of key sustainability competencies

Source: developed by the authors

According to the teachers, critical thinking is most affected (78.7%), as AI capabilities stimulate students to analyse, compare, and evaluate information generated by AI systems and chatbots. A total of 75.5% of respondents agreed that learning with AI tools contributes to the development of systems thinking. In general, 72.7% of respondents confirmed that learning with AI develops the ability to integrated problem-solving. According to 69.1% of respondents, educational practices with AI tools contribute to the development of anticipatory thinking. 66.4% of respondents agreed that learning with AI contributes to the development of strategic thinking. According to 64.0% of respondents, learning with AI tools contributes to the development of collaboration ability. According to 60.8% of respondents, learning supported by AI tools has the potential to form students' value orientation. 57.5% of respondents agreed that AI-supported learning promotes self-awareness and reflexivity.

However, the respondents noted that building of sustainability competencies requires the use of additional pedagogical methods. Teachers ranked the problem-based learning method, the project method, the "live case" method, and critical discussions as priority methods (Table 5).

Table 5. Correlation between additional learning methods and sustainable development competencies

Teaching methods	Sustainability competencies							
	Critical Thinking	Systems Thinking	Integrated Problem-Solving	Anticipatory Thinking	Strategic Thinking	Collaborative Ability	Value Orientation	Self-Awareness and Reflexivity
Problem-based learning method	0.62	0.58	0.47	0.63	0.70	0.42	0.45	0.10
Project-based learning method	0.55	0.64	0.50	0.52	0.67	0.39	0.43	0.11
Critical discussion method	0.60	0.09	0.45	0.08	0.62	0.48	0.54	0.37
Practical learning method through case analysis	0.52	0.50	0.49	0.53	0.66	0.44	0.46	0.12
"Live cases" method	0.69	0.72	0.64	0.70	0.76	0.57	0.59	0.44
Method of experimental hypothesis testing	0.34	0.07	0.06	0.05	0.08	0.06	0.37	0.07
Method of "error analysis"	0.42	0.08	0.07	0.45	0.09	0.06	0.48	0.40
Interdisciplinary learning method	0.07	0.43	0.46	0.06	0.08	0.05	0.44	0.06
Method of scenario modelling	0.06	0.47	0.49	0.52	0.50	0.08	0.07	0.06
Method of modelling and simulation	0.07	0.45	0.48	0.50	0.47	0.07	0.06	0.05
Method of systems analysis	0.06	0.40	0.08	0.46	0.44	0.06	0.05	0.05
Method of system modelling and visualization	0.05	0.42	0.07	0.48	0.45	0.06	0.05	0.06
Method of solution design	0.06	0.07	0.44	0.47	0.49	0.08	0.07	0.42
Method of trend analysis and forecasting	0.05	0.06	0.06	0.39	0.42	0.06	0.05	0.06
Method of future design	0.06	0.07	0.06	0.43	0.46	0.07	0.06	0.40
Method of role-playing forecasting	0.05	0.06	0.05	0.37	0.40	0.05	0.05	0.06
Method of business role-playing games	0.06	0.07	0.08	0.09	0.45	0.52	0.58	0.49
Method of strategic analysis	0.05	0.06	0.05	0.07	0.34	0.06	0.05	0.06
Method of collaborative learning	0.06	0.07	0.08	0.09	0.10	0.49	0.53	0.47
Method of "peer learning"	0.06	0.07	0.08	0.10	0.09	0.47	0.55	0.45
Method of coaching and mentoring	0.05	0.05	0.06	0.06	0.07	0.06	0.32	0.06

Source: developed by the authors

The results of the survey confirmed that an effectively organized educational process and practical use of AI tools by students in education contribute to building of sustainability competencies. However, it is necessary to create learning conditions using effective pedagogical approaches. In this regard, it is appropriate to provide the following recommendations:

1. Application of a problem-oriented project teaching method.

2. Inclusion of the method of practice-oriented learning through case analysis.

3. Integration of systems analysis, modelling and simulation methods into educational contexts.

4. Use of live Case Studies with an emphasis on strategy, analytical, and predictive methods.

5. Inclusion of the strategic analysis method for working on sustainable development projects.

6. Implementation of the collaborative learning method aimed at group work on projects, joint task solving, and mutual learning of students from each other.

7. Organization of discussions, discussion circles, and round tables on sustainable development issues.

8. Organization of project work with social significance aimed at developing sustainable solutions, integrating ethical values and norms.

4. Discussion

The realization of the potential of AI in education is functionally closely related to the creation of a more effective, inclusive and sustainable educational environment. The study by Ferk Savec and Jedrinović (2025) analysed the transformative potential of AI in higher education to achieve the SDGs. An example was the integration of AI into 26

courses at the University of Ljubljana (Slovenia). The results of the study showed that AI has the potential to transform education into a priority for sustainable development. This transformation is based on the concept of a double transition, the essence of which is that digital transformation is the basis of sustainable development, offering a strategic path for education systems. The results of the study by Alshamsi et al. (2024) showed that the opportunities and risks associated with the integration of AI in education do not have a direct impact on progress in achieving the SDGs. At the same time, new approaches to assessing learning outcomes, changing the educational paradigm, and using generative AI technologies are making a significant contribution to this process. In a study by Nikolopoulou (2025), the potential of generative AI (ChatGPT) in promoting sustainable development was studied. The results showed that the integration of generative AI into higher education qualitatively contributes to progress in the field of sustainable development. The opportunities included improving educational practices, optimizing resource use, supporting inclusive and accessible education, as well as increasing environmental awareness and sustainability. The results of our study demonstrated a fairly high level of teachers' trust in the ability of AI to improve the quality of education. Most respondents assessed its impact as noticeable or significant, but not decisive. This partially confirms Hypothesis 1 that teaching using AI tools improves the quality of education. Teachers who participated in the study identified the most valuable functions of educational AI technologies in improving the quality of education. The possibilities of AI to ensure flexibility and dynamism of the educational process ranked first. The possibility of AI in implementing applied interactive learning experiences in authentic environments and AI-simulated realistic learning scenarios ranked second. Automation, optimization and standardization of administrative tasks, as well as promotion of lifelong learning ranked third. Implementation of applied learning using AI tools will enable forming a qualified workforce with the necessary skills to implement the SDGs. On average, more than 70% of respondents believed that the use of AI contributes to improving the quality of education by improving educational practices and increasing teaching efficiency.

Sustainability competence can be viewed as an integrated system of knowledge and skills focused on proactive action towards sustainable development. As researchers Dias and da Silva Onevetch (2022) argue, the development of competences should be shaped by integrated, interdisciplinary, and comprehensive educational approaches. The results of the study by Kayaalp et al. (2024) showed that the integration of AI into sustainable development courses contributes to the effective acquisition of key principles of the concept and increases awareness of sustainability issues. The results of the study by Hariyani et al. (2025) confirm that digital technologies contribute to the achievement of SDGs by offering innovative solutions to global problems. The results of our study showed that the synergy of AI capabilities, innovations in pedagogy and sustainability narratives creates an educational environment that is stimulating for learning. Practical application of knowledge, critical evaluation, forecasting, modelling, strategic planning, active interaction – all of this contributes to learning with high purposefulness and effectiveness. This confirms Hypothesis 2 that the use of AI tools in the educational process contributes to building students' sustainability competencies.

Practical application of knowledge, critical assessment, forecasting, modelling, strategic planning, active interaction – all this contributes to learning with high purposefulness and effectiveness. This confirms Hypothesis 2 that the use of AI tools in the educational process contributes to the development of students' sustainability competencies.

The formation of a priority in finding a balance between technological progress, economic development, environmental protection and ensuring social justice contributes to strengthening the sustainable development paradigm. The importance of implementing sustainable development principles in curricula was emphasized in the studies of Gregori-Giralt et al. (2025), Díaz-Torres et al. (2025). The study of Gregori-Giralt et al. (2025) emphasized the importance of rethinking and reorganizing curricula in accordance with the digital transformation challenges. The need for the gradual introduction of sustainable development narratives and principles into educational contexts was also emphasized. The study by Díaz-Torres et al. (2025) demonstrated how the integration of digital technologies under ethical conditions can strengthen digital, social and environmental literacy. Educational practices influenced by AI ethics can reorient higher education towards SDGs, socially inclusive, and technologically relevant learning. The results of our study confirmed Hypothesis 3, which states that the synergy of digital solutions, modern pedagogical approaches and sustainable development narratives has a positive effect. It contributes to the development of students' thinking aimed at solving the 21st-century problems. According to the authors of this study, the use of AI tools should be integrated into practical learning.

4.1 Limitations

The main limitations of the study are territorial and time factors. The study was conducted over a period of 3 months, and the sample included representatives of only Ukrainian HEIs. The involvement of only teachers of the humanities and the absence of a control group lead to certain limitations in the reliability and representativeness of the results.

5. Conclusions

Creating conditions for training highly professional innovative and thinking specialists, focused on SDGs, capable of

ensuring economic, social and environmental progress in the future, is the goal of higher education. The respondents confirmed that targeted educational practices using AI tools can have a qualitative impact on the development of key sustainability competencies in higher school students. A total of 68.1% of respondents agreed that learning with AI affects the development of key sustainability competencies. High affectivity was assigned to critical thinking (78.7%), systems thinking (75.5%), and integrated problem-solving (72.7%). Low – to students' value orientation (60.8%), self-awareness, and reflexivity (57.5%). It was determined that the use of educational tools based on AI in education should occur in a combination of technological, ethical and socio-emotional development of students. Training should be adjusted in accordance with the recommendations of ethics and safety, and the principles of sustainable development should form the thematic focus of educational interactions. The results of the study may be of interest to scientists who study the issues of digital transformation of education, as well as teachers and developers of digital educational programs. They will be useful for representatives of organizations and initiatives that promote the principles of sustainable development at the national and international levels. The results of the study can be applied in the development of educational programs with the integration of artificial intelligence tools. In addition, they can serve as the basis for the formation of programs for the development of competencies in the field of sustainable development for students of higher education institutions. Further research prospects involve studying the impact of AI on the development of sustainability competencies as part of empirical research with the involvement of students of European HEIs.

Acknowledgments

The authors did not receive any funding during conducting the research.

Authors contributions

Not applicable.

Funding

Not applicable.

Competing interests

Not applicable.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Redfame Publishing.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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