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Application of Artificial Intelligence in Ukrainian Education of the Future

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Abstract: **Aim:** The purpose of this study is to determine the most appropriate list of digital tools based on the use of artificial intelligence to improve the educational sector in Ukraine. **Methods:** The study included the following stages: compiling a list of expert organisations with assessments of the impact of AI technologies on education; evaluating AI solutions by experts and forming individual ratings; calculating relative ratings based on the frequency of mentions of AI solutions; identifying priority AI solutions by their leading positions; forming an optimal nomenclature of AI solutions; developing practical recommendations for the introduction of AI in education; analysing the future development of education using AI. **Results:** The study found that the use of AI to modernise the Ukrainian education system is best done using a comprehensive three-tier deployment system. The first level involves creating an infrastructure for AI, ensuring the interaction of systems. The second level involves optimising and enhancing learning. The third level is aimed at automating and improving educational and support processes. The proposed practical recommendations address the ethical, technical, and pedagogical aspects of AI implementation, allowing for the creation of a modern, efficient educational system that meets the requirements of the present and forms competent specialists of the future. **Discussion:** The research findings are crucial for modern education in Ukraine. The study identified opportunities and benefits of using AI in education, such as individualised learning, improved communication, and process automation. Recommendations for optimal artificial intelligence solutions will allow for a balanced approach to the implementation of these technologies, avoiding negative consequences and ensuring safety. These results provide a basis for the development of national standards for the use of AI in education and determine the vectors of further development of the industry, contributing to the creation of a modern, individualised and effective educational system that trains competent specialists of the future. Overall, the research findings define a strategic course for the integration of artificial intelligence into the educational space, which can significantly improve the quality and accessibility of education in Ukraine.

Keywords: Machine Learning, Natural Language Processing, AI-powered Virtual Assistants, AI-driven Education Ecosystem, E-learning, EdTech, Virtual & Augmented Reality, Cloud Technology, Intelligent Tutoring System, Smart Content

Introduction

Artificial Intelligence (AI) in the context of education represents a collection of computer technologies and programs designed to enhance learning and the learning environment. These technologies encompass systems for intelligent data analysis, virtual assistants, adaptive learning platforms, and other innovative tools. The use of AI in education is one of the most promising and relevant areas of research. Education is the basis of social development, and in the context of rapid technological progress, it is important to determine how artificial intelligence can affect the educational process and what benefits it can have for the future of Ukrainian education (Filgueiras, 2023; García-Peñalvo, 2023; Udvaros & Forman, 2023).

Individualised learning is one of the key advantages of using AI in education. Each student has their own personal characteristics, pace of perception, and assimilation of information. Artificial intelligence systems can analyse data on completed tasks, reactions to new material, and other parameters, which can help them customise the learning process for each individual student. This will help to achieve greater learning efficiency and increase the level of knowledge acquisition (Fuhrmann & Niemetz, 2023; Lamb et al., 2023; Malek et al., 2023).

However, along with the benefits of using AI in education, there are also ethical issues. It is important to consider the aspects of privacy and protection of students' personal data. The security and

transparency of algorithms used in AI-based educational systems need to be carefully studied and fully regulated (Masters, 2023; Nguyen et al., 2023; Uunona & Goosen, 2023).

In addition, it is important to keep in mind that the introduction of AI should not be limited to the automation of educational processes. Teachers have an integral role in the development and education of students, and their functions may be expanded by the use of new technologies. It is important to prepare the teaching staff to work with AI and develop methodological approaches that will help to effectively use these technologies in the educational process (Celik, 2023; Chiu et al., 2023; Park, 2023).

It should also be borne in mind that the introduction of AI in education should be based on research and evidence-based practice. It is important to design and implement AI systems based on mostly positive experiences, and to constantly evaluate their effectiveness and impact on the quality of learning (Dogan et al., 2023; Holmes et al., 2023; Nemorin et al., 2023).

Thus, the use of artificial intelligence in Ukrainian education of the future is a complex and multifaceted task that requires in-depth research, careful analysis of the impact, and careful consideration of ethical, pedagogical, and socio-cultural aspects.

Research Problem

The problem under study is to determine the optimal directions and opportunities for the use of AI in the future of Ukrainian education. Given the accelerated development of information technologies, there is a need to explore the possibilities of using AI to optimise educational processes, improve the quality of education and train competent specialists (Alqahtani et al., 2023; Chen et al., 2023; Karyy et al., 2023).

The central scientific problem is to develop strategies and methods for introducing AI into the educational space of Ukraine, taking into account the peculiarities of the national educational system and the requirements of modern society. The implementation of this task requires a deep analysis of AI capabilities, study of implementation experience in similar contexts, and development of conceptual frameworks that will achieve optimal results (Al-Worafi et al., 2023; Bilanych & Bokotey, 2013; Crompton & Burke, 2023; Teng et al., 2023).

However, along with the potential benefits of using AI in education, ethical issues arise. The problem of preserving the confidentiality and security of the personal data of participants in the educational process, as well as the exclusion of algorithmic bias in AI systems, requires careful consideration and development of appropriate regulatory mechanisms (Flores-Vivar & García-Peñalvo, 2023; Kassymova et al., 2023; Kooli, 2023).

However, it is important to note that the introduction of AI involves more than simple automation of educational processes. It involves developing new methodologies, adapting learning content to the needs of the modern labour market, and studying the impact of these changes on the role of the teacher and the student (Decuyper et al., 2023; Huang et al., 2023b; Järvelä et al., 2023).

Thus, the problem of applying artificial intelligence in Ukrainian education of the future requires in-depth research and a comprehensive approach to develop effective implementation models, taking into account ethical, technical, and pedagogical aspects.

Research Focus

The central focus of the study is to identify the best ways and opportunities to use AI in the future of Ukrainian education. Given the rapid development of technologies and their impact on modern

education, the study focuses on analysing and identifying specific methods, strategies and approaches to integrating AI into the educational process. An important aspect is the study of the possibilities of providing quality training for students based on the use of modern AI technologies.

The main focus of this study is to develop an optimal strategy for the implementation of AI technologies in the educational system of Ukraine. The key aspect of the study is the systematic analysis and identification of existing opportunities for the introduction of AI in the context of the educational process, as well as the development of specific recommendations that will help optimise teaching practices and improve the quality of education.

The study also focuses on an in-depth analysis of the peculiarities of the national educational system of Ukraine, namely the identification of key aspects that can be improved or optimised through the use of AI technologies. At the same time, great attention is paid to the adaptation of innovative methods to the specifics of the national educational paradigm.

Research Aim and Research Questions

The purpose of the study is to establish the optimal nomenclature of digital software tools based on the use of AI in order to modernise the educational sector of Ukraine.

Research question:

1. Establishing up-to-date facts about the benefits and risks of using AI in education, which will allow to identify key drivers and vectors of development of the system of digital adaptation of the education system.
2. Formation of a sample of the expert community, which will allow to establish the practical plane and subject area of AI in education.
3. Identification of the nomenclature of digital tools based on the use of AI, the potential of which allows to modernise the educational sector of Ukraine.
4. To determine the optimal composition of AI transformation tools for the education sector with the development of appropriate practical recommendations for the implementation of AI tools in the Ukrainian education system.
5. To formulate analytical conclusions about the promising points of development of education in Ukraine in the future, provided that the latest digital software and technologies are used, which will summarise the main results of the study and identify prospects for the future development of the education sector.

Research Methodology

General Background

The global AI in education market, which was valued at USD 1.82 billion in 2021, is projected to grow at a CAGR of 36.0% from 2022 to 2030. Factors contributing to this growth include increased investment in artificial intelligence and EdTech from both the private and public sectors, as well as the growing popularity of Edutainment. In 2020, according to a report by the Organisation for Economic Co-operation and Development (OECD), venture capitalists invested more than USD 75 billion in companies specialising in the development of AI startups (Grand View Research, 2021).

These indicators indicate that the level of AI's influence on the global education industry is

constantly increasing, which is ensured by the impact of certain transformation processes.

First, AI facilitates the personalisation of learning. By analysing data about the learner and their interaction with platforms, it is possible to create an individual learning path, taking into account the level of knowledge, learning pace, and personal characteristics. This allows each student to learn the material as efficiently as possible (Bhutoria, 2022; Huang et al., 2023a; Xu et al., 2023).

Another important aspect is the possibility of gamification of learning. The use of game elements, challenges, and rewards can increase the motivation of students to actively participate in the learning process. This contributes to deeper learning and active engagement with the content (Bezzina & Dingli, 2023; Lampropoulos, 2023a; Yang et al. 2023).

Additionally, AI allows collecting and analysing a huge amount of learning data. This gives teachers the opportunity to receive detailed reports on students' progress, identify gaps, and respond to them in a timely manner. This approach allows for an individualised approach to each student and provides more effective control over the learning process (Baidoo-Anu & Owusu Ansah, 2023; Liu & Wang, 2021; Martínez et al., 2023).

In turn, the use of virtual and augmented realities in AI-assisted learning allows for an immersive learning environment. Students can learn difficult and abstract concepts in an interactive format, which contributes to a deeper understanding of the material (Lampropoulos, 2023b; Ma, 2021; Saghiri et al., 2022).

Taking these aspects into account, we can conclude that AI opens up new opportunities for modern education to improve the learning and development of students, providing personalisation, motivation, and effective control over the learning process.

A summary of the key development drivers that contribute to the rapid implementation of AI in the global education sector is shown in Table 1.

Table 1

A Brief Description of the Drivers of AI Integration into the Global Educational Space

Development driver	Characteristics	Scientific description
Adaptability	AI systems can adapt the content and tasks according to the student's performance, ensuring a more efficient learning process.	Xie et al. (2022)
Analytics	AI allows collecting and analysing learning data, which helps teachers and administrators improve the learning process.	Ouyang et al. (2023)
Virtual and augmented reality	The use of AI can allow learners to explore virtual worlds in depth or use augmented reality for learning.	Rusillo-Magdaleno et al. (2023)
Gamification	The use of game elements and tasks helps to create interest and motivation for learning.	Modi and Gochhait (2023)
Global access	AI-powered online platforms allow you to get a quality education from anywhere, regardless of geographic location.	Rangel-de Lázaro and Duarte (2023)
Feedback	AI provides immediate feedback and hints to help students understand their mistakes and correct them.	Hooda et al. (2022)

Reducing routine tasks	AI can automate routine tasks, allowing teachers to use more time for individual work with students.	Rensfeldt and Rahm (2023)
Innovation	The introduction of AI promotes new approaches to learning and the creation of innovative teaching methods.	Tan (2023)
Personalised training	AI allows you to create individualised curricula, taking into account the needs, level of knowledge, and pace of learning of each student.	Xiao and Yi (2023)
Collaboration and communication	AI provides opportunities for teamwork and interaction among students, which helps to develop communication skills.	Esplugas (2023)

Source: author's own development.

Thus, the introduction of artificial intelligence into the educational process brings about positive changes, improves learning efficiency, and creates new opportunities for the development of students.

However, AI also has a number of limitations that have been identified through comparative analysis (Cheng et al., 2023; Cribben & Zeinali, 2023; Voskoglou & Salem, 2020) – Table 2.

Table 2

Risk-Based Analysis of AI Application in Education

Advantages.	Disadvantages.
Accessibility: AI-powered online platforms and applications make learning accessible to everyone, regardless of location or time.	Deep understanding learning: Some aspects of learning that require deep understanding and critical thinking may be difficult for AI to replicate.
Assessment efficiency: AI allows collecting and analysing learning data, which contributes to a more objective assessment and identification of students' difficulties.	Threat to data privacy: The use of AI may raise questions about the privacy and protection of personal data of students.
Engaging students: The use of game elements and interactive platforms engages learners in learning and makes it fun.	Dependence on technology: In the event of technical problems or lack of access to technology, learning can be hindered.
Resource optimisation: AI helps teachers to use time and resources efficiently by focusing on the individual needs of students.	Cost and support: Implementing and maintaining AI systems can be costly and time-consuming.
Personalised learning: AI allows you to create individual learning paths for each student, taking into account their needs, abilities, and pace of learning.	Lack of a humane element: AI cannot completely replace the interaction between a teacher and a student, especially in difficult issues and moral aspects.
Improving the learning experience: Interactivity and adaptation of content to learners' learning styles contribute to better learning.	Technical limitations: Effective use of AI requires the availability of appropriate infrastructure and technical resources.

Source: authors' own development.

The uncontrolled use of artificial intelligence (AI) in education has raised a number of accompanying moral and ethical dilemmas that require careful analysis and management to ensure ethical practice in the educational process. The main ones are outlined in Table 3.

Table 3

Moral and Ethical Aspects of AI Implementation in Education

Aspects	Characteristics	Scientific description
Competence matching and training	The use of AI by students to perform individual tasks may violate the principle of competence acquisition. Individual AI tasks can lead to insufficient work on educational material, deprive students of the opportunity for active training and self-development, which affects the quality of their education.	Shidiq (2023)
Dependence on technology	Over-reliance on AI can lead to a loss of independent thinking and problem-solving skills. Students may lose the ability to critically analyse and think creatively, which are important competencies in the modern world.	Fitria (2021)
Shifting the emphasis in education	The use of AI can lead to a focus on the outcome of tasks, rather than an emphasis on understanding and meaningful learning. This can lead to superficial knowledge acquisition without deep understanding and analysis.	Malinka et al. (2023)
Moral aspects of automating the interaction of participants in the educational process	The introduction of AI may raise questions about the morality of using technology, especially in the context of automatic assessment and interaction. For example, the ethical aspects of automatic plagiarism detection may raise questions about the fairness and transparency of such decisions.	Wach et al. (2023)
Insufficient transparency of algorithms	The lack of transparency in the functioning of AI algorithms can create a risk of losing trust in this technology among participants in the educational process. If users do not understand how decisions are made by algorithms, this can lead to doubts about the reliability of the results and even refusal to use them.	Grimmelikhuijsen (2023)
Unreliability of information bases	A breach in the AI training system can lead to the appearance of unreliable data in the relevant information databases. This may be due to inadequate data filtering, errors in the input data, or lack of transparency in the algorithms. Such a case can lead to unforeseen consequences, such as incorrect estimates and even an increased risk of inaccurate information.	Sison et al. (2023)

Source: authors' own development.

All the identified aspects (advantages and disadvantages) are taken into account when developing practical recommendations for the implementation of AI in the Ukrainian educational space.

Sample / Participants / Group

In order to develop practical recommendations for the modernisation of Ukrainian education, the following specialised organisations were selected as an expert community - **Table 4**.

Table 4

List of expert organisations in the field of AI application for education

Organisation.	Description.	Link
Appinventiv	Appinventiv is an expert organisation specialising in software and technology solutions. One of their resources is a blog that analyses how artificial intelligence is transforming the education industry. Their articles help to understand how technology is affecting education and provide perspectives on transformation.	Appinventiv (2023)
eLearning Industry	eLearning Industry is a leading online resource dedicated to e-learning and technology in education. They focus on analysing innovations in learning, including the use of artificial intelligence. Their articles and materials reveal the impact of technology on the transformation of the education sector.	Mistry (2023)
Global Market Insights Inc.	Global Market Insights Inc. is a leading analytical company that specialises in market research and forecasting for various industries. One of their areas of expertise is researching the AI in education market. They provide analyses and data to help understand the trends and prospects for AI in education.	Global Market Insights (2023)
Grand View Research, Inc.	Grand View Research, Inc. is a leading expert organisation specialising in market research. One of its key areas of expertise is researching the artificial intelligence market in education. They provide a comprehensive analysis of market dynamics, collect statistics, identify trends, and forecast development. The results of their research are valuable for business, academia, and investors interested in the use of artificial intelligence in education.	Grand View Research (2021)
HolonIQ	HolonIQ is an influential analytical company specialising in researching the global education and technology market. One of their most recent publications is Artificial Intelligence in Education 2023: Survey Insights, which covers trends and forecasts for the use of artificial intelligence in education.	Education Intelligence Unit (2023)
Market Research Future	Market Research Future is a leading market research company specialising in providing forecasts and analysing market trends. They study a variety of industries, including the artificial intelligence market in education. One of their most recent publications is the Artificial Intelligence Education Market research report.	Munde (2023)
Soocial	Soocial is a resource specialised in analysing and providing statistics on the use of artificial intelligence in education. their data and analyses provide important insights into trends and forecasts of AI in education.	Soocial (n.d.)
U.S. Department of Education, Office of Educational Technology	The U.S. Department of Education, Office of Educational Technology is the official structural unit of the U.S. Department of Education that deals with educational technologies. The organisation researches and develops strategies for the use of technology, including artificial intelligence, in education. Their report “Artificial Intelligence in Education” analyses the role of artificial intelligence in education.	Office of Educational Technology (2023)
V7	V7 is an expert organisation specialising in the research and development of artificial intelligence technologies. Their blog	Sajid (2023)

Organisation.	Description.	Link
	analyses the role of artificial intelligence in education. They provide articles and materials that reveal the prospects of using AI in the field of education.	
West Agile Labs Blog	The West Agile Labs Blog is a platform owned by West Agile Labs, a software development and technology consultancy. Their blog analyses the use of artificial intelligence in the education sector. They provide articles that reveal eight ways artificial intelligence can be used in education.	West Agile Labs (n.d.)

Source: author's own development

The analytical data of the above expert organisations (Table 4) describe the technologies used to modernise the global education system.

Instrument and Procedures

The study was carried out in several iterations:

1. A list of relevant expert organisations has been compiled (**Table 4**), which contains up-to-date data and professional assessments of the impact of certain AI technologies on the education sector.
2. Each of the expert organisations involved in the study has formed a cross-sectional field of individual ratings of each of the educational AI solutions.
3. According to the analysis of individual rating scores, a relative ranking by the frequency of references to educational AI solutions in the expert community was formed - (1):

$$RRMF_i = \frac{\sum_{i=1}^n IR_i}{FM_i}, \quad (1)$$

where $RRMF_i$ is the relative ranking by the frequency of mention of educational AI solutions in the expert community; $\sum_{i=1}^n IR_i$ is the sum of the individual ratings of each expert organisation for educational AI solutions; FM_i is the frequency of mention of educational AI solutions in the expert community.

4. According to the number of times each of the considered educational AI solutions took the leading position according to the individual assessment of each of the expert organisations involved in the study, a relative priority rating is formed - (2):

$$RRP_i = RRMF_i \times \left(1NTO1LP + \frac{1}{2}NTO2LP + \frac{1}{3}NTO3LP + \frac{1}{4}NTO4LP + \frac{1}{5}NTO5LP \right), \quad (1)$$

where RRP_i is the priority ranking of each of the considered educational AI solutions; $NTO1LP...NTO5LP$ is the number of times each educational AI solution was ranked first and fifth in

the individual ranking according to the rating organisations, respectively.

5. Based on the results of the priority ranking (2), the optimal nomenclature of educational AI solutions has been formed, which is advisable to implement in the educational sector of Ukraine.

6. In accordance with the established digital software solutions, practical recommendations for the AI modernisation of the Ukrainian educational system have been developed.

7. Analytical conclusions on the future development of the Ukrainian education sector in the context of global digitalisation and the implementation of educational AI solutions are formed.

The proposed research scheme allowed us to identify the most appropriate vectors of development of Ukrainian education, taking into account global educational trends and technologies, which will allow Ukrainian educators to train students in accordance with the best international standards.

Data Analysis

Based on the results of the individual assessment of educational solutions by each of the expert organisations involved in the study, an array of digital software solutions and tools was formed, which is further analysed in accordance with the proposed methodology (Table 5).

Table 5

General Nomenclature of Educational AI Solutions

An AI solution for education	Brief description
AI-driven Education Ecosystem	AI-driven Education Ecosystem is an integrated education system that uses AI technologies to optimise and improve all aspects of the learning process. This ecosystem includes intelligent analytical tools, personalised curricula, adaptive platforms, and other innovative solutions that facilitate effective learning, assessment, and interaction between all participants in the learning process.
AI-powered Chatbot	An AI-powered chatbot is an application or system that uses AI technology to interact with users in an automated manner via text or voice messages. These chatbots are capable of understanding and analysing questions, providing answers, performing tasks, and providing information using trained AI algorithms and models.
AI-powered Virtual Assistants	AI-powered Virtual Assistants are applications or systems that use AI technology to provide support and perform tasks for users through text or voice interfaces. These virtual assistants can perform a variety of tasks, including answering questions, managing tasks, making recommendations, and interacting with users using intelligent algorithms.
Automated Assessment & Grading Tasks	Automated Assessment & Grading Tasks is the process of using automated technologies, including AI, to evaluate and grade various tasks and works in the learning process. These technologies allow you to automatically analyse and evaluate student work, providing a quick and objective reconciliation of results.
Cloud Technology	Cloud Technology is a system architectural solution that enables the use of cloud resources and infrastructure to provide the computing power and data storage required for the implementation and development of AI in educational programmes and platforms.
Computer Vision	Computer Vision is a branch of AI that focuses on the development of algorithms and models for computers capable of detecting and recognising visual objects depicted in images or videos.

An AI solution for education	Brief description
Digital Skills	Digital Skills are the skills that enable learners to use AI technologies for effective learning and interaction. This may include the ability to analyse data, use AI tools for personalised learning, understand and interact with intelligent systems, and use digital resources to acquire new knowledge and skills.
EdTech	EdTech is an educational system that includes the use of technologies, including AI, to improve the learning process, provide access to knowledge, and develop skills.
Edutainment	Edutainment is an educational system that uses AI technologies to create learning programmes and platforms that combine the learning process with entertainment elements.
E-learning	E-learning is a form of learning where AI technologies are used to create personalised and adaptive curricula, analyse the knowledge gained, and ensure effective interaction between students and learning resources.
Fraud & Risk Management	Fraud & Risk Management is the process of identifying, analysing, and mitigating possible fraud and risks in learning environments. The use of AI technologies helps to detect inappropriate actions, fraud, or other negative situations that can affect the learning and safety of students, teachers, and other participants in the educational process.
Intelligent Adaptive Learning	Intelligent Adaptive Learning is an approach to learning that uses AI technology to create personalised and tailored learning programmes that adapt to the needs and abilities of each learner, ensuring more effective and efficient learning.
Intelligent Tutoring System (ITS)	ITS is a digital educational system that uses AI to provide individualised and personalised support to students during their studies.
Learning Platform & Virtual Facilitators	Learning Platforms & Virtual Facilitators are systems and technologies (including AI) that provide learning platforms and virtual facilitators to support learning and facilitate interaction between participants in the educational process. These solutions allow educational institutions to create effective learning environments, including interactive online courses, collaborative learning, and interaction through virtual interfaces.
Machine Learning (ML)	ML is a branch of AI that studies the development of algorithms and models that allow computers to learn from data and improve their performance over time without explicit programming.
Natural Language Processing (NLP)	NLP is a branch of AI that develops algorithms and models for understanding and interacting with natural language, such as human speech. It allows computers to analyse, interpret and generate human speech, enabling them to interact with systems and applications through language.
Personalised Education	Personalised Education is an approach to learning in which the learning process and materials are adapted to the individual needs and capabilities of each student. The use of AI technologies helps to create personalised curricula, recommendations, and assignments, ensuring a more efficient and engaging learning process.
Smart Content	Smart Content is a body of data, such as learning materials, resources, or platforms, that uses AI and analytics technologies to improve access to knowledge and learning. It can be personalised, interactive, and tailored to the needs of learners, facilitating effective teaching and learning.
Virtual & Augmented Reality (VR/AR)	VR/AR are technologies that create immersive virtual or augmented environments for users. They allow you to interact with objects and information in the virtual world (VR) or augment the real world with digital elements (AR), providing new opportunities for learning and interaction.

An AI solution for education	Brief description
Vision & Voice Applications	Vision & Voice Applications is a system of technological solutions that combines computer vision and voice interaction to improve the learning process. This may include recognising objects in images in educational materials, interacting with platforms using voice commands, creating interactive voice questions and answers to assess student knowledge, etc.

Source: authors' own development.

The identified information array (Table 5) covers the entire range of AI applications in education and allows for a subject-specific analysis to determine the optimal range of digital software tools for the modernisation of Ukrainian education.

Research Results

In accordance with the proposed methodology, we will set up a cross-reference field for the individual rating of each of the educational AI solutions according to the assessments of the involved expert organisations (Table 6).

Table 6

Cross-Referencing Individual Rankings of Educational AI Solutions

Digital technologies of AI education	Grand View Research, Inc.	HolonIQ	Market Research Future	Social	Global Market Insights Inc.	Appinventiv	West Agile Labs Blog	eLearning Industry	V7	Office of Educational Technology
EdTech	1	7		4		2				
Edutainment	2							10		
Intelligent Tutoring System (ITS)	3				6		6	5	3	
Cloud Technology	4		4			5	2			
Machine Learning (ML)	5	1	1		10	10	1			1
Natural Language Processing (NLP)	6	3	2	1	4	4			10	3
Smart Content	7			5	7	6	5	4		
Virtual & Augmented Reality (VR/AR)	8		3		3	3	7			
Computer Vision	9								5	2
Intelligent Adaptive Learning		2						9		
Vision & Voice Applications		4					3		6	
Digital Skills		5								
AI-driven Education Ecosystem	11	6	5	3	2	8		7	9	5
AI-powered Chatbot		10		2		9				
AI-powered Virtual Assistants					1	7	4	3	1	

Digital technologies of AI education	Grand View Research, Inc.	HolonIQ	Market Research Future	Soocial	Global Market Insights Inc.	Appinventiv	West Agile Labs Blog	eLearning Industry	V7	Office of Educational Technology
Fraud & Risk Management	10	8			8					
Learning Platform & Virtual Facilitators	12	9			5			8	7	
E-learning					9	1		1	8	
Automated Assessment & Grading Tasks								2	4	4
Personalised Education								6	2	

Source: author's own development.

According to the data presented in Table 6, we observe a randomised distribution of rating scores for each digital educational solution using AI technology, which indicates the independence and absence of bias among the selected and involved in the current study members of the expert community. The wide range of educational AI solutions indicates that the research sample is interested in a wide range of modern possibilities of using the technology under study to modernise the field of education and science.

Using the system of cross-evaluation by frequency of mention and individual ranking of educational solutions using artificial intelligence, which is denoted in the corresponding mathematical apparatus (f , f), we will form the corresponding analytical plane (Table 7).

Table 7

The Analytical Plane of Educational Solutions Using Artificial Intelligence

Digital technologies of AI education	Frequency of mention	Relative Ranking by Mention Frequency	Number of Times of Occupying the First Leading Position	Number of Times Occupying the Second Leading Position	Number of Times Occupying the Third Leading Position	Number of Times Occupying the Fourth Leading Position	Number of Times Occupying the Fifth Leading Position	Relative Ranking by Priority
EdTech	4	0.0476	1	1	0	1	0	0.083
Edutainment	2	0.0238	0	1	0	0	0	0.012
Intelligent Tutoring System (ITS)	5	0.0595	0	0	2	0	1	0.051

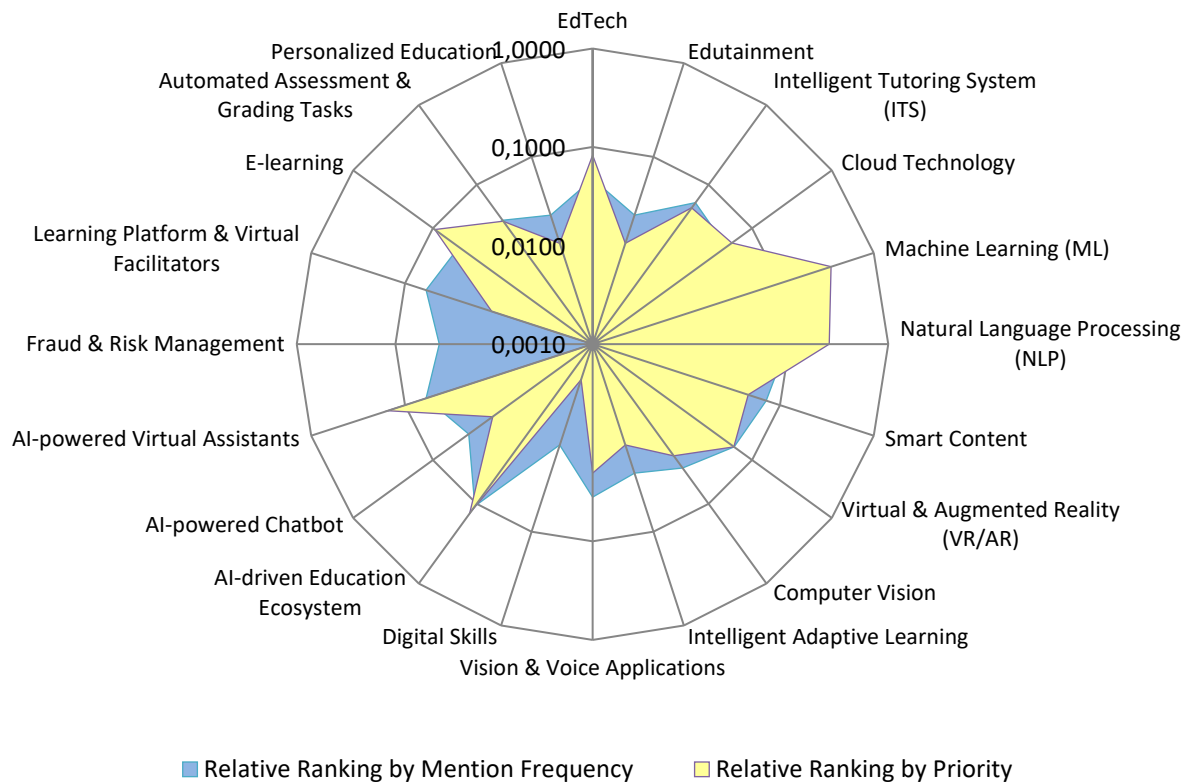
Cloud Technology	4	0.0476	0	1	0	2	1	0.056
Machine Learning (ML)	7	0.0833	4	0	0	0	1	0.350
Natural Language Processing (NLP)	8	0.0952	1	1	2	2	0	0.251
Smart Content	6	0.0714	0	0	0	1	2	0.046
Virtual & Augmented Reality (VR/AR)	5	0.0595	0	0	3	0	0	0.059
Computer Vision	3	0.0357	0	1	0	0	1	0.025
Intelligent Adaptive Learning	2	0.0238	0	1	0	0	0	0.012
Vision & Voice Applications	3	0.0357	0	0	1	1	0	0.020
Digital Skills	1	0.0119	0	0	0	0	1	0.002
AI-driven Education Ecosystem	9	0.1071	0	1	1	0	2	0.132
AI-powered Chatbot	3	0.0357	0	1	0	0	0	0.018
AI-powered Virtual Assistants	5	0.0595	2	0	1	1	0	0.153
Fraud & Risk Management	3	0.0357	0	0	0	0	0	0.000
Learning Platform & Virtual Facilitators	5	0.0595	0	0	0	0	1	0.012
E-learning	4	0.0476	2	0	0	0	0	0.095
Automated Assessment & Grading Tasks	3	0.0357	0	1	0	2	0	0.035
Personalised Education	2	0.0238	0	1	0	0	0	0.012

Source: authors' own development.

The results of the relative cross-ranking by the frequency of mention and the number of times the leading positions of individual expert ratings (top 5) were occupied (Table 7) allow us to form an indirect and independent rating of educational solutions and tools based on the use of artificial intelligence, according to which it is possible to determine the optimal nomenclature of digital software solutions for the modernisation of education in Ukraine (Figure 1).

Figure 1

Determining the Optimal Nomenclature of AI-Based Digital Software Tools for the Modernisation of the Ukrainian Education Sector



Source: authors' own development.

The analysis of the ranking data (Figure 1) shows that in the context of AI education, the importance of certain digital technologies varies depending on the frequency of mention and the priority of their use. In particular, technologies such as Machine Learning (ML) and Natural Language Processing (NLP) have a high level of mention and a higher priority, which may indicate their importance for the development of educational solutions.

In addition, AI-driven Education Ecosystem is also noted as a technology with a high level of mention and a medium level of priority, which may indicate its potential as an integrated system for optimising learning. It is worth noting that some concepts, such as Fraud & Risk Management, have a low priority, which may reflect their lower impact on the learning process.

In general, the conclusion is that Machine Learning, Natural Language Processing, and AI-driven Education Ecosystem appear to be key technologies with high potential in the application of artificial intelligence in education.

In contrast, some concepts, such as Edutainment, Intelligent Adaptive Learning, and Personalised Education, show that they are less frequently mentioned, but may still have significant potential to transform the educational process. Such innovations can help to increase engagement and learning effectiveness for each individual student.

According to the data, Cloud Technology, and Learning Platform & Virtual Facilitators also have a relatively high level of mention and priority. This reflects the growing popularity of online learning and the use of virtual platforms for collaborative learning.

Based on the analysis, it can be concluded that the development and implementation of educational solutions based on artificial intelligence technologies has great potential to improve the

educational process, taking into account the specifics of each technology and its impact on education.

In addition, it is important to note that some concepts, such as Virtual & Augmented Reality (VR/AR) and Computer Vision, show relatively average levels of recall and priority. These technologies can provide immersive and more adaptive learning environments, which can help improve learning.

In the context of education, AI-powered Chatbots and AI-powered Virtual Assistants have also proved to be important as they can support students and teachers in real-time by answering questions and helping with tasks.

Overall, the data analysis indicates a multifaceted approach to the use of AI technologies in education, with a focus on the importance of each specific technology in improving learning and student engagement.

According to the ranking (Figure 1), the best educational AI solutions for modernising Ukraine's education sector are:

- Machine Learning (ML):
 - Machine Learning (ML); $RRMF = 0,0833$ $RRP = 0,350$: the ability to analyse and summarise large amounts of data can improve individualised learning, as well as provide a deeper understanding of learners' cognitive needs;
 - Natural Language Processing (NLP): ; $RRMF = 0,0952$ $RRP = 0,251$: the use of NLP technologies facilitates the understanding and analysis of textual information, which allows for improved communication and interaction between participants in the learning process;
 - AI-powered Virtual Assistants: ; $RRMF = 0,0595$ $RRP = 0,153$: this solution provides individual support and advice to students and teachers in real-time;
 - AI-driven Education Ecosystem: ; $RRMF = 0,1071$ $RRP = 0,132$: integration of various aspects of education into a single system contributes to a more organised and efficient learning process;
 - E-learning: ; $RRMF = 0,0476$ $RRP = 0,132$: the use of electronic learning platforms provides access to knowledge for a wider range of students and ensures flexibility of learning.

Other AI tools that were singled out from the overall ranking are also useful in the process of modernising the Ukrainian education sector:

- EdTech: ; $RRMF = 0,0476$ $RRP = 0,083$: promotes changes in learning formats by providing access to digital tools and resources for effective learning;
- Virtual & Augmented Reality (VR/AR): ; $RRMF = 0,0595$ $RRP = 0,059$: the use of virtual and augmented reality creates immersive learning environments where students can immerse themselves in and interact with realistic situations;
- Cloud Technology: ; $RRMF = 0,0476$ $RRP = 0,056$: the use of cloud technology facilitates access to learning resources from any device and location, improving learning and collaboration;
- Intelligent Tutoring System (ITS): ; $RRMF = 0,0595$ $RRP = 0,051$: intelligent tutoring systems provide individualised learning and support for each student, helping to grow their abilities and competencies;

- Smart Content: ; $RRMF = 0,0714$ $RRP = 0,046$: the use of interactive and adaptive learning materials creates conditions for a more effective learning process.

It is worth noting that digital software solutions that increase the automation of the educational process are also useful for the modernisation of the Ukrainian education sector based on AI solutions:

- Automated Assessment & Grading Tasks: ; $RRMF = 0,0357$ $RRP = 0,035$: automate the process of grading student assignments and papers, ensuring accuracy and speed of assessment;
- Computer Vision: ; $RRMF = 0,0357$ $RRP = 0,025$: allows you to analyse visual data such as images and videos, which can contribute to the creation of interactive and enriched learning materials;
- Vision & Voice Applications: ; $RRMF = 0,0357$ $RRP = 0,020$: open up opportunities for using voice and visual interfaces in educational processes, which contributes to the convenience and accessibility of learning for different groups of students.

These digital software solutions can greatly enhance the learning process by providing greater objectivity, efficiency and interactivity. However, it is important to remember that successful implementation of these tools requires proper training, consideration of the specifics of the learning context, and support for the appropriate infrastructure.

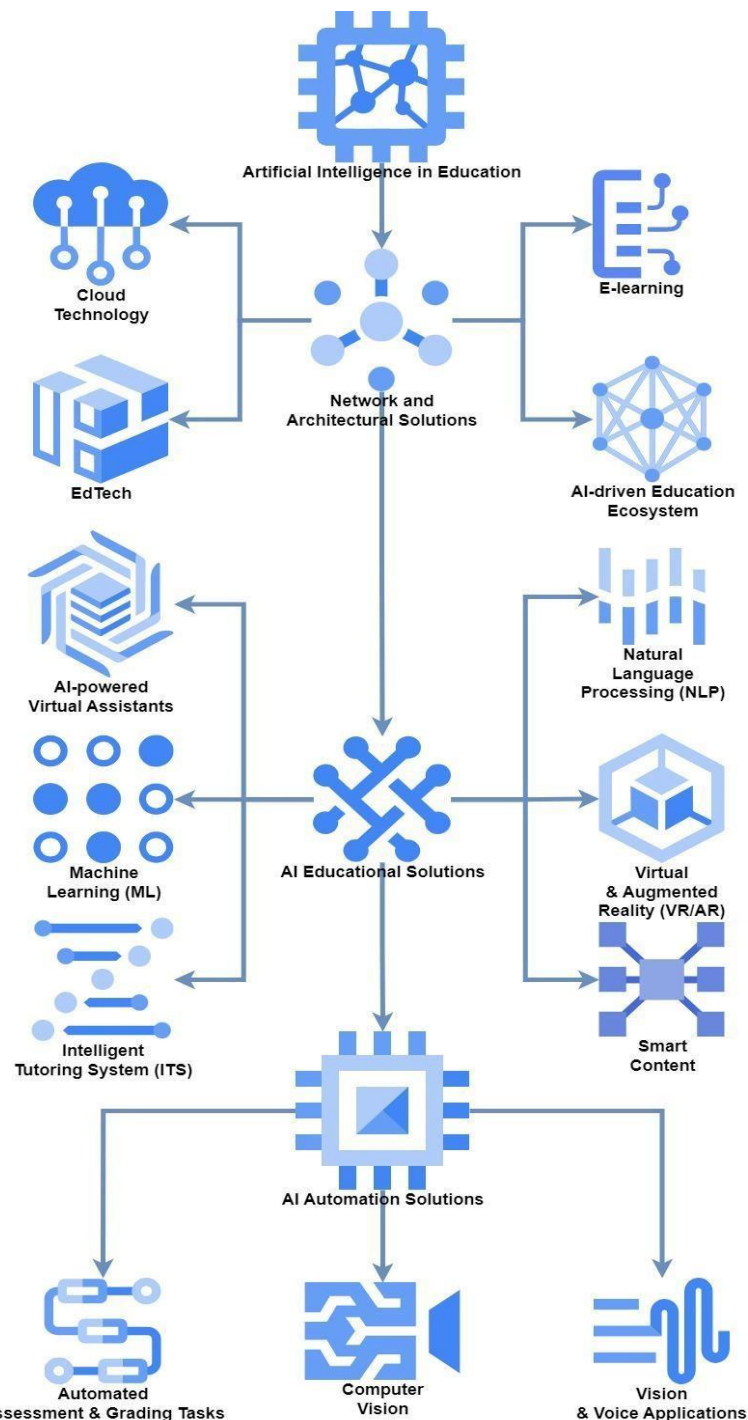
Based on the optimal nomenclature of AI tools, we will formulate practical recommendations for the modernisation of Ukraine's educational system:

- develop national standards on systemic and ethical norms for the use of AI in the educational space;
- to develop system-architectural educational structures that ensure the effective functioning of educational processes and their improvement using AI optimisation: E-learning, EdTech, AI-driven Education Ecosystem, Cloud Technology;
- to implement tools to improve the efficiency of the educational space: AI-powered Virtual Assistants, Virtual & Augmented Reality (VR/AR), Intelligent Tutoring System (ITS), Smart Content;
- to automate the educational process support system by reducing routine tasks and in-depth interaction with AI: Automated Assessment & Grading Tasks, Computer Vision, Vision & Voice Applications; Machine Learning (ML); Natural Language Processing (NLP).

2. The general concept of modernising the Ukrainian educational system with AI is shown in **Figure 2.**

Figure 2

The Concept of AI Modernisation of Ukrainian Education



Source: authors' own development.

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The proposed system of modernisation of Ukrainian education by means of artificial intelligence (Figure 2) contains three logical levels of deployment:

1. System and architectural level: development and implementation of infrastructure for AI functioning.
2. The level of optimisation and improvement of the quality of educational processes: the use of adapted and individualised digital educational environments.
3. The level of automation of educational processes: implementation of solutions to

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reduce and optimise routine tasks to support educational processes using AI technologies.

The developed practical recommendations provide a holistic approach to the modernisation of Ukraine's education system, focusing on ensuring national standards, personalised learning, and the effective use of AI to automate learning processes and interact with students. This approach helps to ensure quality and individualised education in line with the modern requirements and challenges of the education sector.

Discussion

The following theses established in the current study are put forward for discussion:

- AI technologies have significant potential to modernise Ukraine's educational system;
- A wide range of AI technologies that can be used in the educational space has been installed;
- The author identifies moral and ethical threats arising from the uncontrolled use of AI in the educational sector;
- Based on the analysis of individual expert ratings, an optimal nomenclature of educational AI solutions was formed, based on which practical recommendations for the modernisation of the Ukrainian educational space were developed;
- The optimal strategy for implementing AI mechanisms in the educational space is a three- tiered deployment system that involves the formation of infrastructure and architecture, filling the educational space with effective learning tools, and integrating system solutions for automating the support of educational processes.

The results of the study confirm the adaptability of educational AI solutions identified in the publication (Xie et al., 2022): intelligent AI systems can customise content and tasks according to learning progress, contributing to a more efficient learning process.

Architectural and system solutions have also been established that confirm the possibility of forming specialised analytical arrays on the parameters of educational processes, as reported in Ouyang et al. (2023): the use of AI allows collecting and analysing educational data, which contributes to the improvement of the educational process by the teachers and administrators involved.

The results of the current study have established the importance of developing immersive learning environments implemented by means of Virtual & Augmented Reality (VR/AR). Similar conclusions were reached by researchers in the publication (Rusillo-Magdaleno et al., 2023): the use of AI enables students to explore virtual environments in more depth or use augmented reality technology for learning.

The elements of immersiveness of the educational space are also confirmed by the solutions for gamification of the educational space, as described in the study (Modi & Gochhait, 2023): the introduction of game components and tasks helps to generate interest and stimulates the desire to learn.

The importance of system-architectural solutions is confirmed in the publication (Rangel-de Lázaro & Duarte, 2023), in which researchers focus on the development of cloud infrastructure for the deployment of AI educational services: AI-based online educational platforms allow to obtain high-quality education from any location, regardless of geography.

Among the solutions that improve the efficiency and quality of educational processes, which are

established as practical recommendations for the modernisation of the Ukrainian education sector, are support, assistance, and quick feedback. The need to develop the support aspect is emphasised in the study (Hooda et al., 2022): AI provides instant feedback and advice to help students realise their mistakes and correct them.

Among the factors identified in this study that demonstrate the need to integrate AI technologies into the educational space is the need to automate learning processes and reduce routine tasks of the same type. This aspect is confirmed by the results described in Rensfeldt and Rahm (2023): thanks to the use of AI, it is possible to automate everyday tasks, which allows teachers to allocate more time for individual work with students.

This study also emphasises the possibility of increasing the efficiency of educational processes with AI solutions aimed at personalising learning materials. This has also been reported in (Xiao & Yi, 2023): with the help of AI, it is possible to develop personalised curricula, taking into account the individual needs, level of knowledge, and pace of learning of each student.

At the same time, studies (Esplugas, 2023; Tan, 2023) point to the significant innovative potential of the subject area in terms of developing integrated educational systems that will help to improve the efficiency of educational processes and the involvement of a wide range of stakeholders.

Based on the results of the development of practical recommendations for the modernisation of the Ukrainian educational sector, it was established that it is necessary to take into account the moral and ethical aspects of the use of AI, which should be reflected in the relevant national standard. The following aspects should be taken into account:

- the uncontrolled use of AI by students to solve individual tasks, which was also noted in the publication (Shidiq, 2023);
- modernisation of the assessment system to prevent a shift in emphasis from the learning process to its effectiveness, i.e., the lack of detailed and meaningful perception of learning materials among students, which was also highlighted by researchers in the publication (Malinka et al., 2023);
- uncontrolled use of educational process automation solutions threatens to reduce the quality of education due to the lack of appeal to students' creative abilities, which is confirmed by the results of the study (Wach et al., 2023);
- There are also a number of technical problems: the risk of becoming dependent on technology (this aspect is confirmed in Fitria (2021); lack of understanding of the principles of AI functioning, which can cause various consequences (Grimmelikhuijsen, 2023); uncontrolled and unsystematic AI training, which leads to the use of false data in advance (as noted in Sison et al., 2023).

At the same time, the main difference between the current study and the aforementioned ones is the formation of a systematic, rational, and balanced approach to the implementation of AI technologies in the educational space.

Further research will focus on detailing the proposed conceptual scheme for modernising the Ukrainian education sector, in particular, developing optimal mechanisms for integrating each of the educational AI solutions.

It is also important to investigate the effectiveness and efficiency of various AI tools in teaching, comparing them to traditional methods. Further research could reveal which aspects of the student learning experience can be improved by AI, as well as identify the limitations and challenges that

educational institutions may face when implementing these technologies.

In addition, it is important to study the impact of AI on the development of skills and competences that students acquire in the course of their education. This may include analysing changes in critical thinking, creativity, collaboration, and other key aspects of education.

Research can also be conducted on the effectiveness of integrating AI into different levels of education, from primary school to higher education. This will help identify the best approaches and strategies for implementing these technologies at different stages of education.

To summarise, further research in the field of artificial intelligence in education should be aimed at unlocking the potential of these technologies to improve educational processes, as well as addressing ethical, methodological, and practical issues that arise during their implementation.

Conclusions and Implications

The study has revealed a number of important theses on the use of artificial intelligence in the modernisation of the Ukrainian education system. First, artificial intelligence is receiving considerable attention as a potential means of improving the educational space. A wide range of artificial intelligence technologies that can be used in education is noted. However, it is important to consider the ethical aspects of integrating these technologies to avoid negative consequences.

The results of the analysis of expert ratings show that the selected optimal range of artificial intelligence solutions has great potential for modernising the education sector. The use of Machine Learning can contribute to the individualisation of learning and a deeper understanding of students' needs. The use of Natural Language Processing will improve communication between participants of the educational process. AI-powered Virtual Assistants will help to provide individual support for students and teachers. AI-driven Education Ecosystem will facilitate more organised learning. The use of E-learning will provide access to knowledge for everyone.

It is also important to consider other artificially intelligent tools that also have great potential for modernising the educational space. EdTech is changing learning formats, VR/AR is creating interactive environments, Cloud Technology is facilitating the availability of resources, and ITS and Smart Content are contributing to individualisation and learning efficiency.

In general, the developed nomenclature of artificial intelligence solutions and recommendations for their implementation are aimed at creating a modern, efficient, and individualised educational system in Ukraine. Taking into account the technological capabilities of artificial intelligence and their integration into the educational process will help improve the quality of education and train modern specialists.

In order to modernise the Ukrainian educational system based on artificial intelligence, it is necessary to develop national standards of use, develop systemic educational structures to optimise processes, implement solutions to improve efficiency and automate learning support. Such steps will help create a modern and efficient educational system that takes into account the capabilities of artificial intelligence.

This study confirms that the optimal strategy for implementing artificial intelligence mechanisms in the educational space is a three-level deployment system. This strategy provides for a holistic approach to the introduction of artificial intelligence into the educational process and ensures a high level of efficiency and harmony of functioning.

The first level, system-architectural, includes the development and implementation of infrastructure for the use of artificial intelligence in the educational space. This includes the creation of technical tools and infrastructure that will ensure interaction between different artificial intelligence systems.

The second level, the level of optimising and improving the quality of educational processes, involves the introduction of effective learning tools using artificial intelligence. This includes individualised and adaptive learning environments, the use of virtual and augmented reality, intelligent learning support systems, and other solutions that improve the quality of learning and knowledge acquisition.

The third level, the level of automation of educational processes, includes the implementation of system solutions to automate the support of educational processes using artificial intelligence. This helps to reduce routine tasks, increase the accuracy and speed of assessment, and provide feedback to students and teachers.

This three-level implementation strategy allows for a comprehensive approach to the use of artificial intelligence in the educational space. It contributes not only to improving the efficiency of the educational process, but also to creating a modern and individualised educational system that meets the requirements of modern society and trains competent specialists of the future.

The integration of AI in education may lead to a transformation in the types of jobs and skills in demand. Graduates with proficiency in AI-related fields could be sought after, while traditional roles may evolve or diminish. This shift underscores the importance of aligning educational curricula with emerging AI trends to ensure graduates remain relevant.

Moreover, a workforce equipped with AI-enhanced skills may bolster Ukraine's competitiveness internationally. It can attract more investment from tech companies looking for a skilled talent pool, potentially boosting economic growth. However, it also highlights the necessity for continuous learning and adaptability in the face of evolving technologies.

In summary, the study's implications encompass the potential for AI integration to reshape the Ukrainian job market, influence the skills graduates need, and enhance the nation's competitiveness on the global stage, emphasizing the need for strategic planning and adaptability in response to these changes.

Suggestions for Future Research

This study confirmed that the optimal strategy for implementing artificial intelligence mechanisms in the educational space is the three-level deployment system. This strategy provides for a holistic approach to the introduction of artificial intelligence into the educational process and ensures a high level of efficiency and harmony of functioning.

Future research should investigate the long-term impact of implementing artificial intelligence (AI) in education. It should illustrate how these changes may affect the job market, the skill sets demanded of future graduates, and the overall competitiveness of the workforce, both within Ukraine and on a global scale.

Another crucial area of research pertains to the economic implications of AI in education. Analysing the AI improvements driven in education and its potential of boosting the economic growth, attracting tech investments, and stimulating innovation in other sectors will be valuable. Additionally, researchers can explore AI integration and its contribution to the skills gap closing and enhancing

workforce productivity.

The societal adaptation to AI in education is a significant area of interest. Future studies should focus on the acceptance, resistance, and ethical considerations associated with AI-driven educational changes. Investigating the role of policy frameworks and regulations in addressing societal concerns and ensuring equitable access to AI-enhanced education is essential.

Research efforts should also assess the preparedness of teachers and students for AI integration. This includes investigating the training and support mechanisms required for educators to effectively use AI tools in classrooms and analysing the AI capacity to empower students becoming active learners.

Moreover, there should be a focus on assessing the effectiveness of AI in educational assessment and evaluation. Investigating AI-powered assessment methods, their reliability, and their impact on learning outcomes will be of great value. Researchers can also explore innovative ways in order to provide timely and constructive feedback to students using AI.

The integration of AI into educational curricula across various subjects and levels is another area that warrants investigation. Research can delve into best practices for developing AI-focused learning modules and ensuring that students acquire essential AI-related skills and knowledge.

Ethical considerations are crucial, and future research should explore the ethical dimensions of AI adoption in education. This includes analysing the responsible use of AI, data privacy, and potential biases in AI-driven learning systems. Researchers can also explore frameworks for ensuring that AI technologies prioritise fairness and equity.

To gain comprehensive insights, international comparative studies should be conducted, comparing Ukraine's approach to AI in education with other countries. By identifying global best practices and success stories, researchers can assess the transferability of strategies to the Ukrainian context.

Lastly, research should explore the role of AI in enabling lifelong learning and ups-killing. Investigating the AI support ongoing education throughout individuals' careers is essential for the future of learning.

The culmination of this research should result in the development of actionable policy recommendations that facilitate the responsible integration of AI in Ukrainian education, aligning with national goals and international standards.

In summary, future research on AI in education should encompass economic, societal, pedagogical, ethical, and technical dimensions. By adopting a holistic approach and involving various stakeholders, researchers can contribute to the informed and responsible integration of AI into the educational landscape in Ukraine and beyond.

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