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Artificial intelligence in geographical education of Kazakhstan and Uzbekistan: Revolution of knowledge and approaches

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Abstract

In geographic education, artificial intelligence (AI) opens new opportunities for spatial data analysis, personalized learning and the development of interactive educational platforms. This study aims to assess the current state of artificial intelligence (AI) integration into geographic education in Kazakhstan and Uzbekistan, identify key challenges and determine future development prospects. Methodology – The research is based on a comprehensive analysis of scientific literature, national educational policies and data collected through an online survey of 966 geography teachers from Kazakhstan and Uzbekistan. The survey included questions on AI knowledge, readiness for AI implementation and perceptions of digital technologies in education. A correlation analysis was conducted to identify key trends and differences between the two countries. The study findings revealed that Kazakhstan demonstrates a more active integration of AI into school curricula, whereas Uzbekistan focuses on fundamental AI research and the development of national educational platforms. The main obstacles include low digital literacy among educators, a shortage of qualified specialists and limited access to advanced technologies. Conclusion – the successful implementation of AI in geographic education requires improvements in teacher training programs, the expansion of digital infrastructure and the development of government-led initiatives aimed at supporting educational technologies. The study's findings can be valuable for educational policymakers, school administrators, and educators seeking to integrate AI into the learning process. Enhancing teachers' digital competencies and ensuring access to modern technologies are crucial conditions for the effective use of AI in geographic education.

Keywords: Artificial intelligence, Digitalization, Educational technologies geographic information systems, Geographical education.

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1. Introduction

New technologies in education today are associated with digitalization, the use of new communication technologies and the application of artificial intelligence. The growing scale and depth of research is an unconditional evidence of the relevance of the problem [1, 2]. The focus is on issues of data transfer speed, technical innovations and software products used in education, their accessibility for the mass consumer, the level of information literacy and readiness to use technological advances, the effectiveness of VR/AR technologies in the educational process, the interaction of universities and ed-tech companies, etc. [3].

In recent decades artificial intelligence (AI) has rapidly penetrated into various spheres of life, transforming traditional educational systems around the world. Kazakhstan and Uzbekistan as leading countries of Central Asia are actively introducing digital technologies into educational processes, including the system of geographical education.

Geography is a science about spatial processes and relationships that requires complex analysis of large volumes of data. In the context of digitalization, modern AI technologies allow to improve the level of geographical education, providing a deeper understanding of natural and socio-economic processes. Machine learning, neural network models and geographic information systems (GIS) open up new horizons for teachers and students, making learning more interactive, adaptive and personalized [4, 5].

In Kazakhstan, the introduction of AI into the educational process is supported by government initiatives aimed at digitalizing education. The development of “smart” educational platforms and automated systems for analyzing geographic data contributes to the formation of new approaches to studying geography [6, 7]. Uzbekistan is also actively implementing AI technologies, including digital maps, virtual simulations and big data analysis, which allows students to better understand spatial patterns and predict changes in the environment [8].

However, the process of digital transformation of education in the region faces a number of challenges. It is necessary to modernize curricula, train teachers in new digital competencies, and ensure access to modern technologies for all students. Despite these difficulties, the integration of AI into geographic education in Kazakhstan and Uzbekistan is a promising direction that can improve the quality of training specialists and contribute to the formation of a new generation of researchers and analysts.

The relevance of this study is due to the current state of the geographical education system in Kazakhstan and Uzbekistan, the requirements of socio-economic transformation, the country's integration into the global educational space, as well as the structure and dynamics of development of modern society. These processes depend on a number of factors.

Firstly, one of the key areas of modernization of education is its digitalization, which contributes to the increase of accessibility, efficiency and quality of education in the education system. Modern technologies are actively introduced into the educational process, which determines the need to prepare future geography teachers to use digital tools in pedagogical activities. This task is becoming one of the priorities for higher education institutions.

Secondly, modern society must be prepared for the challenges of the digital age, where technology is an integral part of both social development and personal growth. Future geography teachers must be competent in using digital resources and tools necessary for professional activity, which necessitates their integration into educational programs for teacher training.

Thirdly, a high level of digital competencies is an important factor in the competitiveness of specialists in the labor market, ensuring their ability to adapt to the rapidly changing educational environment. Free possession of digital tools will allow future geography teachers to effectively use geographic information systems, cartographic services, geoportals, web resources and other technologies both for their own professional development and in educational practice.

Digitalization of the educational process brings qualitative changes to teaching methods, contributing to the revision of traditional approaches to learning and student development. Future geography teachers should be ready to implement innovative pedagogical technologies, including online learning, digital educational resources and virtual laboratories.

2. Materials and Methods

2.1. Literature review

Digitalization of education is a global trend aimed at improving the quality of the educational process. According to research Al Darayseh [9] artificial intelligence technologies in education contribute to the improvement of learning efficiency, personalization of content and development of adaptive educational programs. Research Amin, et al. [10] indicates that AI can analyze the performance of individual students, helping teachers develop flexible teaching strategies. This is especially relevant in geography education, where data analysis plays a key role.

The development of digital educational platforms and the use of GIS technologies in geography teaching in Kazakhstan and Uzbekistan are considered in a number of scientific papers. A study [11] notes that modern educational systems need the integration of AI to process large amounts of data and model spatial phenomena.

Geographic information systems play an important role in geography teaching by providing interactive methods for analyzing geospatial data. Several studies Lee [12] and Ahmed [13] emphasize that the integration of AI into GIS allows not only to automate the processing of cartographic information, but also to predict environmental changes.

In Kazakhstan, digitalization of geographic education includes the active introduction of GIS technologies into school and university programs. Research Li, et al. [14] notes that the use of GIS with AI elements helps students analyze complex spatial patterns and develop predictive models. Uzbekistan is also working on digitalization of education. Research Redican, et al. [15] shows that the introduction of GIS and machine learning algorithms allows automating the processes of analyzing climate and demographic data, making geography education more practice-oriented.

Personalized educational systems using AI can adapt course content to individual learners' needs. According to Bhimdiwala, et al. [16] AI technologies help automate the learning process, identify gaps in learners' knowledge, and offer personalized assignments.

With the advancement of artificial intelligence (AI) and generative language models such as ChatGPT, new opportunities have emerged to support self-regulated learning. In the study by Ng, et al. [17] research on the implementation of AI chatbots to enhance the quality of science education and support students' self-regulated learning strategies is explored.

Project-Based Learning (PBL) is one of the most effective pedagogical strategies for developing key student competencies, such as critical thinking, collaboration, and autonomy. With technological advancements, AI has become an important tool for personalizing learning and providing adaptive feedback [18, 19].

The successful integration of AI into educational settings requires a comprehensive approach that considers both technological and social aspects. A key focus area is the development of digital literacy among educators. Teacher preparation for AI adoption should include training in digital tools, fostering a critical perspective on data and algorithms, and developing digital security skills [20]. Only with adequate preparation can teachers effectively integrate AI into the educational process while maintaining control over its impact.

Ensuring transparency and ethical AI use is equally essential. The development of clear regulatory standards for AI applications in education will help mitigate risks associated with algorithmic bias, data privacy, and the oversight of automated processes. In this context, coordination among educational institutions, technology developers, and governmental bodies is necessary to establish a fair and inclusive learning environment [21, 22].

A balanced integration of traditional and innovative teaching methods remains a fundamental principle. Despite AI's considerable potential, it should not replace teachers but rather serve as an auxiliary tool. An optimal strategy involves incorporating AI into the learning process in a way that complements conventional teaching approaches, fostering the development of both cognitive and socio-emotional competencies among students [23, 24].

In Kazakhstan, the digital transformation of education includes the development of adaptive educational platforms such as BilimLand and Daryn. Online, which are being actively implemented in educational institutions [25, 26]. They use elements of artificial intelligence that analyze students' knowledge levels and offer individual learning paths.

Virtual (VR) and augmented (AR) reality combined with artificial intelligence open up new possibilities for teaching geography, allowing students to interact with 3D maps, simulate climate processes and explore natural phenomena in an interactive way [27-29].

In Kazakhstan, VR and AR technologies are being actively introduced into the educational process, at Nazarbayev University and the country's leading pedagogical universities [30]. The use of virtual maps and simulators helps students better understand complex geographic processes. Research is being conducted in Uzbekistan on the use of VR/AR in education, in particular at the National University of Uzbekistan, where interactive programs for studying geographic objects are being developed.

Modern research in the field of artificial intelligence confirms that the more opportunities for learning using advanced digital technologies, the more dynamic and effective the education system develops. Artificial intelligence plays a key role in the teaching and learning processes, contributing to their modernization and adaptation to modern requirements. AI has a significant impact on the educational process with its capabilities, opening up new perspectives for students both now and in the future [31, 32].

Despite the significant potential of artificial intelligence in the educational process, its widespread implementation in natural science education does not guarantee an automatic improvement in the quality of teaching. One of the key reasons for this is the lack of readiness of teachers to use AI in educational activities [33]. The effectiveness of the introduction of new technologies directly depends on the attitude of teachers towards digital tools: those who are skeptical about technological innovations and prefer traditional teaching methods often avoid integrating AI into the educational process. The persistence of the traditional approach is attributed to various factors, including concerns about the complexity of new methods and a lack of relevant skills. Such barriers may hinder the use of advanced technologies in the teaching of geographic sciences [34, 35].

Modern technologies are rapidly changing the educational process, making it more visual, interactive and effective. Artificial intelligence, geographic information systems (GIS) and virtual reality technologies play an important role in teaching geography, allowing students to gain a deeper understanding of the world around them. The most important areas of their application are interactive maps and geospatial analysis, satellite monitoring of the environment, as well as gamification and virtual reality [36, 37].

One of the key achievements of artificial intelligence in geographic research is its integration into geospatial data processing systems and interactive mapping services. The use of AI allows for detailed analysis of climate change, spatial distribution of population, and natural processes in real time. In particular, machine learning algorithms used in platforms such as Google Earth provide monitoring of relief transformations, assessment of atmospheric pollution levels, and forecasting of natural disasters based on multi-parameter analysis of Earth remote sensing data. This contributes not only to an in-depth study of geographical patterns, but also to increased visibility of the educational process [38-40].

Artificial intelligence is actively used in the processing and analysis of Earth remote sensing data, facilitating the study of the dynamics of changes in the natural landscape. Machine learning algorithms provide automated detection and monitoring of processes such as glacier degradation, deforestation, urbanization and the level of water pollution. In particular, AI methods developed and applied by NASA allow for a comprehensive analysis of global environmental changes, identifying potential threats to the environment and predicting their further development. The use of relevant

geospatial data for educational purposes helps students develop a scientific approach to studying geographic and environmental processes [41].

One of the promising areas in educational practice is the use of virtual reality (VR) and augmented reality (AR) technologies, which help to increase the visibility and interactivity of the educational process. The integration of VR/AR into geography teaching allows for the modeling of spatial objects and phenomena, giving students the opportunity to study in detail geomorphological structures such as volcanoes, mountain ranges, and deep-sea ecosystems without the need for physical presence in the regions being studied. The use of these technologies helps to increase cognitive engagement and develop spatial thinking in students. An example of the successful implementation of VR solutions in the educational process is the Google Expeditions platform, which provides immersive excursions to remote geographic locations, which helps to enhance visual perception and consolidate theoretical material [42].

The introduction of artificial intelligence (AI) into geography teaching in Kazakhstan and Uzbekistan is at an early stage and is characterized by a number of initiatives and projects aimed at integrating modern technologies into the educational process.

In October 2024, Uzbekistan approved the "Strategy for the Development of Artificial Intelligence Technologies until 2030", aimed at creating conditions for the introduction of AI in various areas, including education. This strategy provides for the development of a regulatory framework, the introduction of AI in the social sphere and the training of qualified personnel. Higher education institutions such as Samarkand State University have departments specializing in artificial intelligence and information systems. The research work of these departments includes the development of artificial intelligence systems and data mining, which creates the preconditions for the introduction of AI in the teaching of various disciplines, including geography.

In Kazakhstan, within the framework of educational programs for geography teachers, special attention is paid to the development of meta-subject competencies, including digital literacy and the use of AI, also development of educational programs and improvement of digital literacy of teachers, integration of AI into school and university education. AI technologies are actively used in the educational process, but mainly in test mode.

Although specific examples of the application of AI directly in geography teaching in these countries are still few, existing initiatives and strategic plans create favorable conditions for the integration of AI into the educational process. The use of AI in geography teaching is expected to expand in the coming years, helping to improve the quality of education and students' interest in the subject. Uzbekistan focuses on creating institutional conditions for the implementation of AI, while Kazakhstan is more focused on the practical application of technology in schools.

2.2. Application of Artificial Intelligence in Geography Education: An Empirical Analysis of Pedagogical Practices in Kazakhstan and Uzbekistan

The study, which focused on the role of artificial intelligence (AI) in teaching geography in Kazakhstan and Uzbekistan, used a comprehensive methodological approach, including literature review, comparative study of educational initiatives, examination of government strategies and surveys [43, 44].

The research methodology was based on qualitative and quantitative analysis. Qualitative analysis included the study of existing educational initiatives, their impact on the process of teaching geography and promising areas of development. Quantitative analysis was used to assess the level of AI implementation in educational programs in Kazakhstan and Uzbekistan, as well as to identify trends in its use in various educational institutions.

The development of the research methodology included two consecutive stages.

At the first stage, a comprehensive analysis of regulatory standards and scientific publications related to the issue under consideration was carried out. The main materials of the study were official documents and educational strategies, including the "Strategy for the Development of Artificial Intelligence Technologies until 2030" of Uzbekistan and the digitalization programs of education in Kazakhstan. This analysis is a key component of the study, allowing to identify the current state of the scientific field, identify key trends, and identify problems and challenges associated with the integration of artificial intelligence into geographic education. The use of the document review and literature analysis method helps to develop a comprehensive understanding of existing theories, methodological approaches, and previous research findings, which provides a theoretical basis for further research.

At the second stage of the study, an empirical analysis was conducted by means of a questionnaire survey of geography teachers and master's students, implemented in the format of an online survey. The Google Forms tool was used to collect data, providing the ability to quickly distribute questionnaires via social networks and web resources, as well as ensuring the convenience of processing the obtained data.

The preliminary stage of the work included the development of a separate document, which formulated the purpose and objectives of the study, as well as questions and answer options for the questionnaire. The formation of the list of questions was based on the analysis of a large array of scientific literature and information received from respondents. The involvement of several researchers in the process of developing the questionnaire and interpreting the data is a significant factor that increases the reliability of the study, since it allows for taking into account different scientific approaches and ensuring a comprehensive consideration of the problem under study.

The study included an online survey involving representatives of the academic community, including university professors, doctoral students, master's students, and geography teachers from various cities in Kazakhstan and Uzbekistan. A total of 471 respondents from Kazakhstan and 495 respondents from Uzbekistan provided their responses, expressing their opinions on the importance of integrating artificial intelligence technologies into geography education.

The survey was conducted in three languages – Kazakh, Russian and Uzbek, which ensured coverage of a wide audience and allowed taking into account the language specifics of the respondents. The questionnaire included 12 questions grouped into 4 thematic blocks aimed at studying various aspects of the perception and use of artificial intelligence technologies in educational practice. Table 1 presents the socio-demographic characteristics of respondents from Kazakhstan (n = 471) and Uzbekistan (n = 495), including gender, length of teaching experience, and the type of educational institution where the survey participants work. The survey was conducted anonymously, and the data obtained were used solely for research purposes. The study participants were informed of the voluntary nature of their participation.

Table 1.

Distribution of respondents by length of teaching experience (n = 966).

| Features | Kazakhstan (n = 471) | Uzbekistan (n = 495) |
|--------------------------|----------------------|----------------------|
| Gender: | 102 | 120 |
| Males | | |
| Females | 369 | 375 |
| Teaching experience: | 15 | 7 |
| Less than 1 year | | |
| 1–3 years | 44 | 37 |
| 4–7 years | 85 | 97 |
| 8–10 years | 102 | 106 |
| 11–15 years | 115 | 121 |
| 16–20 years | 81 | 91 |
| More than 20 years | 29 | 36 |
| Educational institution: | 387 | 396 |
| Comprehensive schools | | |
| College | 12 | 19 |
| University | 72 | 80 |

The majority of respondents are teachers of comprehensive schools (Kazakhstan – 387 people, Uzbekistan – 396 people), which makes up the majority of the sample. The number of participants working in colleges is relatively small (Kazakhstan – 12 people, Uzbekistan – 19 people), which may be due to the limited number of disciplines, including geography courses, in the programs of secondary specialized educational institutions. The sample also includes teachers of higher education institutions (Kazakhstan – 72 people, Uzbekistan – 80 people), which ensures the participation of the academic community in the study.

The sample of respondents covers a wide range of teachers, differing in professional experience and level of educational institutions, which contributes to a comprehensive analysis of the peculiarities of perception and potential prospects for integrating artificial intelligence technologies into the system of geographical education. The data were obtained as a result of a survey conducted among teachers in Kazakhstan and Uzbekistan. The study involved teachers from various educational institutions who have experience working with AI or are interested in its application in the educational process.

Before conducting the analysis, the data were structured as a numerical array representing the number of responses in each category. To identify the degree of linear dependence between the responses of teachers from Kazakhstan and Uzbekistan, the Pearson correlation coefficient was used. It is calculated using the following formula:

$$r = \frac{\sum (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum (X_i - \bar{X})^2} \cdot \sqrt{\sum (Y_i - \bar{Y})^2}}$$

where r – Pearson correlation coefficient (shows the strength and direction of the relationship between two variables); X_i – the value of a variable for Kazakhstan (e.g. the number of teachers using AI); Y_i – variable value for Uzbekistan; \bar{X} – average of all data for Kazakhstan:

$$\bar{X} = \frac{X_1 + X_2 + \dots + X_n}{n}$$

\bar{Y} – average of all data for Uzbekistan:

$$\bar{Y} = \frac{Y_1 + Y_2 + \dots + Y_n}{n}$$

$(X_i - \bar{X})$ – deviation of each value from the average for Kazakhstan;

$(Y_i - \bar{Y})$ – deviation of each value from the average for Uzbekistan;

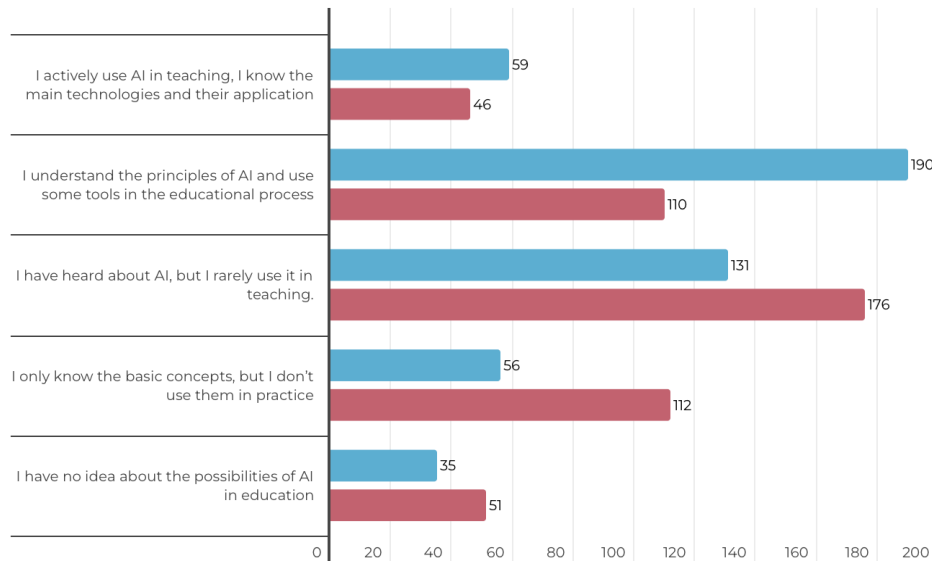
$$\sqrt{\sum (X_i - \bar{X})} - \text{standard deviation for Kazakhstan;}$$

$$\sqrt{\sum (Y_i - \bar{Y})} - \text{standard deviation for Uzbekistan.}$$

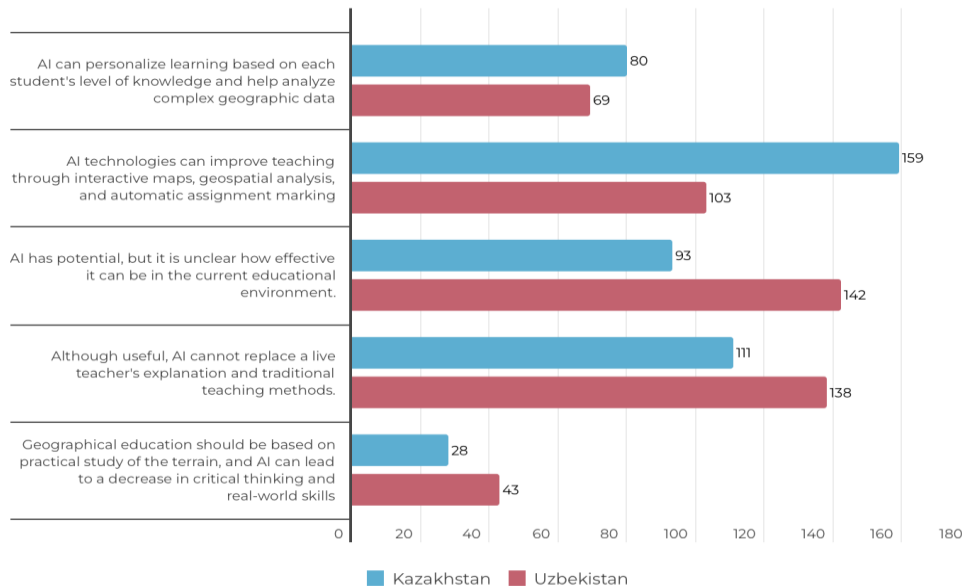
An integrated approach to forming the survey structure contributed to obtaining diverse data that allowed us to identify the level of awareness and readiness of teachers to implement artificial intelligence in the educational process, as well as to identify potential barriers and prospects for its use in geographical education.

3. Results

One of the key aspects of the study is the degree of familiarity of teachers with AI technologies. In Kazakhstan, the largest number of respondents (190 people) said that they understand the principles of AI and use some tools in the educational process. In Uzbekistan, this figure is significantly lower (110 people), indicating a less active implementation of AI in the educational system. (Figure 1).



(a) How familiar are you with artificial intelligence (AI) technologies in education?



(b) Do you think AI can improve geography education?

Figure 1.

Using Artificial Intelligence in Teaching Geography.

Another important difference is the number of people who have heard of AI but rarely use it in their education. In Uzbekistan, this group is the largest (176 people), while in Kazakhstan there are 131 such respondents. This may indicate that AI technologies are more widely used in practice in Kazakhstan. In addition, there are fewer people in Kazakhstan who are only familiar with the basic concepts but do not use AI (56 versus 112 in Uzbekistan), as well as those who have no

idea about the possibilities of AI in education (35 versus 51). This highlights the higher level of awareness of Kazakhstan teachers compared to their Uzbek colleagues.

One of the key areas where AI can demonstrate its effectiveness is geography education. AI technologies enable the use of interactive maps, geospatial analysis, and automatic assessment of assignments. In Kazakhstan, 159 people believe that this will significantly improve the teaching process, while in Uzbekistan, 103 respondents share the same opinion. In addition, 80 people in Kazakhstan and 69 in Uzbekistan note that AI can personalize learning, adjusting to the knowledge level of each student.

However, despite the recognition of AI's potential, many teachers remain skeptical about its effectiveness. In Uzbekistan, 142 people expressed doubts about how useful AI can be in the current educational reality, while in Kazakhstan there were 93 such respondents. An even larger number of respondents believe that AI cannot replace a teacher's live explanation and traditional teaching methods (111 people in Kazakhstan and 138 in Uzbekistan). This highlights that, despite technological progress, the role of the teacher remains key in the educational process.

Of particular concern is the view that geography education should be based on practical study of the area, and that AI can lead to a decrease in the level of critical thinking and real-life skills. In Kazakhstan, this point of view is supported by 28 people, in Uzbekistan – 43. This indicates the need to combine digital technologies with traditional teaching methods to avoid possible negative consequences.

Figure 2 shows the relationship between respondents' answers from Kazakhstan and Uzbekistan to questions related to the use of artificial intelligence (AI) in education. The orange dots represent specific data for each category, and the red line represents the linear regression showing the overall trend of the relationship between the two variables.

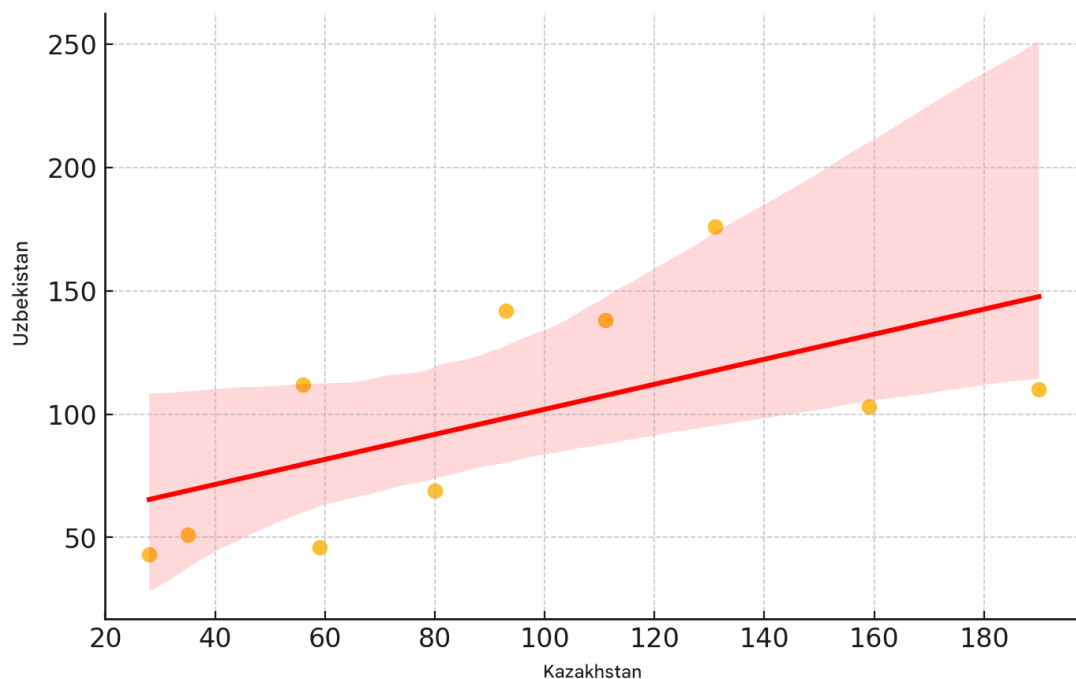


Figure 2.

Correlation of responses between Kazakhstan and Uzbekistan regarding the use of digital technologies in teaching geography.

Correlation analysis showed a positive relationship between the opinions of respondents from the two countries ($\rho=0.595$), indicating similar views on the impact of AI in the educational process. The graph shows a positive correlation between the answers of respondents from Kazakhstan and Uzbekistan. This means that the trends in the use of digital technologies in geography teaching are similar in both countries. The more teachers in Kazakhstan use certain technologies, the more teachers in Uzbekistan also use them. However, the scatter of data shows differences in the level of technology use, which may be due to different conditions of educational systems, availability of tools, or the level of training of teachers.

3.1. Using Digital Technologies in Teaching Geography.

Digital technologies have become an integral part of the geography teaching process, allowing for expanded opportunities for data visualization and analysis. According to the survey, the most popular tools are interactive maps and 3D models (Google Earth, Google Maps, National Geographic MapMaker, etc.), which are used by 107 teachers in Kazakhstan and 135 in Uzbekistan. This indicates a high demand for geographic information systems for modeling spatial objects.

A significant number of respondents use multimedia presentations and videos (74 in Kazakhstan, 96 in Uzbekistan), which indicates the need for visual reinforcement of educational material. However, online platforms for testing and

learning (Kahoot, Quizlet, Google Classroom and Moodle) are less popular in Uzbekistan (51 teachers) compared to Kazakhstan (68 teachers), which may indicate a difference in the availability of online resources and educational platforms.

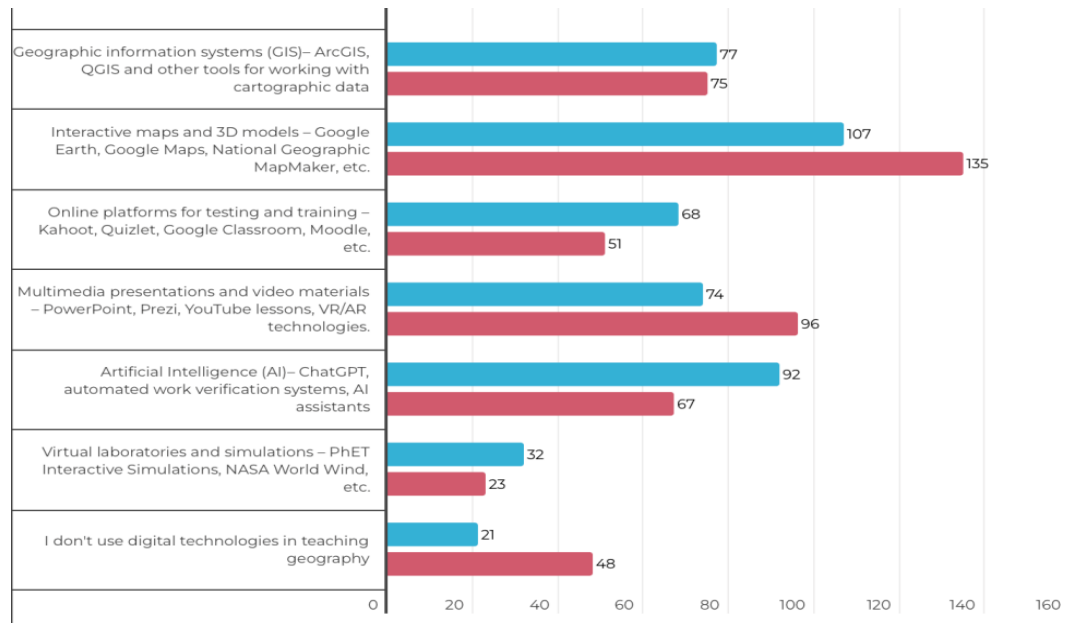
In Kazakhstan, 92 teachers use AI assistants and work assessment systems, and in Uzbekistan 67. However, virtual laboratories and simulations (PhET Interactive Simulations, NASA World Wind) remain less common tools (32 in Kazakhstan, 23 in Uzbekistan). It is also worth noting that in Uzbekistan 48 teachers do not use digital technologies, which is more than twice the same figure in Kazakhstan (21 teachers).

Teachers' attitudes towards AI potential.

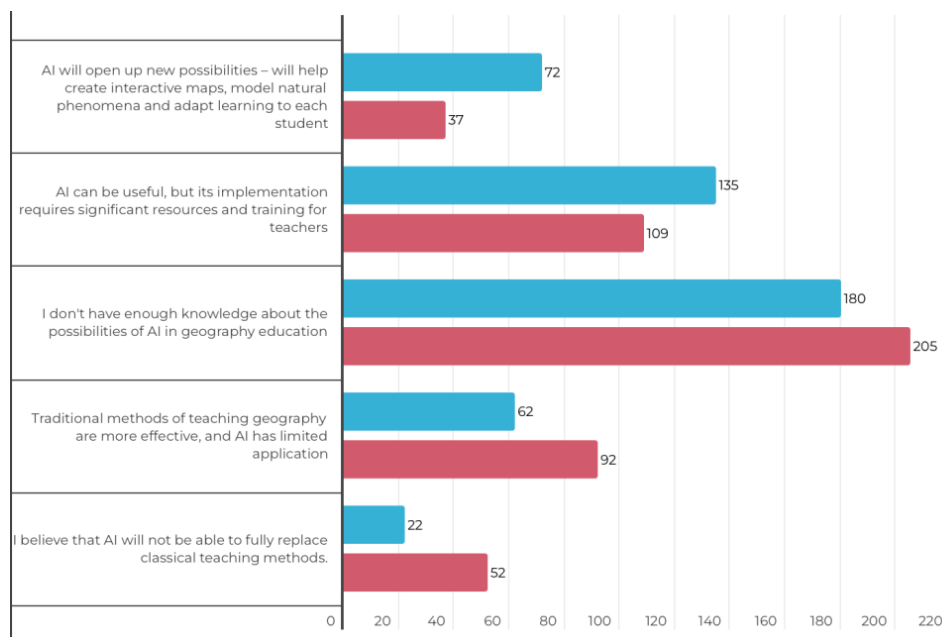
Despite the active development of artificial intelligence, many teachers do not yet have sufficient knowledge about the capabilities of AI in geography education (180 respondents in Kazakhstan and 205 in Uzbekistan). This indicates the need for additional training and advanced training of teachers.

Meanwhile, 135 teachers in Kazakhstan and 109 in Uzbekistan see benefits in using AI, but note that its implementation requires significant resources. Only 72 respondents in Kazakhstan and 37 in Uzbekistan are confident that AI will open up new opportunities, such as creating interactive maps and personalizing learning.

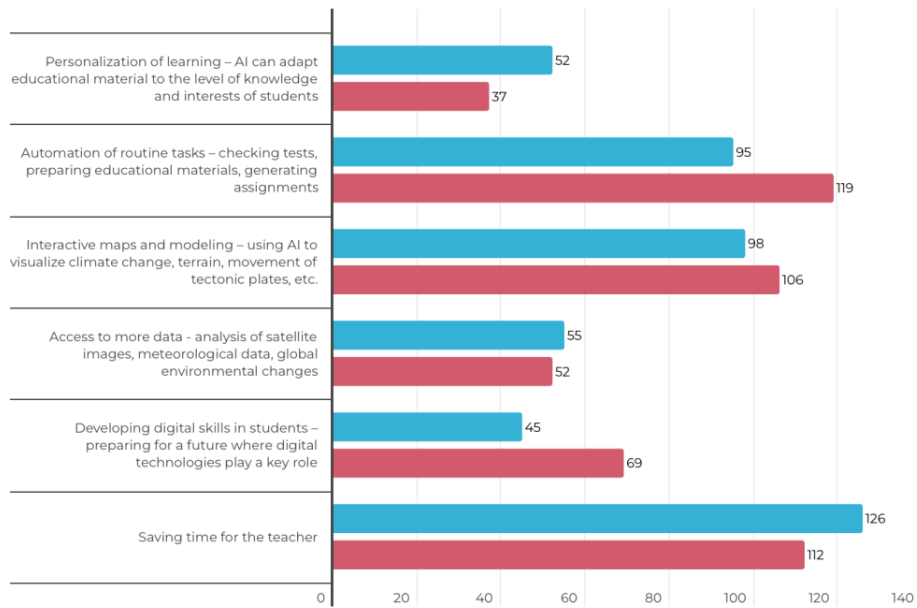
There is also caution about the complete replacement of traditional teaching methods by AI: 62 teachers in Kazakhstan and 92 in Uzbekistan consider classical methods more effective. At the same time, 22 and 52 respondents, respectively, are confident that AI will not be able to fully replace traditional approaches (Figure 3).



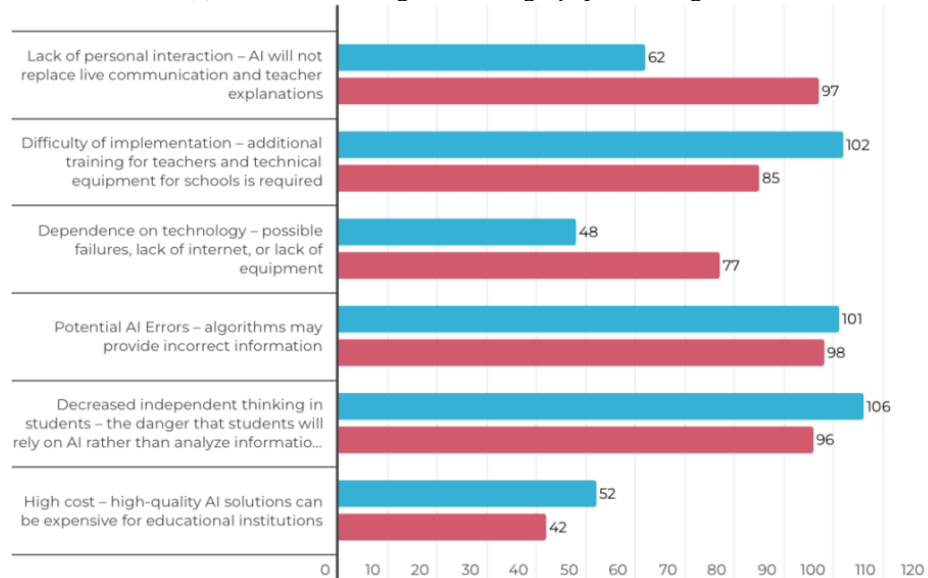
(a) What digital technologies do you already use in teaching geography?



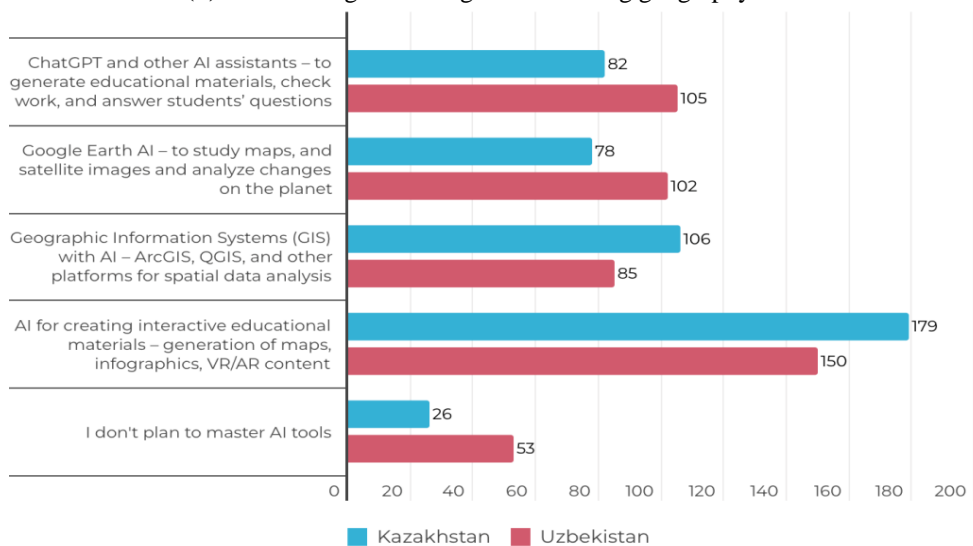
(b) Do you see the potential for AI to create interactive maps, model geographic processes or personalize learning?



(c) Benefits of Using AI in Geography Teaching



(d) Disadvantages of using AI in teaching geography



(e) What AI tools did you want to master?

Figure 3. Artificial Intelligence in Geographical Education: Pros, Cons and Prospects.

3.2. Advantages and Disadvantages of AI in Teaching Geography.

The main advantages of AI in education, according to respondents, are the automation of routine tasks (95 in Kazakhstan, 119 in Uzbekistan) and the use of interactive maps and modeling (98 and 106 teachers, respectively). It is also important that AI helps save teachers' time (126 in Kazakhstan, 112 in Uzbekistan), which allows them to pay more attention to individual work with students.

However, despite the obvious advantages, teachers see a number of serious disadvantages. One of the main risks is a decrease in students' independent thinking, as students may begin to rely entirely on AI without analyzing information on their own (106 in Kazakhstan, 116 in Uzbekistan). Also of concern is dependence on technology, possible technical failures, and a lack of necessary equipment (48 and 77 teachers, respectively).

Additional challenges are related to potential AI errors that can lead to incorrect data and distorted information (101 in Kazakhstan, 98 in Uzbekistan). In addition, the high financial costs of implementing AI remain a significant barrier for educational institutions.

The most popular tools among teachers are AI for creating interactive educational materials (generation of maps, infographics, VR/AR content). In Kazakhstan, this tool interested 179 teachers and in Uzbekistan, 150. Geographic information systems with AI are also popular (106 and 85 respondents, respectively), as well as Google Earth AI for analyzing satellite images (78 in Kazakhstan, 102 in Uzbekistan). Interest in ChatGPT and other AI assistants is also quite high - 82 teachers in Kazakhstan and 105 in Uzbekistan would like to master them for generating educational materials and checking work.

However, 26 teachers in Kazakhstan and 53 in Uzbekistan said they had no plans to learn AI tools, which may indicate skepticism or a lack of motivation to learn new technologies.

Figure 4 shows a strong positive correlation between the countries in question. The more digital technologies are used in Kazakhstan, the more they are used in Uzbekistan. However, there is a spread (the confidence interval is not narrow), which may mean that the influence of other factors (e.g., availability of technologies, level of training of teachers) also plays a role.

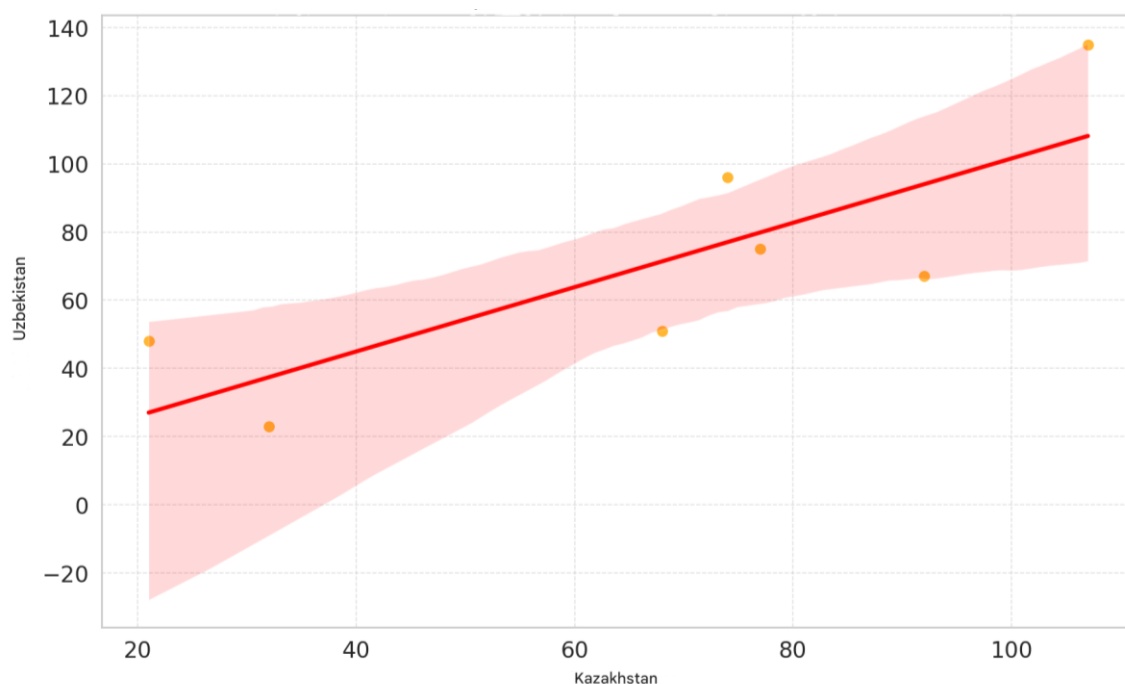


Figure 4.
Correlation of AI implementation in education: Kazakhstan and Uzbekistan.

One of the main areas of AI implementation is cooperation with large international technology companies (e.g. Google, ESRI, NASA). However, the survey shows that this initiative is supported by only 50 specialists in Kazakhstan and 70 in Uzbekistan, which indicates a reserved attitude towards dependence on foreign technologies. Instead, the creation of local AI solutions for geography is more approved in Kazakhstan (102 respondents) and less in Uzbekistan (55 respondents). This may indicate different levels of readiness for independent development of national educational platforms.

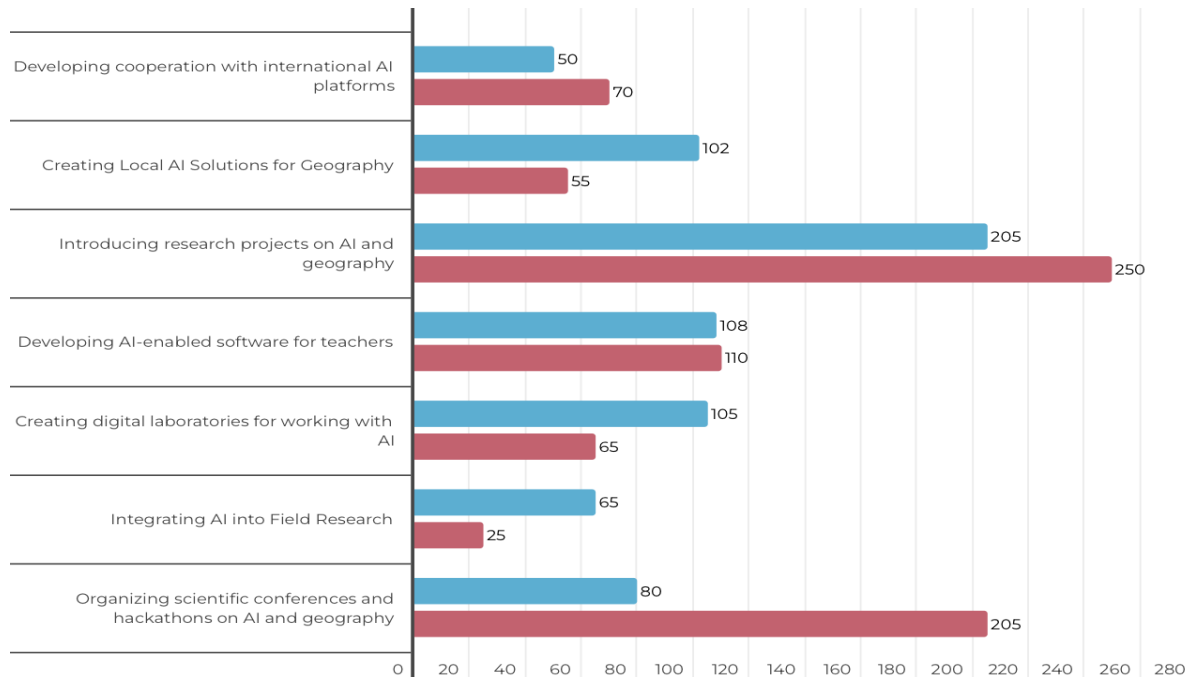
An important step towards digitalization of education is encouraging students and schoolchildren to develop their own AI projects. The survey shows that research initiatives receive the greatest support: 205 teachers in Kazakhstan and 250 in Uzbekistan consider this an important area. In addition, significant attention is paid to organizing scientific conferences and hackathons, but less attention is paid to this area in Kazakhstan (80 respondents versus 205 in Uzbekistan).

One of the practical applications of AI is the analysis of geodata using GIS systems, satellite images and drones. In Kazakhstan, the initiative to create digital laboratories is supported by 105 respondents, while in Uzbekistan – 65. However, the least popular initiative remains the integration of AI into field research – only 65 teachers in Kazakhstan and

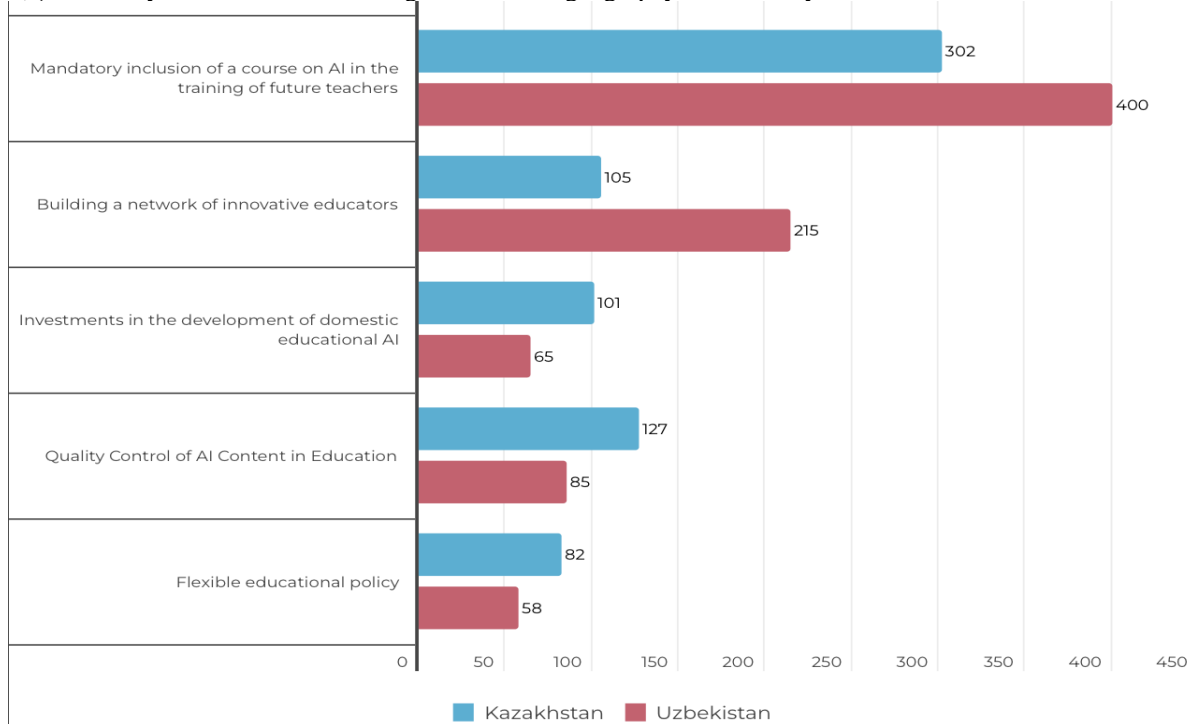
25 in Uzbekistan consider this a priority. This may be due to the high cost of equipment and the lack of specialized courses for working with such technologies.

Successful implementation of AI requires not only initiative from educational institutions, but also systemic support from the state. Survey data show that the greatest attention is paid to training future teachers and creating professional communities.

The most popular support measure is the inclusion of an AI course in the training program for future teachers. In Kazakhstan, 302 respondents and in Uzbekistan, 400 consider this step critically important. The second most important measure is the creation of a network of innovative teachers, where teachers can share experiences and implement best practices. This idea was supported by 105 respondents in Kazakhstan and 215 in Uzbekistan, which indicates a higher interest among Uzbek specialists in exchanging experiences (Figure 5).



(a) How do you think AI can be integrated into the geography education system in Kazakhstan and Uzbekistan?



(b) What kind of support from the government or educational institutions do you think is necessary to successfully implement AI in teaching?

Figure 5.

Artificial Intelligence in Geographical Education of Kazakhstan and Uzbekistan: Prospects for Integration and

State Support.

Developing our own AI products is also seen as an important area, but support for startups and research in educational AI received moderate support – 101 respondents in Kazakhstan and 65 in Uzbekistan. This may indicate that countries are not yet ready to create technologies on their own and rely on international solutions.

Concerns about false data and information accuracy lead to the need for government control over AI content. 127 respondents in Kazakhstan and 85 in Uzbekistan consider it important to regulate this aspect to avoid the dissemination of false information in the educational process. At the same time, the idea of simplifying the procedures for introducing digital technologies into educational programs has not yet received widespread approval (82 respondents in Kazakhstan and 58 in Uzbekistan), which may indicate existing bureaucratic barriers.

4. Discussion

Modern technologies are rapidly changing the educational process and artificial intelligence is becoming an important part of digital transformation. However, despite its enormous potential, the introduction of AI in geography teaching faces a number of serious challenges. The main problem is not the availability of technology, but the training of teachers themselves. Many of them simply do not have sufficient knowledge about the possibilities of AI in education. According to the survey, 180 teachers in Kazakhstan and 205 in Uzbekistan said that they lack information on how to use AI in the educational process. Why does this situation arise and what obstacles prevent teachers from mastering new technologies?

The first and most obvious problem is the lack of training of teachers. Many of them are not familiar with artificial intelligence tools and do not know how to adapt them to school programs. While modern students easily use ChatGPT, Google Earth AI and VR technologies, for a significant number of teachers these technologies remain a mystery. This is especially true for older teachers who are not always confident in using even basic digital tools.

In addition, there is currently no systematic training for AI teachers. Most pedagogical universities do not include AI technology in the training programs for future teachers. Even working teachers rarely have the opportunity to take advanced training courses related to the use of AI in teaching. Solving this problem requires the creation of special educational programs and online courses that will help teachers master new technologies. After all, AI will not replace teachers - it can become their reliable assistant if they learn to use it correctly.

If a teacher is willing to learn and use AI, the next question is: does their school have the technical capacity to do so?

Many educational institutions lack stable internet, and their computers are outdated and do not support modern programs. Many AI tools require high computing power or paid subscriptions, making them inaccessible to most schools. This is especially true for rural areas where digital infrastructure is poorly developed.

This problem can be solved by developing cloud technologies and free educational platforms. For example, Google already offers free access to Google Earth AI and educational tools, and government programs for digitalization of education can help provide schools with the necessary equipment.

Another important factor is the perception of AI by teachers. Many teachers fear that technology will replace them in the educational process, and students will stop thinking independently, relying entirely on AI.

There are also concerns that AI may make mistakes and provide incorrect information. This is a fair argument, as AI models can indeed make mistakes. However, teachers must learn to monitor and correct AI responses so that it becomes a supplement to traditional teaching rather than a replacement.

Modern teaching of geography is impossible without the use of digital technologies. The introduction of geographic information systems (GIS), Earth remote sensing tools, automated educational platforms and artificial intelligence significantly expands the capabilities of teachers. However, despite the obvious advantages, many teachers face difficulties in mastering these technologies. The reasons for these difficulties are related to both the technical aspects of the software and the methodological and psychological barriers that prevent their effective use in the educational process.

Main groups of complex programs for geography teachers:

1. Geographic information systems (GIS) – complexity of working with spatial data (ArcGIS, QGIS, MapInfo, Google Earth Pro). Difficulties: High level of complexity of the interface and the need for deep knowledge in the field of cartography, geostatistics and data analysis; Lack of adapted training courses for teachers focused on the use of GIS in the educational process; Large volumes of data and complex processing algorithms that require high computing power; High cost of licenses for commercial products (ArcGIS), which makes them inaccessible to most educational institutions.

2. Earth remote sensing programs – complexity of interpreting satellite data (ENVI, ERDAS Imagine, Sentinel Hub, Google Earth Engine). Difficulties: Working with multispectral and hyperspectral images requires knowledge of physics, ecology and digital image processing methods; Most of the tools are in English, which makes it difficult for teachers to master them; High requirements for computer power for processing satellite images.

3. Statistical and analytical programs – complexity of mathematical processing of geographic data (SPSS, Python (pandas, geopandas), GeoDa). Difficulties: High entry threshold, since working with such programs requires knowledge of statistics, programming and spatial analysis; most teachers do not have experience working with code, which makes it difficult to use programming languages (Python, R); large volumes of data require understanding of algorithms for their processing, which is beyond the standard training of geography teachers.

4. Virtual labs and simulations – difficulty in integrating into the educational process (PhET Interactive Simulations, NASA World Wind, Google Expeditions). Difficulties: Additional equipment is required (VR headsets, powerful computers); Virtual simulations may not correspond to the standard curriculum, which complicates their integration into school courses; Teachers do not have enough experience with VR and AR technologies, which causes difficulties in their use.

5. Artificial intelligence and automated systems – difficulty in monitoring results (ChatGPT, Google Bard, automated test checking systems (ExamSoft, AI Tutor)). Difficulties: AI does not always provide accurate answers, which requires additional verification of information by the teacher; Lack of understanding of the principles of AI operation leads to mistrust of its recommendations; Problem of task adaptation – AI may not always correctly evaluate complex geographic questions.

In Kazakhstan, special attention is paid to training teachers and improving their digital competence. Interactive maps and GIS systems using artificial intelligence technologies to analyze geographic data are being actively introduced in Kazakhstani schools and universities. These tools help students visualize climate change, tectonic processes, and geomorphological features of different regions. However, virtual tour technologies using AI are still at the testing stage. Only a few schools are experimenting with such methods, but their widespread implementation requires additional investment in equipment and methodological support.

In Uzbekistan, the focus is on developing university initiatives and creating research centers for the study of artificial intelligence. Universities are opening AI departments that are developing educational solutions for teaching geography. These departments are working on creating new software products, analyzing big data, and integrating AI into educational processes.

Schools and universities in Uzbekistan are also actively developing online platforms and virtual laboratories that allow the use of AI to analyze natural processes, climate change, and geodata. Such platforms help students not only study the theoretical aspects of geography, but also conduct practical research using satellite images and modeling natural phenomena. In addition, immersive VR/AR solutions for teaching geography are being developed in Uzbekistan. These technologies allow students to “travel” to different regions of the world in a virtual format, studying climate zones, terrain and ecosystems. However, at the moment, such solutions are at the testing stage, and their mass implementation requires revision and adaptation to educational programs.

Kazakhstan is actively training teachers to use AI and applying it in geography lessons, while Uzbekistan is focusing more on long-term academic research and infrastructure building.

Unlike Kazakhstan, Uzbekistan has a long-term strategic approach. The country is opening specialized AI departments, conducting research and actively training specialists in this field. However, at the moment, the impact of AI on school education remains limited, since the implementation of technologies is concentrated in the academic environment and requires significant time for integration into school curricula. The problems of introducing AI into geography teaching in Kazakhstan and Uzbekistan are discussed in Table 2.

Table 2.
Analysis of the challenges and opportunities of introducing AI into geography teaching in Kazakhstan and Uzbekistan.

| Problem | Kazakhstan | Uzbekistan |
|----------------------------|--|--|
| Lack of personnel | There is a shortage of teachers who are proficient in AI tools. | Training of personnel in the field of AI is underway, but there are not enough specialists yet. |
| Limited funding | There is government support, but projects are mainly implemented at the pilot level. | Initiatives with government support are actively developing, but so far without mass implementation. |
| Lack of a unified strategy | The use of AI in geography teaching is not yet regulated at the national level. | There is a state strategy, but its implementation takes time. |

In Kazakhstan, AI is already being used in geography teaching, but without large-scale government support. Uzbekistan has a strategy and plan for implementing AI, but their implementation takes time.

Geography today is not just the study of maps and reliefs, but a complex discipline that includes data analysis, climate change forecasting, and modeling economic and social processes. AI allows to process large arrays of geospatial data faster and more accurately; to develop forecasts of natural disasters, which is extremely important for regions with high seismic activity; to improve mapping using satellite images and machine learning algorithms; to create personalized educational programs for students based on their preferences and progress.

The education system is traditionally based on static materials, but artificial intelligence makes learning more interactive and dynamic, providing adaptive learning, in which AI analyzes student progress and adjusts materials individually. The use of augmented and virtual reality (AR and VR) technologies facilitates the study of maps, climate zones and geological processes in real time, and modeling and simulations allow the creation of virtual models of cities, ecosystems and climate change for practical study of complex processes. In addition, students have the opportunity to work with real geodata and learn forecasting using neural network technologies for data analysis.

Kazakhstan and Uzbekistan are actively developing the digital economy by investing in IT education, scientific research and startups. However, to become leaders it is necessary to create specialized AI centers in universities – platforms for research and implementation of technologies in the educational process. Form partnerships with international technology giants – Google, Microsoft, NVIDIA, to gain access to advanced technologies and educational resources. Develop state programs for training teachers in AI skills. Invest in cloud and supercomputer capacities for processing and analyzing geodata at the national level.

AI will be fully integrated into the educational process by 2030. Virtual geographic labs will become the norm, students will be able to study global ecosystems in real time via VR/AR. Geoanalytics with AI will be actively used to predict climate change and plan cities. With the right strategy, Kazakhstan and Uzbekistan can become educational hubs, attracting students and researchers from all over the world.

5. Conclusions

The integration of digital technologies and artificial intelligence into the teaching of geography is an important area of education modernization. In Kazakhstan, the focus is on the practical application of AI, which is expressed in the training of teachers, the development of interactive tools and the organization of practical seminars. In Uzbekistan, on the contrary, a strategic approach is predominant, focused on fundamental research, the creation of scientific departments and the training of specialists in this field. Both approaches have their advantages, but their further development requires the elimination of a number of challenges.

Key challenges in implementing AI and digital technologies in geography teaching include the complexity of working with geographic information systems (GIS) and satellite data, high technical requirements for software, a lack of teaching materials, and resistance from older teachers to new technologies. To effectively address these issues, it is necessary to develop specialized training courses and teaching aids, include digital technologies in training programs for future geography teachers and create adapted versions of complex programs with a simplified interface and ready-made templates.

A comprehensive and balanced approach to integrating AI and digital technologies into geography teaching will significantly improve the quality of geography education, making it more modern, interactive and focused on practical application. The introduction of innovative methods will not only expand teachers' capabilities, but will also help develop students' critical thinking, analytical skills and ability to work with modern information resources.

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