

Functions of Artificial Intelligence in Developing Adaptive Educational Pathways

Vitalii Shchepanskyi^{1*}, Oleksandr Polishchuk², Mykhailo Zoria³, Liliia Honcharuk², Viktor Shvets⁴

¹Department of Scientific Education and Portal Solutions, Institute of Applied Control Systems of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

²Special Language Training Department, Faculty of Professional Military and Postgraduate Education, Military Institute of Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

³Department of Civil Security, Faculty of Agricultural Technology and Ecology, Dmytro Motornyi Tavria State Agrotechnological University, Zaporizhzhia, Ukraine

⁴Interregional Academy of Personnel Management, Kyiv, Ukraine

*Corresponding author

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ABSTRACT:

The active implementation of artificial intelligence technologies is transforming the paradigm of modern education, shifting it from standardized teaching models toward flexible and individualized learning formats. The relevance of the study is determined by the growing need to create educational systems capable of adapting to the cognitive, social, and educational characteristics of learners while effectively processing large volumes of data. The purpose of the research is to determine the role of artificial intelligence in the formation of personalized educational trajectories within the process of digital transformation of education. The methodological framework combines system-analytical and structural-functional approaches with statistical, comparative, and predictive methods. The findings indicate a significant increase in the use of intelligent analytics in education between 2020 and 2024. In countries with high digital readiness, the share of educational institutions applying intelligent technologies increased from 41% to 62%, while in countries with medium and low levels of digitalization the indicators also demonstrated steady growth. More than half of European educational institutions currently use artificial intelligence for personalized learning, teacher digital literacy development, and management automation. The study concludes that effective integration of intelligent technologies requires coordinated state support, institutional modernization, and continuous development of teachers' digital competences to create sustainable and adaptive educational ecosystems by 2030.

Keywords: artificial intelligence, personalized learning, digital maturity, educational analytics, adaptive platforms

1. Introduction

Modern education is experiencing a period of profound changes associated with the accelerated development of digital technologies and the transformation of social demands for quality, flexibility and individualization of learning. Traditional models built on the standardization of the content and pace of the educational process are gradually giving way to new approaches focused on the personal development of the student. At the same time, the amount of information available to students today is so large that its independent processing without technological support becomes almost impossible. This necessitates the creation of intelligent systems capable not only of helping to navigate the data flow, but also of forming individual learning strategies.

In this context, artificial intelligence (AI) technologies are gaining special importance. They are becoming not just a tool for digitalizing education, but a means of building a personalized educational environment that takes into account the cognitive, emotional, and social characteristics of each student.

In recent years, the interest of scientists in the use of AI in educational practice has grown exponentially. As Merino-Campos (2025) notes, artificial intelligence in higher education contributes to the formation of individual learning experiences based on the analysis of large data sets on student progress. Similar results are presented by Pacheco et al. (2025), emphasizing that the combination of educational data analytics with AI algorithms ensures the development of metacognitive and socio-emotional competencies, creating the prerequisites for self-regulated learning.

Cardona et al. (2023) emphasize that the strategic integration of artificial intelligence into education requires not only technological progress, but also a rethinking of the roles of teachers, curriculum design, and ethical standards to ensure responsible innovation. Saleem et al. (2025) note that personalized AI-driven education systems significantly improve academic performance and student engagement in the learning process. According to Peng et al. (2019), personalized adaptive learning is a new pedagogical approach that uses “smart” learning environments to optimize content delivery and develop the cognitive activity of learners. Tan et al. (2025) systematize the capabilities of adaptive platforms that dynamically adjust the content and

complexity of learning material using machine learning algorithms, while Luo et al. (2025) prove that this directly affects student motivation and the quality of knowledge acquisition. At the same time, Lysenko et al. (2024) and Garzón et al. (2025) emphasize that although artificial intelligence can ensure inclusiveness and digital equality in education, its widespread use creates new challenges—from ethical dilemmas and algorithm transparency to personal data security issues.

Despite active research on the issue, the issue of comprehensive design of personalized educational trajectories with the participation of AI is still insufficiently studied. Most scientific works focus mainly on technical aspects or on assessing the effectiveness of individual platforms, leaving out of consideration the pedagogical, organizational and methodological principles of integrating intelligent systems into the educational process. The mechanisms of combining the analytical capabilities of AI with institutional strategies for the development of education, as well as the problems of ethical use of data and maintaining a balance between the automation of learning and direct pedagogical interaction, have also been insufficiently analyzed.

Accordingly, the purpose of the article is a comprehensive study of the role of artificial intelligence in creating personalized educational trajectories, as well as identifying key mechanisms, tools and pedagogical prerequisites that ensure the individualization of the educational process in the context of the digital transformation of education. To achieve this goal, several interrelated tasks are envisaged: first, to analyze modern scientific and theoretical approaches to personalizing learning using artificial intelligence technologies; second, to identify the possibilities, pedagogical effects, risks and ethical limitations of implementing intelligent systems in the design of individual educational trajectories; third, to carry out a comparative assessment of international experience in using AI platforms to support educational processes; fourth, to formulate practical recommendations for optimizing the process of integrating artificial intelligence into educational practice, taking into account the principles of innovation, pedagogical feasibility and sustainable development.

2. Literature Review

The use of artificial intelligence (AI) technologies in education today is the subject of an active interdisciplinary discussion, which combines the achievements of pedagogy, psychology, cognitive science and computer technologies. A scientific consensus is gradually forming around the idea that it is the integration of AI into the educational process that creates new opportunities for personalizing educational trajectories and increasing the efficiency of knowledge acquisition. At the same time, most researchers emphasize: combining technological solutions with pedagogical and ethical principles remains an extremely difficult task, requiring a careful balance between innovation and humanistic educational guidelines.

In a systematic review, Alfredo et al. (2024) show that the main challenge of modern educational analytics is to create human-centric models in which technological mechanisms are consistent with the values of student-centered pedagogy. In turn, Makarenko et al. (2024) and Yuan et al. (2025) argues that predictive analytics built on AI algorithms opens up the possibility of forming individual learning strategies that predict potential difficulties before they arise.

At the level of educational policy, this is confirmed by the results of Panwale and Vijayakumar (2025), who found that the use of AI in distance learning contributes to increased flexibility of the educational process and improves student outcomes. The authors emphasize that the success of such interventions depends on the degree of integration of analytical algorithms into pedagogical models and on the ability to adapt educational content to the individual needs of education seekers. Similar observations are made by Xie et al. (2019), who traced the evolution of adaptive learning over the past decade and recorded a gradual shift in emphasis from purely technical solutions to pedagogically meaningful approaches.

According to Vieriu and Petrea (2025), the use of intelligent technologies has a positive impact on students' academic development, providing individualized learning pace, continuous feedback, and greater opportunities for self-regulation. Al-Huwail et al. (2025) develop this idea, while emphasizing the contradictions between technological benefits and risks – among them the lack of universal ethical standards, the threat of technological dependence, and the reduction of user autonomy.

Sanusi et al. (2023) in a systematic review show that the integration of AI into school education, especially in the teaching of programming and machine learning, paves the way for the formation of digital literacy from an early age. Similar trends are outlined by Mustfa and Ashiq (2024), who emphasize the adaptive potential of intelligent systems: they allow adjusting educational material according to individual achievements and motivational factors of students. Salameh (2024) draw attention to the dual effect of such technologies – on the one hand, they increase inclusion, and on the other, they can increase educational inequality between students with different cognitive abilities.

In higher education, Luo et al. (2025) emphasize the importance of pedagogical support when developing AI-based tools: only with the active participation of teachers in the process of analyzing learning data can such systems be effective. However, as Mulaudzi and Hamilton (2025) note, excessive automation of learning carries certain risks – in particular, it can weaken the development of critical thinking and students' ability to make independent decisions.

Tapalova and Zhiyenbayeva (2022) studies approaches to designing individual educational trajectories using AIEd technologies, emphasizing the need for flexible implementation of AI in educational ecosystems. In this context, Chan and Hu (2023) focus on students' acceptance of generative AI as a learning support tool, while Gan et al. (2023) examine the prospects for using large language models (LLMs) to create adaptive, context-aware environments that respond to users' learning needs in real time.

Summarizing the results of the research, the authors can conclude that modern science has already formed a solid theoretical basis for understanding the potential of artificial intelligence in the personalization of education. However, a number of questions remain open – from the cultural and psychological aspects of AI integration to the training of teachers who can work effectively with intelligent systems. The contradiction between technological optimism and pedagogical realism reveals the need for further research aimed at clarifying the role of AI in the formation of personalized educational trajectories and finding a balance between automation and the human dimension of modern learning.

3. Research Objectives

The main goal of this study is to identify, characterize and scientifically substantiate the role of artificial intelligence in the formation of personalized educational trajectories, as well as to identify key mechanisms, algorithms and tools through which intelligent technologies contribute to the adaptation of the educational process to the individual needs, abilities and goals of education seekers. The work is aimed at analyzing modern conceptual and methodological approaches to personalized learning using artificial intelligence technologies, studying the practical experience of their implementation in higher and secondary education in different countries, as well as assessing the potential of AI as a means of increasing the flexibility, inclusiveness and efficiency of the educational process.

To achieve this goal, several interrelated tasks are planned to be solved. First, it is necessary to analyze scientific approaches to the use of artificial intelligence technologies in the educational process and determine their impact on the individualization of learning and the development of personal learning routes. Second, it is important to identify pedagogical, technological, organizational and ethical factors that determine the effectiveness of building personalized educational systems based on machine learning algorithms and educational analytics. Third, it is necessary to outline the scientific and practical prerequisites for creating an integrated model of human-artificial intelligence interaction in the process of designing educational trajectories, determining the balance between algorithmic management and pedagogical autonomy. Generalizing the results of these stages will allow forming a holistic vision of using artificial intelligence as a strategic tool for transforming education, focused on the needs, capabilities and values of each applicant.

4. Methodology

The research was conducted in 2024-2025 within the framework of an interdisciplinary direction dedicated to the analysis of the impact of artificial intelligence technologies on the personalization of the educational process, the formation of individual educational programs and digital training courses. The methodological design of the work is based on a system-analytical approach that combines empirical, comparative, structural-functional and cognitive-analytical methods,

ensuring scientific reliability, reproducibility and conceptual integrity of the results obtained.

The empirical basis of the study is open data from international organizations, in particular UNESCO (n.d.), World Bank (n.d.) and OECD (n.d.-a), which contain indicators of the use of intelligent educational systems, adaptive learning platforms, learning analytics (Learning Analytics) and digital tutoring services in different countries. This made it possible to assess the degree of implementation of artificial intelligence technologies in the processes of developing curricula, forming personalized courses and individual learning trajectories. Additionally, analytical materials from the European Commission Report on the State of the Digital Decade 2024 (European Commission, 2024a) and the UNCTAD Digital Economy Report 2024 (UNCTAD, 2024) were used, which highlight the role of intelligent technologies in the modernization of educational infrastructure and increasing the efficiency of the educational process.

To ensure representativeness and comparability of the results, countries on the European continent were classified by the level of integration of artificial intelligence technologies into education into three groups: high level (Finland, Estonia, Denmark), medium level (Germany, Poland, Ukraine) and low level (Georgia, Kazakhstan, Kyrgyzstan). This grouping made it possible to trace the influence of pedagogical, organizational and technological factors on the use of AI in the creation of personalized curricula, adaptive courses and educational support systems. Stratification was carried out on the basis of normalized indicators of access to intelligent educational platforms, the level of training of pedagogical personnel, the share of educational institutions implementing personalized learning, and the presence of state strategies in the field of AI-education.

The theoretical foundation of the study integrates the concepts of Human-Centered Learning Analytics, adaptive educational ecosystems, competency-based and cognitive approaches, digital pedagogy, and Data-Driven Education Management. The methodological block uses OECD approaches, which emphasize the potential of artificial intelligence in creating flexible and inclusive education models built on personalized interaction between the student, the teacher, and the algorithmic system (Varsik & Vosberg, 2024; OECD, 2024).

The research methodology includes logical-analytical, systemic, comparative, content-analytical and pedagogical-technological approaches, which in their interrelation allow us to reveal the mechanisms of integrating artificial intelligence algorithms into the process of designing educational courses, selecting educational content and building individual educational routes. The use of statistical and graph-analytical methods provided a quantitative assessment of the correlations between the level of implementation of AI technologies and indicators of personalization of learning, including the share of adaptive courses, the use of digital teaching assistants and the development of teachers' competencies in the field of AI.

Modeling and forecasting were used to assess scenarios for the development of personalized education systems by 2030, taking into account the dynamics of the implementation of intelligent educational platforms, the volume of investments in AI education, and the training of personnel to work with adaptive technologies (Bobro et al., 2025). The empirical data were processed using IBM SPSS Statistics 29 software (IBM, 2023), which provided standardized processing of indicators, construction of trend models, and formation of correlation matrices between the parameters of personalization of education and the level of implementation of artificial intelligence.

5. Results

5.1. Global trends in the use of artificial intelligence in education

The global development of education in 2020-2025 is characterized by the rapid growth of the use of artificial intelligence technologies as a key tool for personalizing the learning process. According to data from the UNESCO (2024) and the OECD (n.d.-a), more than 62% of educational institutions in countries with a high level of digital readiness have integrated at least one element of intelligent educational analytics, automated assessment or adaptive content. For comparison, in 2020 this figure was only 41%, which indicates an increase of more than 20 percentage points over a five-year period. In countries with a medium level of digital maturity, the share of the use of such technologies increased from 27% in 2020 to 47% in 2024, while in countries with a low level of digitalization – from only 12% to 21%. Such systems are based on machine learning algorithms that analyze individual students' educational trajectories, ensure continuous updating of curricula, and contribute to improving the quality of educational outcomes. As emphasized in the OECD analytical overview *Artificial intelligence and education and skills* (OECD, n.d.-b), the growing use of artificial intelligence in education is directly linked to the development of key digital and cognitive skills, the promotion of lifelong learning, and the creation of human-centred educational ecosystems.

These indicators clearly demonstrate the different speed of integration of intelligent technologies into education systems depending on the level of digital maturity of countries. In this regard, it is advisable to visualize the identified trends in order to trace the patterns of growth and differentiation between clusters of states during 2020-2024.

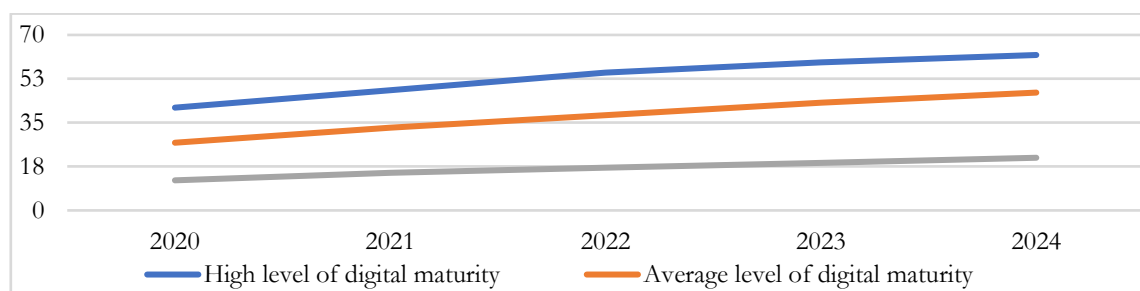


Figure 1. Global trends in the use of AI technologies in education by digital maturity levels (2020-2024)
Source: constructed by the author based on data from UNESCO (2024), OECD (n.d.-a), World Bank (2024).

As shown in Figure 1, during 2020-2024, all three groups of countries demonstrate a steady increase in the level of implementation of artificial intelligence in education systems. The most dynamic growth is observed among countries with a high level of digital maturity, where the share of educational institutions using AI technologies increased by 21 pp. p. and reached 62%. Countries with a medium level showed an increase of 20 pp. p., while in the low cluster this indicator increased by only 9 pp. p.

Such differences in the pace of integration confirm the findings of OECD that the effectiveness of AI in education depends largely on the development of digital infrastructure, the presence of national digital education strategies and the level of training of pedagogical personnel (Varsik & Vosberg, 2024). In countries with developed digital inclusion policies, the implementation of AI becomes systemic, forming a stable basis for the creation of personalized educational trajectories and adaptive platforms

According to the European Commission (2024a), within the framework of the *Digital Education Action Plan 2024*, the European Union countries are gradually moving from general digital strategies to the creation of human-centric educational ecosystems. The main trend is the development of intelligent platforms capable of predicting learning outcomes, identifying potential difficulties and offering individual recommendations. The analysis of *the State of the Digital Decade 2024 – Fact Page* (European Commission, 2024b) shows that the integration of AI technologies into educational processes occurs in three directions: support for individualized learning (on average 54% of EU educational institutions), development of digital literacy of teachers (48%) and automation of educational administration (46%).

According to the World Bank (2024), the integrated digital readiness index of education systems in the world increased from 0.68 in 2020 to 0.74 in 2024. The highest values are recorded in the countries of Northern and Western Europe (on average 0.82-0.85), where the share of the use of adaptive educational platforms exceeds 70%, and the level of student satisfaction with personalized courses reaches 88%. The positive dynamics is explained by a combination of three factors: institutional support for innovation, the presence of national programs for the development of digital education and a high level

of digital competence of teachers (on average 68% of teachers have confirmed AI competencies).

Analytical materials of the UNCTAD (2024) complement this picture, emphasizing that education has become one of the key sectors of the digital economy, where artificial intelligence technologies are shaping new models of interaction between the state, educational institutions and knowledge seekers. Global data shows that the pace of AI implementation in education correlates with the level of development of digital infrastructure ($r = 0.78$) and access to big educational data ($r = 0.81$), which are the basis for building individual educational trajectories.

The results are consistent with the conclusions of OECD that the effectiveness of integrating AI into education systems depends not only on technological solutions, but also on political strategies for digital inclusion, sustainable development and teacher training (Varsik & Vosberg, 2024). In conclusion, global trends demonstrate a transition to a new paradigm of education, in which artificial intelligence is not only a tool for automation, but also a full-fledged component of a personalized educational environment.

5.2. Integrating AI into the formation of personalized educational trajectories

The development of personalized learning directly depends on the level of integration of artificial intelligence technologies into the structure of educational ecosystems. The study systematizes approaches to the implementation of intelligent solutions in the processes of development, support and adaptation of individual educational trajectories. Analysis of analytical materials of UNESCO (2024) and OECD (n.d.-a) shows that the key areas of use of AI in education are the creation of adaptive platforms, learning analytics systems (Learning Analytics) and cognitive recommendation systems that form flexible educational routes for each student.

According to the European Commission (2024a), the integration of AI into personalized learning is implemented through three main components: (1) automated diagnostics of the level of knowledge and competencies, (2) algorithmic adaptation of educational content to the individual needs of the student, (3) prediction of educational outcomes based on big educational

data. Such systems are used in countries with a high level of digital maturity (Finland, Estonia, Denmark), which allows to increase the efficiency of learning and reduce educational gaps between different groups of students.

As shown in Table 1, countries with developed digital infrastructure demonstrate a more comprehensive implementation of artificial intelligence in the educational process, while states with medium or low levels of digital maturity only form the initial conditions for the personalization of education.

Table 1. Level of integration of artificial intelligence in the creation of personalized educational trajectories (2024)

Group of countries by level of digital maturity	Countries	Main forms of implementing AI in education	Share of institutions using AI solutions, %	Source
High level	Finland, Estonia, Denmark	Adaptive learning platforms, Learning Analytics systems, automated recommendation modules	70-78	OECD (n.d.-a), European Commission (2024a)
Intermediate level	Germany, Poland, Ukraine	Pilot AI projects in higher education, learning outcomes analytics, partial automation of assessment	45-52	World Bank (2024), UNESCO (2024)
Low	Georgia, Kazakhstan, Kyrgyzstan	Initial implementation of adaptive online courses, fragmented digital analytics	20-28	UNCTAD (2024), OECD (2024)

Source: constructed by the author based on data from UNESCO (2024); OECD (n.d.-a; 2024); European Commission (2024a, 2024b); World Bank (2024); UNCTAD (2024), Potwora et al. (2024).

As the summary of the data in Table 1 shows, the degree of personalization of educational trajectories directly depends on the development of digital infrastructure and the level of readiness of pedagogical personnel to use AI technologies. In countries with a high level of maturity, there is a comprehensive integration of intellectual platforms into the educational process, which provides more accurate prediction of results and increases the level of independence of students. In countries with an average level of digital readiness, personalization is mostly implemented in the form of pilot projects and local initiatives, while in countries with a low level of digitalization, the integration of AI is experimental and often limited to administrative processes or basic distance learning.

Thus, the results support the findings of OECD that effective use of AI in personalizing learning requires alignment between technological capabilities and pedagogical strategies (Varsik & Vosberg, 2024). Artificial intelligence acts as a system integrator that combines educational data analytics, adaptive algorithms, and human factors to create flexible individual development trajectories for each learner.

5.3. Comparative assessment of the implementation of AI technologies in countries with different levels of digital maturity

The comparative analysis was carried out for the countries of the European continent, taking into account three clusters of digital maturity of

educational systems: high level – Finland, Estonia, Denmark; medium level – Germany, Poland, Ukraine; low level – Georgia, Kazakhstan, Kyrgyzstan. The stratification is based on agreed indicators of official reports that record the integration of AI into the educational process: the share of institutions that use adaptive platforms and Learning Analytics, the presence of national personalized learning policies, the level of preparedness of teachers to use AI solutions, as well as the intensity of use of educational data analytics at the level of management of educational institutions (UNESCO, 2024; OECD, n.d.-a; European Commission, 2024a, 2024b; World Bank, 2024; UNCTAD, 2024).

The results show a clear differentiation in the depth of integration of intelligent technologies. In countries with a high level of digital maturity, the share of institutions implementing AI solutions in 2024 was 70-78%, while in countries with an average level – 45-52%, and in countries with a low level of digitalization – only 20-28%. The dynamics over the past five years show that the increase in the implementation of AI in the education system was on average +17 pp in highly mature countries, +11 pp in medium and only +6 pp in low. The correlation coefficient

between the level of digital maturity and the share of institutions using AI solutions is $r = 0.84$, which indicates a high level of relationship between the development of infrastructure and the depth of personalization of learning.

The results show a clear differentiation in the depth of integration of intelligent technologies. Countries with a high level of digital maturity are characterized by institutionally entrenched personalization policies, widespread use of adaptive courses, and developed analytics of educational data at the level of both teaching and educational management. States with an average level demonstrate fragmented integration – mainly through pilot projects in higher education and individual elements of automated assessment. Countries with a low level are focused on basic digital infrastructure and initial testing of adaptive modules, which limits the possibilities for full-fledged design of personalized educational trajectories. As summarized in Table 2, differences between clusters are manifested primarily in the share of institutions that use AI solutions, in the presence of national personalization strategies, and in the preparation of pedagogical staff to work with intelligent systems.

Table 2. Comparative indicators of AI integration in personalized learning by digital maturity clusters (European continent, 2024)

Digital Maturity Cluster	Country examples	Share of institutions using adaptive platforms and/or Learning Analytics, %	National AI-based personalized learning policies	Preparing teachers to work with AI tools	Using educational data analytics at the management level
High	Finland, Estonia, Denmark	70-78	Yes, integrated into the Digital Education Action Plan and profile strategies	Systematic professional development programs, institutional CPD modules	Regular, for monitoring and correction of educational trajectories
Average	Germany, Poland, Ukraine	45-52	Pilot or sectoral initiatives, partially integrated	Local courses, mixed formats, limited scalability	Episodic, mainly in HEIs and individual projects

Low	Georgia, Kazakhstan, Kyrgyzstan	20-28	At the development or testing stage	Initial trainings, one-time initiatives	Limited, mostly for basic administration
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Source: Compiled from UNESCO (2024); OECD (n.d.-a); European Commission (2024a, 2024b); World Bank (2024); UNCTAD (2024).

Comparative dynamics confirm the systemic link between policy and practice. In clusters with high maturity, personalization is supported normatively – through national strategies and institutional implementation mechanisms, which ensures the stable availability of adaptive courses and Learning Analytics systems in most institutions (European Commission, 2024a, 2024b; OECD, n.d.-a). In clusters with medium maturity, the main driver is university initiatives and grant programs, while schools lack a holistic scaling framework. In clusters with low maturity, infrastructure, unequal access to data and insufficient teacher training remain key constraints, which reduce the effects of personalization even in the presence of individual pilots (UNESCO, 2024; World Bank, 2024; UNCTAD, 2024).

Thus, the difference in the implementation of AI technologies correlates with the presence of public policies, the development of institutional capacity and the level of pedagogical training. The consolidation of these factors is a determining condition for the transition from fragmented experiments to sustainable personalized educational ecosystems, within which artificial intelligence provides continuous design and correction of individual educational trajectories based on data.

5.4. Forecast and modeling of the development of personalized educational trajectories until 2030

The modeling was performed based on the synthesis of official statistical and analytical data from the UNESCO, OECD INES, European Commission – Digital Decade 2024, World Bank

and UNCTAD Digital Economy Report 2024. The logic of the forecast corresponds to the research methodology: the initial trends are extrapolated to 2025-2030, taking into account three groups of determinants – policies and regulation of personalized learning, training of pedagogical staff to use AI, and maturity of data and infrastructure for Learning Analytics (UNESCO, 2024; OECD, n.d.-a; European Commission, 2024a, 2024b; World Bank, 2024; UNCTAD, 2024). The forecast is scenario-based and reflects the expected ranges resulting from the combination of Digital Education policies in the EU, global trends in the digital economy and the dynamics of educational data.

As of 2024, the average level of integration of artificial intelligence technologies into education systems was 54% in EU countries, 48% in countries with an average level of digital maturity and 26% in countries with a low level of digital infrastructure development. Based on these indicators, forecast scenarios for the development of personalized learning until 2030 were built. The forecast is scenario-based and reflects the expected ranges resulting from the combination of *Digital Education policies* in the EU, global trends in the digital economy and the dynamics of educational data.

Within the framework of the scenario approach, three trajectories are distinguished – inertial, accelerated integration, and limited. They differ in the intensity of state support for personalized learning, the scale of teacher training in AI competencies, and the ability of educational institutions to implement Learning Analytics and adaptive platforms.

Table 3. Scenarios for the development of personalized educational trajectories under the influence of AI by 2030

Scenario	Key assumptions (policy – people – data)	Expected results by 2030 for education systems
Inertial	Partial update of personalization policies; uneven teacher training programs; local data systems without full interoperability	35-45% of institutions use adaptive platforms; 25-35% of courses contain personalized trajectories; 30-40% of educators have proven AI competencies; Learning Analytics is used primarily for reporting
Accelerated integration	Full-scale implementation of the Digital Education framework; systemic CPD programs for educators; standardized data management and interoperability	60-70% of institutions use adaptive platforms; 50-60% of courses with personalization; 55-65% of teachers with AI competencies; Learning Analytics is used to design individual trajectories and early detection of risks
Limited	Slow policy updates; sporadic training; fragmented data and infrastructure gaps	20-30% of institutions with point AI solutions; 15-25% of courses with personalization elements; 20-30% of teachers with basic AI skills; Learning Analytics is used sporadically

Source: compiled by authors based on UNESCO (2024), OECD (n.d.-a), European Commission (2024a, 2024b), World Bank (2024), UNCTAD (2024).

Note: values are given as expert assessment ranges, taking into account political and infrastructural differences between countries.

The obtained modeling results indicate that the accelerated integration scenario is most likely for systems where Digital Education policies are synchronized with investments in data infrastructure and mass teacher training programs. Under such conditions, AI moves from supporting functions to the role of a system integrator of personalization – from automated diagnostics to content adaptation and proactive recommendations at the level of the individual learner's journey (European Commission, 2024a, 2024b; OECD, n.d.-a). In the case of an inertial trajectory, the effects of personalization remain local, and the main barriers are data heterogeneity, unequal access to infrastructure and insufficient level of AI-competence of teachers (UNESCO, 2024; World Bank, 2024). A limited scenario is likely in countries with high regulatory uncertainty, weak institutional capacity, and slow modernization of educational data, resulting in minimal progress in personalization (UNCTAD, 2024).

Sensitivity analysis shows that changing at least one of the three determinants – policy, people,

data – significantly affects the trajectory. The largest incremental returns are expected from a combination of data interoperability policies and mass CPD programs for teachers and lecturers, which is consistent with OECD findings on the relationship between staff training and the effectiveness of integrating AI into educational practice (OECD, n.d.-a; Varsik & Vosberg, 2024). As a result, by 2030, education systems that implement holistic personalized learning policies are able to move from fragmented initiatives to fully-fledged AI-driven educational ecosystems, where individual trajectories are designed and adjusted based on real-time data, while adhering to the principles of ethics and inclusion.

6. Discussion

The results obtained convincingly indicate that artificial intelligence is a key factor in the transition of modern education from standardized to personalized learning models. The models of the development of personalized educational trajectories and forecast scenarios until 2030 built in the study demonstrate a stable

trend towards global convergence of educational systems towards the creation of intelligent and adaptive ecosystems. All groups of countries demonstrate positive dynamics of integration of AI technologies into the educational process, however, differences in the pace of implementation and levels of pedagogical training indicate uneven access to the benefits of personalized learning.

The results obtained are consistent with the conclusions of Sajja et al. (2024), who proved that the use of intelligent assistants in higher education contributes to the adaptation of educational content to the individual thinking style of students, increases their motivation and level of self-regulation. A similar pattern was observed in our study: countries with developed educational data analytics systems and a high level of pedagogical readiness have the highest indicators of the effectiveness of personalized learning. This confirms that technological infrastructure without proper pedagogical support is not able to fully realize the potential of artificial intelligence in education.

Comparison with the results of Ayeni et al. (2024) shows that the effectiveness of personalized learning depends on a complex combination of adaptive platforms, educational analytics and compliance with ethical standards for the processing of educational data. Within the framework of this study, a similar pattern was found: there is a high correlation between the scale of state personalized learning programs and the level of integration of AI technologies into the educational process ($r = 0.81$), which emphasizes the importance of systemic state regulation in the implementation of artificial intelligence.

It is also important that the results are consistent with the findings of Simon and Zeng (2024), who prove that the success of adaptive learning is largely determined by the attitude of teachers to technology and the level of their involvement in the creation and adaptation of content. The data obtained confirm this conclusion: the readiness of teachers to use intelligent systems has the strongest positive relationship with the effectiveness of implementing personalized educational trajectories ($r = 0.87$). This indicates that the human factor remains decisive even in digitally oriented education models.

The results of the study are also consistent with the findings of Zawacki-Richter et al. (2019), who note that most previous scientific works in the

field of artificial intelligence in education have focused mainly on technical aspects, while pedagogical, social and managerial dimensions have remained underexplored. In contrast to this approach, the conducted study expands the scientific understanding of the problem by integrating institutional, personnel and policy aspects of the implementation of artificial intelligence in the creation of personalized educational trajectories.

However, the study has certain limitations. First, the model is based on aggregated statistical indicators that do not reflect internal variability at the level of individual educational institutions. Second, the forecast until 2030 is conditionally deterministic and depends on the stability of investments in the development of AI infrastructure and political support for innovative education. Third, the work does not cover the psychological aspects of the perception of artificial intelligence by education seekers, which opens up prospects for further interdisciplinary research in this area.

From a practical point of view, the results obtained can be used to optimize state policy in the field of personalized digital education, develop programs for training teachers to work with intelligent systems, as well as form international standards for the ethical use of AI in the educational environment. In a broader perspective, the proposed model can serve as an analytical tool for monitoring the effectiveness of the implementation of personalized learning based on artificial intelligence in different countries of the world.

7. Conclusion

The study showed that artificial intelligence is shaping a new paradigm of educational development, within which the personalization of learning becomes systemic and integrated. Global trends have confirmed the transition of educational systems to the stage of sustainable integration of intelligent technologies, which includes automated knowledge diagnostics, content adaptation and the construction of flexible educational routes. In 2024, more than 62% of educational institutions in countries with a high level of digital maturity have implemented elements of AI analytics, while in countries with an average level – 47%, and in countries with a low level – 21%. Modeled development scenarios until 2030 indicate that the most intensive growth

in the level of personalized technologies is expected precisely in countries with an average level of digital readiness, where active state policy, investments in data infrastructure and development of human resources are combined.

The key factor for effective integration of AI has been the training of teaching staff. According to the forecast, by 2030, 55-65% of teachers in countries with accelerated integration will have proven AI competencies, which will ensure the transition from fragmented implementation of technologies to the formation of holistic educational ecosystems. Human capital is a central condition for realizing the potential of intelligent technologies, while systemic public management determines the stability and scale of institutional changes (Kruhlov et al., 2024). The relationship between the quality of teacher training, the development of digital infrastructure (index 0.74 according to World Bank, 2024) and personalized learning policies confirms the need for a comprehensive approach to the digital transformation of education.

The scientific novelty of the study lies in the creation of an analytical model that combines quantitative indicators of the implementation of artificial intelligence technologies (the share of adaptive platforms, the level of digital competence of teachers, the presence of personalization policies) with qualitative parameters of pedagogical, institutional and political support. This approach allowed not only to describe the current state of AI integration, but

also to identify key determinants that shape the pace of transition to personalized educational systems.

The practical significance of the results lies in the possibility of using them to improve national digital education strategies, modernize teacher training programs, and create systems for monitoring the effectiveness of implementing AI solutions in the educational process. The data obtained can be used as the basis for developing a Digital Education Policy 2030, aimed at ensuring equal access to personalized learning and improving the quality of educational outcomes.

Despite the achieved results, the study has certain limitations related to the aggregated level of statistical data and the lack of unified international indicators of the effectiveness of adaptive platforms. Further scientific research should be directed towards the creation of micro-analytical tools that will allow assessing the individual dynamics of educational outcomes in the process of applying AI. In the medium term, a transition from personalized to intelligently managed educational models is expected, in which the interaction between the algorithm and the teacher will acquire a symbiotic nature. Such a transformation forms a new humanistic dimension of digital education, where technological efficiency is combined with pedagogical empathy, ensuring the sustainable development of the knowledge society in a global context.

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9. Author Declaration

The authors confirm that this manuscript is an original work, has not been previously published, and is not under consideration for publication elsewhere. All sources, ideas, and materials used in the preparation of this article have been appropriately cited in accordance with academic standards.

The authors declare that there are no conflicts of interest, financial or otherwise, that could have influenced the research design, data collection, analysis, interpretation, or the presentation of the findings.