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DIGITALIZATION OF GEOGRAPHY EDUCATION AND INNOVATIVE TEACHING TECHNOLOGIES UNDER THE NEW UKRAINIAN SCHOOL REFORM

Abstract

The article examines current trends in the digitalization of geography education and the implementation of innovative teaching technologies within the framework of the New Ukrainian School reform and the operation of general secondary education institutions under martial law in Ukraine. A comparative analysis of the current national curriculum and two model geography curricula for Grades 6–9 was conducted to identify their content characteristics, competency-based orientation, digital potential, and capacity to support innovative teaching practices.

The study systematizes contemporary pedagogical approaches to geography teaching, including project-based learning, STEM/STEAM education, problem-based learning, inquiry-based learning, and blended learning. Particular attention is paid to the integration of these approaches with Geographic Information Systems, digital mapping services, artificial intelligence technologies, interactive educational platforms, and other digital learning resources.

Based on the comparative analysis, the study proposes an original conceptual model of innovative pedagogical technologies for geography education in the context of educational digitalization. The proposed model demonstrates the interrelationship between the digital learning environment, innovative teaching approaches, and expected learning outcomes aimed at developing geographical, digital, research, and other key competencies of students.

The study identifies the major challenges affecting the implementation of digital and innovative technologies in geography teaching, including inadequate technological infrastructure in schools, the need to strengthen teachers' digital competence, and the necessity of adapting innovative teaching methods to different forms of educational process organization.

The findings substantiate priority directions for the further development of geography education through the integrated application of digital technologies and innovative pedagogical approaches. Such integration contributes to improving the quality of education, fostering students' key competencies, and ensuring the continuity and resilience of the educational process under conditions of digital transformation and martial law.

Keywords: geography education; digitalization of education; digitalization of geography education; innovative teaching technologies; New Ukrainian School (NUS) reform; competency-based education; Geographic information systems (GIS); digital learning resources; STEM/STEAM education; educational process organization.

Problem statement. The reform of Ukraine's general secondary education system in accordance with the principles of the New Ukrainian School concept has necessitated the modernization of educational content, teaching methods, instructional approaches, and learning technologies. These transformations are particularly significant in geographical education, which plays a crucial role in

developing students' comprehensive understanding of natural and socio-economic processes, fostering spatial thinking, environmental awareness, research skills, and key competencies required for successful participation in contemporary information society [2, 3, 7, 8, 16].

The rapid advancement of digital technologies, geographic information systems (GIS), interactive educational platforms, virtual and augmented reality technologies, electronic cartographic resources, and mobile applications has considerably expanded the possibilities for geography teaching and learning. These technologies enhance the visualization of geographical phenomena, increase students' cognitive engagement, and contribute to the development of digital competence. However, the effectiveness of innovative educational technologies depends not only on the level of technological infrastructure available in educational institutions but also on the scientifically grounded selection of pedagogical approaches, teachers' professional readiness to integrate digital tools into the learning process, and their compliance with contemporary educational standards.

The relevance of this study is determined by the need to further improve geographical education within the framework of the New Ukrainian School reform, which aims to develop competent, creative, and socially responsible individuals. The ongoing digital transformation of society, the widespread implementation of information and communication technologies, and the continuous evolution of educational environments require the modernization of methodological approaches to geography teaching. This includes the extensive integration of digital educational resources, geographic information systems, interactive teaching methods, and innovative forms of organizing the educational process to ensure the development of students' subject-specific and transversal competencies [1, 4].

Despite these positive developments, the practical implementation of educational reforms in general secondary education institutions has revealed a number of persistent challenges. These include insufficient material and technical resources, varying levels of teachers' digital competence, the need to adapt innovative technologies to the specific conditions of individual educational institutions, and the necessity of improving the methodological support for geography teaching. Consequently, there is an increasing need for a comprehensive analysis of contemporary educational technologies, an assessment of their didactic potential, and the development of evidence-based approaches to their effective integration into the school geography curriculum.

Analysis of recent research and publications. The modernization of geographical education, the implementation of the competency-based approach, and the integration of innovative educational technologies into the teaching and learning process have become the focus of extensive research conducted by both Ukrainian and international scholars. Significant contributions to the development of the theory and methodology of geography education have been made by Ukrainian researchers, including I. A. Arsenenko, O. S. Arabadzhy, I. A. Donets, H. I. Denysyk, O. D. Lavryk, V. V. Tsymbaliuk, V. Luniachek, K. Borysenko, Yu. Iievlieva, D. S. Malchykova, R. Lozynskyy, V. Bilanyuk and K. V. Mezentsev [1, 5, 6, 7, 8, 14]. Their studies address the improvement of geographical education content, the development of methodological foundations for competency-based learning, and the application of digital educational technologies, geographic information systems (GIS), and modern information and communication technologies (ICT) in geography teaching.

A review of recent scholarly publications indicates that, despite the considerable body of research devoted to various aspects of educational digitalization, several issues remain insufficiently explored. In particular, there is a lack of comprehensive studies focusing on the analysis of contemporary model

geography curricula, the systematization of innovative teaching technologies, and the identification of effective approaches to their practical implementation in general secondary education institutions within the framework of the New Ukrainian School reform. These research gaps have determined the choice of the present study and underline its scientific relevance.

Purpose of the article. The purpose of this study is to provide a comprehensive analysis of contemporary approaches to the integration of innovative technologies into the school geography curriculum within the framework of the New Ukrainian School (NUS) reform. The study aims to examine the characteristics of contemporary model geography curricula, identify effective innovative teaching methods, digital technologies, and instructional approaches, and substantiate the prospects for their application in fostering students' geographical subject-specific competence as well as key competencies in general secondary education.

Presentation of the main material of the study . One of the key priorities of the reform of general secondary education in Ukraine is the modernization of educational content in accordance with the competency-based framework of the New Ukrainian School (NUS). An essential instrument for implementing this reform has been the introduction of model curricula developed on the basis of the State Standard of Basic Secondary Education. Their primary purpose is to define the expected learning outcomes, thematic content, recommended learning activities, and methodological approaches aimed at developing both subject-specific and key competencies among students.

Unlike traditional curricula, model curricula provide teachers with considerably greater flexibility in designing the educational process. Educators are empowered to determine the sequence of topics, select appropriate teaching methods and instructional strategies, integrate interdisciplinary content, incorporate contemporary digital educational resources, and adapt the curriculum

to the specific characteristics of individual educational institutions and students' educational needs. Such an approach is fully consistent with the principles of teachers' academic autonomy and contributes to improving the quality of geographical education.

In accordance with the provisions of the NUS reform, two model geography curricula for Grades 6-9 were introduced into the educational process in 2022. The first, "Model Curriculum: Geography. Grades 6-9 for General Secondary Education Institutions," was developed by S. H. Kobernik, R. R. Kovalenko, T. H. Hilberg, and L. M. Datsenko. The second curriculum of the same title was prepared by a broader team of authors, including S. P. Zapototskyi, H. I. Karpiuk, R. V. Hladkovskyi, A. I. Dovhan, V. V. Sovenko, L. M. Datsenko, T. H. Nazarenko, T. H. Hilberg, I. H. Savchuk, A. V. Nikytchuk, V. S. Yatsenko, H. D. Dovhan, V. D. Hroma, and O. V. Horovyi [10, 11].

The implementation of these curricula has been gradual. During the 2025/2026 academic year, they were already being used for teaching students in Grades 7 and 8. At the same time, Grade 9 students and upper secondary school students (Grades 10-11) continue to study geography under the national curriculum approved by Order No. 698 of the Ministry of Education and Science of Ukraine, dated 3 August 2022. This phased implementation ensures continuity in geography education while facilitating the transition to competency-based learning in accordance with the objectives of the NUS reform.

An analysis of the currently implemented model geography curricula demonstrates that, although all of them are based on the common principles of the State Standard of Basic Secondary Education, they differ in the organization of educational content, the sequencing of thematic units, the proposed learning activities, and the approaches employed to implement competency-based education. Despite differences among the author teams, all curricula are designed to foster students' geographical competence, develop spatial thinking, research

skills, environmental awareness, digital literacy, and the ability to apply geographical knowledge to the interpretation of contemporary natural and socio-economic processes.

To identify the distinctive features of these curricula, the authors conducted a comparative analysis focusing on their structural organization, competency-based orientation, digital components, and the integration of innovative teaching methodologies. The results of this analysis are presented in Table 1.

Table 1

Author's comparative analysis of the Model Geography Curricula for Grades 6-9 in general secondary education institutions in the context of the digitalization of geography education and the implementation of innovative teaching methodologies [10, 11].

Analysis criterion	Geography curriculum approved by the Ministry of Education and Science of Ukraine (Order No. 698, 2022)	Model curriculum by S. H. Kobernik, R. R. Kovalenko, T. H. Hilberg, and L. M. Datsenko	Model curriculum by S. P. Zapototskyi et al.	Relevance to the research topic (Authors' assessment)
Conceptual framework	Developed in accordance with the State Standard of Basic Secondary Education	Competency-based educational framework with an enhanced activity-based approach	Comprehensive competency-based framework emphasizing the spatial integration of educational content	All curricula are consistent with the principles of the New Ukrainian School (NUS); however, they differ in the extent and approaches to implementing the competency-based paradigm.
Content structure	Classical sequence of physical and human geography topics	Traditional content structure retained, with enhanced thematic units	Integrated thematic modules and consolidated content strands	The curricula demonstrate a gradual transition from a traditional content structure to an integrated competency-based framework.
Competency development	Development of subject-	Greater emphasis on inquiry-	Competencies are systematical-	The competency-based approach is im-

potential	specific and key competencies	based, practical, and communicative competencies	ly integrated across all learning activities	plemented most comprehensively in the curriculum developed by S. P. Zapototskyi et al.
Digitalization of teaching and learning	Provides for the use of digital maps, ICT, and electronic educational resources	Promotes the use of digital learning platforms, electronic cartographic resources, and online services	Emphasizes the application of digital technologies, geospatial data, and contemporary information resources	All curricula recognize digitalization as a key component of geography education; however, they differ in the extent to which digital technologies are integrated and specified.
Innovative teaching methodologies	Competency-based, activity-based, and inquiry-based approaches	Project-based learning, STEM/STEAM education, inquiry-based methods, and interactive teaching technologies	Problem-based learning, project-based learning, integrated learning, and inquiry-based learning	The curricula demonstrate a gradual expansion of innovative teaching methodologies, reflecting contemporary trends in geography education.
Organization of learning activities	Practical exercises, field observations, and map-based activities	Project-based activities, practical workshops, collaborative learning, and inquiry-based investigations	Comprehensive integration of inquiry-based, practical, and project-based learning activities	The curriculum developed by **S.** P. Zapototskyi et al. demonstrates the highest level of alignment with the principles of contemporary competency-based education.
Development of spatial thinking	Development of spatial thinking through map-based activities and territorial analysis	Practical investigations, cartographic analysis, and the use of spatial models	Spatial analysis of the interactions between natural and socio-economic processes	The spatial dimension is systematically embedded in all curricula; however, it is implemented most comprehensively in the curriculum developed by **S.** P. Zapototskyi et al.
Regional studies component	Includes the study of students' own administrative region	Places considerable emphasis on the study of the local region (*native region*)	Regional studies are integrated into the study of the territorial organization of Ukraine	The regional studies component constitutes an essential element in the development of students' civic and geographical competencies.
Readiness for	Partially ad-	High	High	Further integration of

the integration of advanced digital technologies	dressed			GIS, open geospatial data, artificial intelligence (AI) technologies, and digital modeling tools is recommended to enhance geography teaching and learning.
Overall authors' assessment	Establishes the regulatory and methodological foundation for contemporary geography education	Demonstrates the most balanced methodological framework for the integration of contemporary pedagogical approaches and teaching technologies	Provides the most comprehensive implementation of the competency-based, digital, and activity-based approaches	All curricula comply with the contemporary requirements of geography education; however, they require further enhancement of the digital component to address the challenges of educational digital transformation and the conditions imposed by martial law in Ukraine.

The comparative analysis of the model geography curricula revealed several common trends in the development of contemporary geography education in Ukraine. All curricula have been developed in accordance with the provisions of the State Standard of Basic Secondary Education and are designed to implement a competency-

based approach while fostering students' spatial thinking, subject-specific competence, digital competence, inquiry skills, and civic competence.

The findings indicate a gradual transformation in approaches to organizing the educational process. Whereas the geography curriculum approved by Order No. 698 of the Ministry of Education and Science of Ukraine (2022) primarily provides the regulatory framework for the structure and content of geography education, the model curricula developed by different author teams place greater emphasis on competency-based, activity-based, and inquiry-based approaches to teaching and learning. These curricula incorporate a wider range of project-based

learning, practical investigations, STEM/STEAM education, integrated learning, and the use of contemporary digital educational resources, thereby creating more favorable conditions for the development of students' key and subject-specific competencies [2, 3, 5].

A distinctive feature of the contemporary model geography curricula is the transition from a predominantly content-oriented approach to a learner-centered model that emphasizes active student engagement in the learning process. Considerable attention is devoted to practical exercises, inquiry-based investigations, the analysis of cartographic materials, statistical data, digital maps, and other sources of geographical information. Consequently, geography education is increasingly acquiring an inquiry-oriented character, fostering students' ability to analyze natural and socio-economic processes, identify causal relationships, and apply geographical knowledge to real-world contexts.

The comparative analysis also demonstrates a gradual strengthening of the digital dimension of geography education. All curricula promote the use of ICT, digital cartographic resources, and contemporary electronic educational tools. However, the educational potential of GIS, open geospatial data, Earth observation and remote sensing services, artificial AI technologies, and digital modelling has not yet been fully realized. This highlights the need for the further enhancement of methodological support and the expansion of the digital toolkit available for geography teaching and learning.

An important finding of this study is that the diversity of the model geography curricula provides genuine opportunities for teachers to exercise academic autonomy by selecting the most appropriate pedagogical approaches, teaching methods, and instructional strategies in accordance with students' educational needs, regional characteristics, and the material and technological resources available in educational institutions. At the same time, the effective implementation of these curricula largely depends on teachers' digital and

pedagogical competencies, the availability of contemporary digital educational resources, and the institutional capacity of schools to integrate innovative educational technologies into the teaching and learning process.

Overall, the findings confirm that the current model geography curricula establish a solid foundation for the digital transformation of geography education, the implementation of innovative pedagogical technologies, and the modernization of educational practices in line with the principles of the NUS reform. These developments have become particularly significant under the conditions of martial law in Ukraine, where digital technologies play a critical role in ensuring the continuity of education, enhancing the flexibility of instructional delivery, and maintaining equitable access to high-quality geography education regardless of security conditions or students' place of residence. Consequently, a further examination of innovative pedagogical technologies and digital learning tools represents a logical continuation of the present study [6, 11, 13, 15, 16].

The digital transformation of society, together with the implementation of the NUS reform, has necessitated a substantial revision of methodological approaches to geography education. Contemporary geography teaching is aimed not only at developing students' geographical knowledge but also at fostering subject-specific, digital, inquiry, environmental, and civic competencies. Achieving these objectives requires the extensive integration of innovative pedagogical technologies that promote active student engagement, critical thinking, the ability to analyze geographical information, and the application of acquired knowledge to solving real-world problems.

In contrast to the traditional teacher-centered model of instruction, contemporary pedagogical approaches emphasize active student interaction with learning materials, the integration of digital educational resources, the implementation of inquiry- and project-based learning activities, collaborative learning, and the development of students' self-directed learning skills. These

approaches are particularly valuable in geography education, as they facilitate the effective integration of natural science, social science, and digital perspectives, thereby promoting a holistic understanding of geographical phenomena and processes.

In the authors' view, contemporary geography education should be oriented toward the development of both subject-specific and key competencies, while fostering students' inquiry skills, critical thinking, and digital literacy. Under the conditions of martial law in Ukraine, the systematic integration of innovative pedagogical technologies has become particularly important, as these approaches promote active student engagement, interdisciplinary knowledge integration, and the practical application of geographical knowledge to the interpretation and solution of real-world problems.

Furthermore, within the context of the ongoing digital transformation of education, the authors identify project-based learning, STEM/STEAM education in geography, problem-based learning, inquiry-based learning, blended learning, and geoinformation technologies as the principal innovative approaches to geography teaching. Collectively, these approaches constitute the methodological foundation for the digital transformation of geography education and contribute to the development of students' geographical, digital, and transversal competencies required in contemporary society.

The innovative pedagogical technologies discussed above should not be regarded as isolated instructional approaches. Their effectiveness is significantly enhanced when they are systematically and comprehensively integrated within a unified digital learning environment. To illustrate their interrelationships and complementary functions, the authors propose an integrated conceptual model of innovative technologies for geography teaching (Figure 1) [1-4, 6].

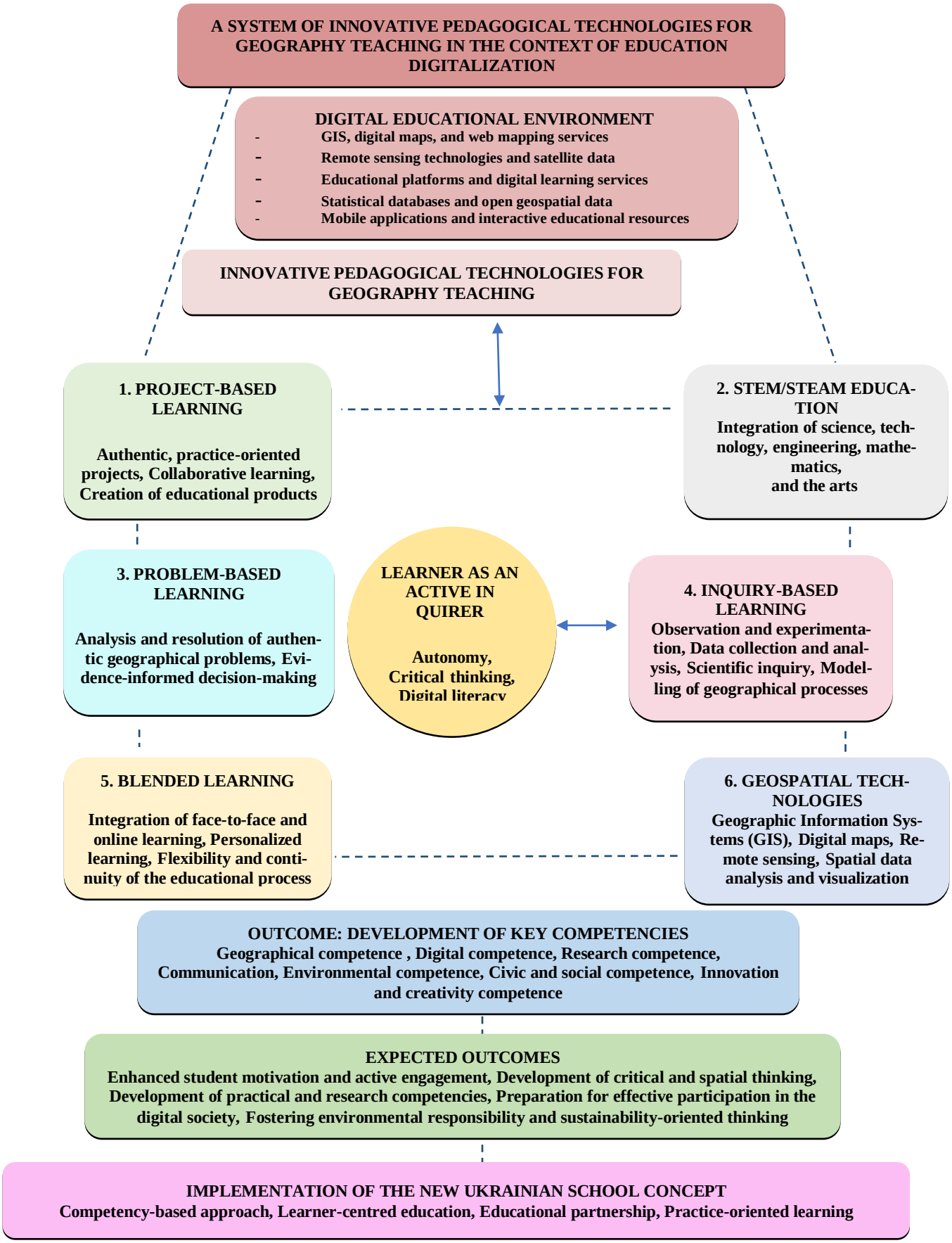


Figure 1. Integrated system of innovative pedagogical technologies for geography teaching in the context of the digital transformation of education (authors' conceptual model).

The conceptual model presented in Figure 1 illustrates the interdependence, complementarity, and integrated functioning of innovative pedagogical technologies within a unified digital learning environment. Unlike conventional approaches, which typically examine individual teaching technologies separately, the proposed model conceptualizes them as interconnected components of a coherent educational system. This integrated perspective highlights the synergistic effects of combining multiple pedagogical approaches and demonstrates their collective contribution to improving the quality of geography education in the context of digital transformation.

The conceptual core of the proposed model is the student, who is viewed as an active learner and inquirer, serving as the central participant in the educational process.

The development of students' subject-specific, digital, inquiry, and social competencies is achieved through the integrated application of project-based learning, problem-based learning, inquiry-based learning, blended learning, STEM/STEAM education, and geoinformation technologies.

Within the proposed framework, the digital learning environment functions as an integrative platform that enables the interaction of all pedagogical technologies through the use of digital learning platforms, electronic educational resources, GIS, digital cartographic services, open geospatial data, and contemporary ICT. This integrated approach facilitates the transition from the passive acquisition of knowledge to active inquiry-based learning, thereby promoting students' engagement, critical thinking, and the practical application of geographical knowledge.

A distinctive feature of the proposed system is its integrated nature, whereby each pedagogical technology performs a specific didactic function while simultaneously complementing the others. Project-based learning enhances the practical orientation of the educational process; the STEM/STEAM approach

promotes the integration of scientific knowledge across disciplines; problem-based learning fosters critical thinking; inquiry-based learning develops students' research skills and scientific reasoning; blended learning increases the flexibility of instructional delivery; and

geoinformation technologies provide powerful tools for the spatial analysis, visualization, and interpretation of geographical information.

The interaction of these components supports the development of subject-specific geographical, digital, inquiry, communication, environmental, civic, and innovation competencies, as defined by the State Standard of Basic Secondary Education. At the same time, the proposed model reflects the practical implementation of the core principles of the NUS reform, which is grounded in competency-based, activity-based, and learner-centered approaches to teaching and learning.

The proposed conceptual model demonstrates that the effectiveness of the digital transformation of geography education depends not merely on the isolated use of digital tools, but on their systematic integration with innovative pedagogical technologies and contemporary approaches to the organization of the teaching and learning process. This integrated approach has become particularly important under the conditions of martial law in Ukraine, where digital technologies play a crucial role in ensuring the continuity of education, enhancing the flexibility of instructional delivery, and providing equitable access to high-quality geography education regardless of learners' geographical location or security conditions.

Thus, the conceptual model presented in Figure 1 illustrates the interrelationships among innovative pedagogical technologies operating within a unified digital learning environment and collectively contributing to the achievement of the intended learning outcomes defined by the State Standard of Basic Secondary Education. Furthermore, the proposed framework provides a conceptual basis for examining the educational potential of each pedagogical

technology and identifying the conditions required for their effective implementation in geography teaching practice.

Project-based learning is widely recognized as one of the most effective pedagogical approaches in contemporary geography education. Its core principle lies in organizing students' individual or collaborative learning activities around the investigation of authentic problems and the creation of meaningful educational products. This approach effectively integrates theoretical knowledge with practical application while fostering inquiry skills, communication competence, responsibility, and teamwork.

In geography education, project-based learning may involve investigations of natural landscapes and ecosystems, environmental challenges, the tourism and recreational potential of regions, demographic processes, urbanization, climate change, and the principles of sustainable community development. The integration of digital cartographic services, GIS, statistical databases, and multimedia technologies enhances the quality of project implementation and enables students to develop practical competencies in using contemporary geospatial and digital information resources.

One of the most promising directions for the modernization of geography education is the integration of STEM and STEAM approaches into the teaching and learning process. The primary objective of these educational approaches is to integrate science, technology, engineering, mathematics, and the arts in order to foster a holistic scientific worldview and develop students' practical competencies. In geography education, the STEM approach is implemented through the analysis of natural processes, the modelling of geographical phenomena, the application of GIS, digital cartography, Earth observation and remote sensing technologies, statistical analysis, and the implementation of interdisciplinary inquiry-based projects. These learning activities contribute to the development of spatial

thinking, geospatial data literacy, the ability to identify causal relationships, and evidence-based decision-making.

STEAM education extends the STEM framework by incorporating the arts, thereby creating additional opportunities for the development of creativity, design thinking, spatial visualization, and communication skills. Within geography education, this approach is reflected in the creation of thematic maps, infographics, digital presentations, multimedia projects, the visualization of research findings, and the modelling of geographical and environmental processes. The integration of STEM and STEAM approaches enhances students' learning motivation, strengthens interdisciplinary connections, and promotes the development of competencies essential for successful participation in the digital economy and the knowledge society.

Problem-Based Learning (PBL) organizes the educational process around the investigation of authentic or simulated geographical problems that require students to identify, evaluate, and justify alternative solutions. This learner-centered approach promotes active engagement in the learning process while fostering critical thinking, analytical reasoning, and evidence-based decision-making skills.

In geography education, problem-based learning may address issues such as climate change, natural resource management, urbanization, environmental sustainability, the sustainable use of natural resources, demographic change, and regional development. Through the analysis of these complex geographical challenges, students learn to work with multiple sources of information, critically evaluate the reliability of evidence, construct well-reasoned arguments, and develop practical, context-specific solutions [1-4, 6].

Inquiry-based learning represents another essential component of contemporary geography education, as it promotes scientific ways of thinking and equips students with the practical skills required to investigate and interpret natural and socio-economic environments.

In geography education, inquiry-based learning is implemented through field observations, the analysis of cartographic materials, statistical datasets, satellite imagery, and geospatial information resources, as well as through the investigation of natural and socio-economic processes. Inquiry-based learning has become particularly significant in the context of the digital transformation of education, where contemporary digital technologies enable students to access, analyze, model, and visualize large volumes of geospatial data.

Blended learning combines traditional face-to-face instruction with digital learning platforms, electronic educational resources, and online learning technologies. This instructional model enhances the flexibility of the educational process, expands opportunities for personalized learning, and promotes students' self-directed learning skills and responsibility for their own learning outcomes.

In geography education, blended learning is particularly effective because it enables the integration of digital maps, electronic atlases, interactive models, video-based learning resources, and online geospatial services with practical classroom activities, inquiry-based investigations, and fieldwork. Such an integrated approach strengthens students' geographical competencies while supporting the effective application of digital technologies in both classroom-based and experiential learning environments.

The analysis of contemporary innovative pedagogical technologies indicates that their effectiveness depends not on the isolated application of individual digital tools, but rather on their systematic and integrated use in accordance with the learning objectives, curriculum content, and intended learning outcomes. The greatest pedagogical potential is demonstrated by approaches that combine inquiry-based learning, digital educational resources, interdisciplinary learning, and the practical application of geographical knowledge.

In contrast to the traditional content-transmission model of instruction, contemporary pedagogical approaches foster students' autonomy, critical thinking,

digital literacy, communication skills, and the ability to work with geospatial data. These educational outcomes are fully consistent with the conceptual principles of the NUS reform and reflect current trends in the digital transformation of education.

The rapid advancement of digital technologies has fundamentally reshaped approaches to organizing the educational process and created new opportunities for the modernization of geography education. Within the framework of the NUS reform, digitalization is understood not merely as the adoption of contemporary ICT, but as a comprehensive transformation of the educational environment aimed at developing the competencies required for successful participation in the digital society and the future workforce.

Digital transformation is of particular importance for geography education because contemporary geography increasingly relies on the analysis of geospatial data, digital cartography, GIS, Earth observation and remote sensing technologies, interactive models, and digital learning platforms. The effective integration of these technologies promotes the development of spatial thinking, digital literacy, inquiry skills, and students' capacity to analyze and interpret geographical information.

Unlike traditional instructional resources, digital technologies create opportunities for interactive student engagement with learning materials, the modelling of natural and socio-economic processes, the organization of inquiry-based learning activities, and the personalization of learning. Consequently, they serve as a key instrument for implementing the innovative pedagogical approaches discussed in the previous section.

One of the most significant dimensions of the digital transformation of geography education is the integration of GIS, which combine cartographic materials, statistical datasets, Earth observation and remote sensing data, and other geospatial resources within a unified information environment. The educational

application of GIS provides a qualitatively new approach to the study of physical and human geographical processes, promotes the development of spatial thinking, and enhances students' ability to analyze spatial patterns and work with large geospatial datasets. Unlike traditional paper maps, GIS enables multi-criteria spatial analysis, the creation of thematic maps, the modelling of environmental processes, and the investigation of land-use change, demographic dynamics, transportation networks, environmental conditions, and other geographical phenomena [9, 12].

Within geography education, GIS can be effectively incorporated into practical exercises, inquiry-based projects, fieldwork, the analysis of statistical data, and the modelling of geographical processes. The integration of these technologies contributes to the development of subject-specific geographical competence, digital literacy, inquiry skills, and evidence-based decision-making through the analysis and interpretation of geospatial data.

The educational value of GIS is further enhanced through its integration with project-based learning, STEM/STEAM approaches, and inquiry-based learning, thereby strengthening the practical orientation of geography education and increasing students' motivation and engagement.

Among the most accessible digital tools for geography education is Google Earth, which combines the functionality of a virtual globe, high-resolution satellite imagery, three-dimensional terrain visualization, and interactive exploration of geographical environments. Its educational applications enable students to visualize geographical features, analyze natural and socio-economic processes, and investigate relief, urbanization, land-use patterns, and environmental change.

Particularly valuable from a pedagogical perspective are the Street View, Voyager, and Timelapse features, which support virtual field trips, exploration of significant natural and cultural heritage sites, analysis of spatial changes over time, and investigation of the environmental impacts of human activities.

In addition to Google Earth, contemporary web-based mapping platforms provide highly effective resources for geography teaching by offering access to interactive maps, thematic layers, statistical datasets, and open geospatial data. Their integration into the educational process enhances students' spatial data analysis skills, promotes critical thinking, and facilitates the incorporation of digital resources into inquiry-based learning. Moreover, the educational effectiveness of web mapping services depends not on the number of digital tools employed but on their pedagogically appropriate selection and integration in accordance with curriculum content, students' developmental characteristics, and clearly defined instructional objectives.

Augmented Reality (AR) and Virtual Reality (VR) technologies offer significant opportunities for the modernization of geography education. These technologies enable the creation of immersive and interactive learning environments in which students can explore geographical features and processes that are inaccessible to direct observation. Virtual explorations of the world's natural regions, three-dimensional simulations of volcanic activity, earthquakes, landform evolution, climate change, tectonic plate movements, and ecosystem dynamics enhance the visualization of geographical phenomena, foster spatial imagination, and promote a holistic understanding of the interrelationships among the components of the Earth's geographical system.

AR further enriches real-world learning environments by overlaying physical objects with digital models, interactive visualizations, cartographic materials, and multimedia content. This approach creates additional opportunities for fieldwork, educational excursions, map-based learning activities, and the implementation of practical geographical tasks [1-4, 6, 9, 12].

Nevertheless, the effective integration of AR and VR technologies requires appropriate technological infrastructure, adequate pedagogical training, and adherence to the principle of pedagogical appropriateness. These technologies

should therefore be regarded not as an end in themselves, but as effective instructional tools for implementing competency-based education and enhancing the quality of geography teaching and learning.

One of the most rapidly evolving trends in contemporary education is the integration of AI technologies into the teaching and learning process, creating new opportunities for geography education. AI-powered tools can be employed to personalize learning, develop interactive educational materials, automate the analysis of geographical data, generate cartographic visualizations, simulate natural processes, and support students' inquiry-based learning. In geography education, AI can serve as an effective supplementary tool for information retrieval and organization, statistical data analysis, the generation of educational case studies, the preparation of cartographic representations, the design of assessment tasks, and the simulation of spatial processes. These applications contribute to the development of students' analytical thinking, digital competence, and their ability to manage and interpret large geospatial datasets.

At the same time, the educational use of AI requires strict adherence to the principles of academic integrity, critical evaluation of AI-generated outputs, and verification of the accuracy and reliability of information. The pedagogical value of AI lies not in replacing students' learning activities but in enhancing intellectual support, facilitating personalized learning, and expanding opportunities for inquiry-based and research-oriented education [1-4, 6, 9, 12].

Another essential component of the digital transformation of geography education is the use of interactive digital learning platforms and online educational services that promote students' active engagement, provide immediate formative feedback, facilitate collaborative learning, and increase learning motivation. The integration of these digital tools supports the transition from traditional knowledge reproduction to active student interaction within a digitally enriched learning environment.

Among the most effective digital tools currently employed in geography education are LearningApps, Kahoot!, Quizizz, Mentimeter, and Padlet. Although these platforms serve different instructional purposes, they collectively enhance the interactivity of the learning process, foster the development of digital competence, promote collaborative learning, and support both formative and summative assessment of students' learning outcomes.

LearningApps and Quizizz are particularly effective for reinforcing subject knowledge, organizing independent learning activities, delivering interactive exercises, and conducting formative assessment. Kahoot! facilitates the implementation of educational quizzes, thematic surveys, and knowledge assessment through gamified learning experiences, thereby increasing students' engagement and learning motivation [1-4, 6, 9, 12].

Mentimeter and Padlet provide valuable opportunities for collaborative discussion, the presentation of inquiry-based learning outcomes, brainstorming activities, the co-creation of shared digital knowledge resources, and the development of communication skills. These platforms are especially effective when integrated into project-based learning, STEM/STEAM education, and interdisciplinary inquiry-oriented activities.

The conducted analysis of contemporary digital technologies demonstrates that their integration substantially transforms the methodology of geography education by expanding opportunities for the development of both subject-specific and key competencies. Unlike traditional instructional tools, digital technologies promote interactive learning, personalized instruction, immediate access to up-to-date geographical information, and the organization of inquiry-based learning supported by geospatial data.

At the same time, digital technologies should not be regarded as an independent pedagogical system. Their educational effectiveness depends on their integration with innovative instructional approaches, including project-based

learning, inquiry-based learning, problem-based learning, STEM/STEAM education, and blended learning. Such an integrated approach facilitates the development of spatial thinking, digital literacy, critical information analysis, and students' ability to apply geographical knowledge to the solution of real-world environmental and socio-economic challenges.

The digital transformation of geography education has become particularly significant in the context of the rapid advancement of GIS, open geospatial data, AI technologies, and remote sensing applications. The integration of these technologies brings the educational process closer to contemporary scientific research and professional practice, enhances students' learning motivation, and creates favorable conditions for developing the competencies required in a digital society [1-4, 6, 9, 12].

The findings indicate that the successful digital transformation of geography education depends not only on the availability of advanced digital resources but also on teachers' digital competence, the quality of instructional and methodological support, the technological infrastructure of educational institutions, and the pedagogically sound integration of digital technologies into the teaching and learning process. Therefore, the digitalization of geography education should be implemented through a comprehensive approach that combines advanced information technologies, innovative pedagogical strategies, and a competency-based model of educational practice.

The conducted analysis demonstrates that digital technologies substantially expand the opportunities for implementing innovative approaches to geography education. However, their educational effectiveness largely depends on the organization of the teaching and learning process. Therefore, the next stage of this study focuses on the analysis of contemporary instructional formats in geography education, the challenges associated with their implementation, and the

identification of process for their further development within the context of educational digitalization and the implementation of the NUS reform.

The widespread adoption of digital technologies, together with the implementation of the competency-based framework of the NUS, has led to significant changes in the organization of the educational process. Although the traditional classroom lesson remains the fundamental form of geography instruction, contemporary educational practice increasingly emphasizes the integration of face-to-face, online, and blended learning, together with the extensive use of project-based, inquiry-based, and practice-oriented learning activities. This transformation is aimed at developing students' ability to apply geographical knowledge in authentic real-world contexts, work effectively with digital data, critically evaluate information, and make evidence-based decisions.

Contemporary geography education increasingly incorporates a wide range of instructional formats that complement one another and facilitate the implementation of the competency-based approach. The competency-oriented geography lesson remains the principal form of instruction, integrating the presentation of new content, practical learning activities, cartographic analysis, the use of digital resources, collaborative learning, and reflective evaluation of learning outcomes. At the same time, interdisciplinary lessons are becoming increasingly important, strengthening the connections between geography and such disciplines as biology, history, economics, mathematics, computer science, and environmental studies.

Project-based learning has emerged as another essential instructional format, enabling students to investigate contemporary physical and human geographical issues, conduct spatial analyses, work with open geospatial data, and present the results of their own research. When integrated with STEM/STEAM approaches, project-based activities promote interdisciplinary learning and support the development of practical competencies.

Fieldwork, educational excursions, geography practicums, and field expeditions continue to play a crucial role in geography education. The integration of mobile digital devices, Global Positioning System (GPS) technology, GIS, and web-based mapping platforms substantially enhances these instructional formats by enabling the efficient collection, analysis, and visualization of geographical information [1-4, 6, 9, 12].

Blended learning occupies a particularly important place in contemporary geography education, as it combines face-to-face instruction with digital learning platforms, electronic educational resources, and online interaction. This instructional format promotes personalized learning, expands opportunities for independent study, and ensures the continuity and flexibility of the educational process.

Despite the considerable potential of these contemporary instructional formats, their practical implementation is accompanied by a number of objective challenges.

One of the major constraints is the uneven level of technological infrastructure across educational institutions. Limited access to modern computer equipment, mobile devices, multimedia technologies, and reliable Internet connectivity substantially restricts the effective integration of digital technologies into geography teaching and learning.

Another critical factor is teachers' level of digital and pedagogical competence. The continuous evolution of digital technologies requires ongoing professional development, enabling teachers to strengthen their expertise in the use of GIS, web-based mapping platforms, AI technologies, and other advanced interactive digital tools.

Additional challenges arise in the organization of fieldwork and educational excursions, which require adequate financial resources, material support, and effective organizational planning. Under the conditions of martial law in Ukraine,

ensuring the safety of all participants in the educational process has become an even more critical consideration, necessitating the adaptation of traditional forms of field-based learning and the broader adoption of digital alternatives.

Another important challenge concerns the maintenance of academic integrity in the context of the widespread use of digital resources and AI technologies. This underscores the need to cultivate a culture of responsible digital technology use, critical evaluation of information, and adherence to ethical principles in teaching and learning.

The future development of geography education should be based on the systematic integration of traditional pedagogical approaches, innovative instructional technologies, and a modern digital learning environment. One of the most promising directions is the development of a unified digital geo-educational ecosystem integrating GIS, electronic cartographic resources, interactive digital learning platforms, remote sensing services, AI tools, and open geospatial data. Such an integrated environment would facilitate the seamless combination of diverse learning activities while strengthening the development of both subject-specific and key competencies among students [1-4, 6, 9, 12].

An essential prerequisite for the modernization of geography education is the development of a system of continuous professional development for teachers aimed at strengthening their digital, pedagogical, and research competencies. Particular emphasis should be placed on preparing educators to effectively utilize GIS, AI, digital cartography, and other advanced educational technologies.

Another promising direction involves expanding practice-oriented learning through the more extensive use of fieldwork, educational expeditions, interdisciplinary projects, STEM/STEAM initiatives, and partnerships between educational institutions, research organizations, environmental agencies, and local communities. Such collaboration contributes to the development of students' holistic geographical understanding, spatial thinking, environmental responsibility,

and preparedness to address the contemporary challenges of sustainable development.

Therefore, the modernization of instructional formats in geography education should be guided by the principles of pedagogical appropriateness, digital transformation, and competency-based education. Only a comprehensive integration of innovative pedagogical approaches, digital technologies, and practice-oriented learning can enhance the quality of geography education and ensure the effective implementation of the NUS reform.

Conclusions. The findings of this study confirm that the digital transformation of geography education represents one of the key directions for its modernization and an essential prerequisite for improving the quality of teaching and learning within the ongoing transformation of Ukraine's educational system. It facilitates the modernization of educational content, instructional methods, and organizational formats while supporting the implementation of the competency-based framework of the NUS. At the same time, it creates the conditions necessary to ensure continuity of learning, academic mobility, and educational adaptability under the conditions of martial law.

The analysis of contemporary model geography curricula demonstrates their strong emphasis on the development of subject-specific geographical competence, spatial thinking, digital literacy, inquiry skills, environmental responsibility, and civic awareness. However, the successful realization of their educational potential largely depends on the effective organization of the teaching and learning process, teachers' pedagogical expertise, and the pedagogically sound integration of contemporary digital technologies.

The study further revealed that the most effective approach involves the comprehensive integration of innovative instructional strategies, including project-based learning, inquiry-based learning, problem-based learning, blended learning, STEM/STEAM education, GIS, and digital educational resources. The synergy

among these approaches promotes students' active engagement, fosters critical thinking, enhances spatial reasoning, strengthens digital competence, and develops the ability to apply geographical knowledge to the analysis of natural, socio-economic, and societal processes.

The study substantiates that digital technologies serve as an integrative mechanism for implementing innovative instructional approaches in geography education. The use of GIS, web-based mapping platforms, AR and VR technologies, interactive digital learning platforms, and AI enhances visualization, interactivity, inquiry-based learning, and personalized instruction, while simultaneously expanding opportunities for both independent and collaborative learning.

The findings further indicate that the digital transformation of education has fundamentally reshaped approaches to organizing the teaching and learning process. Alongside the traditional classroom lesson, increasing emphasis is being placed on blended learning, project-based learning, digitally supported fieldwork, interdisciplinary instruction, geography practicums, and online learning formats. The comprehensive integration of these instructional formats enhances the flexibility of the educational process, supports personalized learning, promotes students' inquiry engagement, and strengthens their ability to apply geographical knowledge in practical contexts.

The digital transformation of geography education has become particularly significant under the conditions of martial law in Ukraine, where ensuring the continuity of learning, maintaining effective communication among participants in the educational process, and providing access to high-quality educational resources have become critical prerequisites for the functioning of the education system. Digital technologies, online and blended learning formats, electronic learning platforms, geospatial information resources, and contemporary online communication tools enable the organization of teaching and learning regardless

of security conditions, students' geographical location, or the operational format of educational institutions. At the same time, the challenges associated with martial law highlight the importance of developing students' competencies in critical information evaluation, information security, media literacy, and the responsible use of digital technologies and online resources.

The principal factors constraining the effective implementation of digital technologies and innovative teaching methods include disparities in the material and technical resources of educational institutions, the need for the systematic development of teachers' digital and methodological competencies, the improvement of instructional and methodological support, broader access to contemporary digital educational resources, and the assurance of academic integrity and cybersecurity within the educational process.

The scientific contribution of this study lies in its comprehensive synthesis of contemporary approaches to the digitalization of geographical education, the systematization of innovative teaching methods, digital technologies, and organizational forms of the educational process, as well as in substantiating their interrelationships within the framework of the NUS concept and the functioning of the education system under martial law. The author's conceptual generalizations, comparative tables, and conceptual model proposed in this study may serve as a methodological basis for improving educational programmes, developing instructional and methodological materials, enhancing the preparation of prospective geography teachers, and supporting the continuous professional development of in-service educators.

Prospects for further research should focus on the development and experimental validation of models for blended and distance geography education, the integration of GIS, artificial intelligence technologies, and open geospatial data into the educational process, as well as the assessment of their impact on the development of subject-specific, digital, and research competencies among

learners in the context of Ukraine's post-war recovery and sustainable development.

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