Technological adaptation of Ukraine's educational and scientific system under the XXI Century: humanitarian crisis

Adaptación tecnológica del sistema educativo y científico de Ucrania en el Siglo XXI: crisis humanitaria

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Abstract

The digital adaptation of the educational environment is an important direction for ensuring the continuity of the educational process. The purpose of this article is to explore the technological adaptation of Ukraine's educational and scientific systems in the 21st century in the context of a humanitarian crisis. For this issue the PRISMA scientific approach was used, which made it possible to select the most relevant literature (a total of 46 scientific sources were found). The results show that educational institutions have actively adapted to the new realities by introducing modern EdTech solutions, including platforms such as Zoom,

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Moodle, Google Classroom, Coursera, Prometheus, Diya.Osvita. Particular attention in the digital transformation was paid to the development of personalized learning, assessment automation, the use of artificial intelligence language models, and analytical tools. In general, EdTech analytics has the highest potential for scaling. AI has begun to be used in adaptive learning, automatic assessment, and translation, but it remains insufficiently implemented, partly due to financial and technical problems. The most critical issues are digital inequality, weak infrastructure in rural and frontline regions, fragmentation of the educational space. The conclusions emphasize the promise of introducing digital solutions, provided that the negative aspects are overcome.

Keywords: Adaptation, AI, digitization, education, technology.

Resumen

El objetivo de este artículo es explorar la adaptación tecnológica de los sistemas educativos y científicos de Ucrania en el siglo XXI en el contexto de una crisis humanitaria. Para este tema se utilizó el enfoque científico PRISMA, que permitió seleccionar la bibliografía más relevante (se encontraron un total de 46 fuentes científicas). Los resultados muestran que las instituciones educativas se han adaptado activamente a las nuevas realidades mediante la introducción de soluciones EdTech modernas, incluyendo plataformas como Zoom, Moodle, Google Classroom, Coursera y Diya.Osvita. En la transformación digital se prestó especial atención al desarrollo del aprendizaje personalizado, la automatización de la evaluación, el uso de modelos de lenguaje de inteligencia artificial y las herramientas analíticas. En general, el análisis EdTech tiene el mayor potencial de escalabilidad. La IA ha comenzado a utilizarse en el aprendizaje adaptativo, la evaluación automática y la traducción, pero su implementación sigue siendo insuficiente, en parte debido a problemas financieros y técnicos. Las cuestiones más críticas son la desigualdad digital, la debilidad de las infraestructuras en las regiones rurales y fronterizas y la fragmentación del espacio educativo. Las conclusiones destacan el potencial de la introducción de soluciones digitales, siempre que se superen los aspectos negativos.

Palabras clave: Adaptación, digitalización, educación, inteligencia artificial, tecnología.

Introduction

In the 21st century, technology has become an important factor in the transformation of educational and scientific systems around the world, especially in the context of humanitarian crises (Bechi & Almeida, 2024). For Ukraine, the full-scale war that began in 2022 became a catalyst for technological change. The country's educational and scientific system faced the challenge of not only maintaining its functionality but also urgently adapting to new conditions with the help of digital tools, mobile platforms, and innovative technologies.

Contemporary scholars have pointed out that the humanitarian crisis caused by Russian aggression has inflicted significant damage on education and science in Ukraine. The physical destruction of infrastructure (civil, energy, research), the increasing rate of migration of the population to more peaceful regions of the country, and the destabilization of social life have a separate impact on the destruction of stable ties in society and everyday life. The destruction caused by the war has led to the evacuation of many higher education and scientific institutions, the forced displacement of students and teaching staff, and reduced access to educational resources (Rajab, 2018). In such conditions, there was a need for rapid technological adaptation of the educational process to the new reality — through digitalization, distance learning, the use of EdTech solutions, and mobile platforms.

Importantly, Ukraine's educational transformation is occurring in a broader global context in which hybrid education, teacher preparedness, and social inequality have become critical issues during crises. According to Mundaca & Mundaca (2024), "education systems in Latin America face deep structural challenges in preparing teachers for digital and socio-emotional competencies necessary in crisis

contexts." Similarly, Abad-Segura et al. (2020) noted that "the pandemic and social unrest in Latin America have accelerated the digital transformation of education but also revealed the fragility of infrastructure and the need for pedagogical innovation." These global trends highlight the urgency of building resilient, inclusive, and adaptive education systems that can respond to emergencies (Vefago et al., 2020).

The transformation of educational and scientific environments in Ukraine because of military actions is also taking place at a time when representatives of the international community are coming to the important conclusion about the continued relevance of technological adaptation of science and education to function effectively in crisis situations. The methods of technological reform indicate a significant potential for the evolution of the educational and scientific process and the restoration of its functioning even under unfavorable conditions. Research into the Ukrainian experience in such circumstances is becoming a pressing issue, as more than two years of active military action have made it possible to draw certain conclusions about the successes and failures of technological reform in wartime. Therefore, despite the complexity of the situation, the humanitarian crisis has also become a catalyst for change. Ukraine is actively implementing innovative digital solutions, mobile applications, and distance learning platforms. These technologies have made it possible to ensure the continuity of the educational process even in conditions of blackouts, relocation, or military operations. The use of tools such as Zoom, Moodle, Google Classroom, Prometheus, as well as mobile EdTech platforms (Kahoot!, ClassTime, Duolingo, Quizlet, etc.) has become an important element of the new educational reality.

The purpose of this article is to form a comprehensive understanding of the impact of the 21st-century humanitarian crisis caused by the war in Ukraine on the development of the educational and scientific sphere, with a particular emphasis on the processes of transformation caused by technological innovations, digitalization, and adaptation to crisis conditions. The study will analyze examples of implemented technological solutions, identify features of digital inequality among participants in the educational process, schematically present the functioning of educational platforms during the crisis period, and offer important recommendations for countries that may find themselves in similar humanitarian situations.

Literature Review

Digitization of the educational process in Ukraine

Contemporary literature presents various trends that are currently actively taking place in the educational and scientific spheres of Ukraine and EU countries. Modern authors described the main opportunities and directions of distance learning.

The authors also drew attention to the methods and forms of organizing the educational space. A number of recent studies have shown the widespread use of digital tools in the educational process in Ukraine. In general, scientific literature indicates that distance and hybrid learning have become dominant models that have made it possible to effectively maintain the continuity of the educational process. Digital platforms, mobile applications, cloud services, electronic libraries, and other EdTech solutions are used in both schools and universities. According to Hilliger et al. (2020) one of the important aspects is expanding access to online resources and integrating digital skills into the learning process. Hence, some studies have documented the impact of digital technologies, particularly remote learning platforms (Zoom, Google Classroom, Google Meet), on improving the results of students in times of war or other crises.

Educational transformation and digitalization in Latin America in times of crisis

During 2020–2024, educational transformation in Latin America became the subject of numerous studies, particularly in the context of the COVID-19 pandemic, socio-economic instability, and political challenges. The digital divide between urban and rural areas, as well as between public and private educational institutions, remains one of the key research topics. Pedrosa (2020) draw particular attention to the lack of access to stable internet and devices among socially vulnerable groups. Latin American scholars emphasize that most teachers were not ready to transition to online or hybrid formats. According to a study

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by Salas-Pilco et al. (2022) and Cassiolato (2015), teacher training systems in Latin America do not consider the development of digital and socio-emotional competencies necessary for working in crisis situations. The authors emphasize the importance of developing adaptive models of teacher special training. Also, social challenges and the role of education as a stabilizing factor (Acuñar, 2024). The works of Aruguete (2019) note that in conditions of social instability, education performs not only an educational function, but also a social function - as a tool for supporting psychological resilience, communication and cohesion. The author write: "During a crisis, school often becomes the only stable element in a child's life, especially in conditions of displacement or poverty." Studies by Latin American authors point to common challenges that are of global importance: structural digital inequality, lack of a strategic vision for the digitalization of education, insufficient preparation of teachers for crisis conditions, as well as the fragmentation of EdTech implementation (González-Salamanca et al., 2020). At the same time, the development of learning models of the future, the integration of psychological support into digital educational environments are important (Schaube et al., 2022). Corica et al. (2024) noted, education in crisis situations should be based both on technical solutions and on an understanding of the socio-cultural context of the participants.

Education management in crisis situations: features of the adaptation process

Contemporary scholars note that the experience of learning during the COVID-19 pandemic allowed for faster adaptation to distance and, subsequently, hybrid formats during martial law. Scientists generally agree that the technological experience of the pandemic facilitated the transition to hybrid learning during martial law. Separately, scientists drew attention to the importance of developing the university environment, which plays an important role in times of crisis. However, scientific literature indicates that this form of learning still carries risks of deteriorating the quality of education and academic performance, as well as deepening certain educational inequalities. In addition, hybrid learning increases the workload on students and teachers. Thus, along with positive developments, scientific literature points to a number of problems: inequality in access to digital infrastructure, lack of technical support in certain regions, overload of participants in the educational process, and communication limitations. This affects the need to implement digital inclusion strategies and support vulnerable categories of learners. Therefore, an important issue in research is the characterisation of the management of an educational institution in times of crisis. Stender et al. (2024) described the peculiarities of managing an educational institution during the war. The authors drew attention to the noticeable intensification of the social role of universities in times of crisis and their participation in post-conflict recovery. At the same time, Bakhmat et al. (2022) analysed the main modern technologies used to support the development of Ukrainian education. Thus, the literature analysis reveals different points of view of scholars on the implementation of a hybrid learning model. Some authors emphasise the importance of using modern digital resources and forms of learning. At the same time, others point out that this form carries risks of deteriorating the quality of education and contributes to the deepening of social inequalities. However, current trends in the development of education are not comprehensively presented in scientific studies (Sedochenko & Shyyan, 2024; Flórez-Aristizábal et al., 2019). In addition, there is a lack of works that analyse the impact of the humanitarian crisis on the educational and scientific sphere. Most contemporary scholars have focused on the short-term consequences (changes in teaching methods or adaptation to new technologies), but there is a lack of detailed assessment of these works in terms of determining long-term social and cultural transformations. Therefore, this study will fill this gap and provide a holistic view of the impact of the humanitarian crisis on the education and research sector in Ukraine.

Despite the existence of a certain number of studies devoted to the digitalization of education in Ukraine, most of them focus on a general analysis of distance learning or a description of the tools used during the COVID-19 pandemic. At the same time, much less attention is paid to the study of the functioning of the educational and scientific system in the context of a protracted humanitarian crisis of a war-like nature. Existing works rarely take into account the holistic impact of war on science and education, but the issues of digital inequality, the adaptability of technologies to the realities of war, as well as institutional resilience in conditions of instability.

There is a particular lack of an analytical typology of technological solutions that have been or can be applied in extreme circumstances. There is a lack of systematic data on the effectiveness of specific platforms, the level of digital inclusion among education seekers, as well as models of educational process management during the crisis period. In addition, the potential of EdTech tools in the context of long-term reconstruction has hardly been studied, and there is also no scientifically sound approach to shaping technological policy in the education sector during war. Hence, the proposed study has significant relevance: it will allow not only to identify the challenges faced by the educational and scientific system of Ukraine, but also to identify effective technological strategies to ensure sustainable functioning in the conditions of a humanitarian crisis.

Methodology

Research Design

This study is a qualitative systematic literature review and is based on the internationally recognized methodological standard PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This methodological framework was chosen due to its structured approach to identifying, screening and synthesizing scientific publications, which allows assessing the scientific novelty, methodological rigor and empirical results of the selected studies. Peer-reviewed sources pertaining to Ukraine's science and education sectors' technological adaption were found, chosen, and examined as part of the study process. To guarantee uniformity, inclusion and exclusion criteria were established beforehand. With a focus on research from Eastern Europe and comparative contexts, the sources were gathered from prestigious academic databases. This methodological approach allowed us to present the most up-to-date data on the digital transformation of Ukraine's education and research systems during the war in a holistic manner. In addition, the chosen methodology can be adapted for comparative studies in other regions, in particular in Latin America, where countries have also experienced educational disruptions due to social, political or environmental crises. From an ethical point of view, this study did not involve people, personal data or experiments. All sources used are publicly available scientific publications. The study adheres to the principles of academic integrity, transparency and good citation practice.

Materials and Data collection

The study used a purposeful sample of sources using the following criteria:

These inclusion criteria were:

1. Articles published in peer-reviewed journals and indexed in the relevant journals.
2. Research on the impact of the humanitarian crisis of the twenty-first century on the development of the educational and scientific sphere of Ukraine.
3. Publications written in English, as they have undergone a lengthy peer-review process and have been published in relevant scientific journals.
4. Articles should relate to innovative digital solutions and the specifics of implementing digital learning in times of war.
5. Articles could relate to both online and hybrid forms of learning.
6. Given the need to take into account current research findings.

In particular, the Russian aggression in Ukraine escalated into a full-scale invasion in 2022, so the most relevant are works written after 2022. However, there are also some exceptions - for works that are recognised as relevant and that demonstrate the general vectors of development of education and science in Ukraine even in pre-war times.

The search for and selection of scientific sources was based on the search for materials in the scientific and metric databases Scopus, Web of Science, and Erich+. Keywords such as reform, technological

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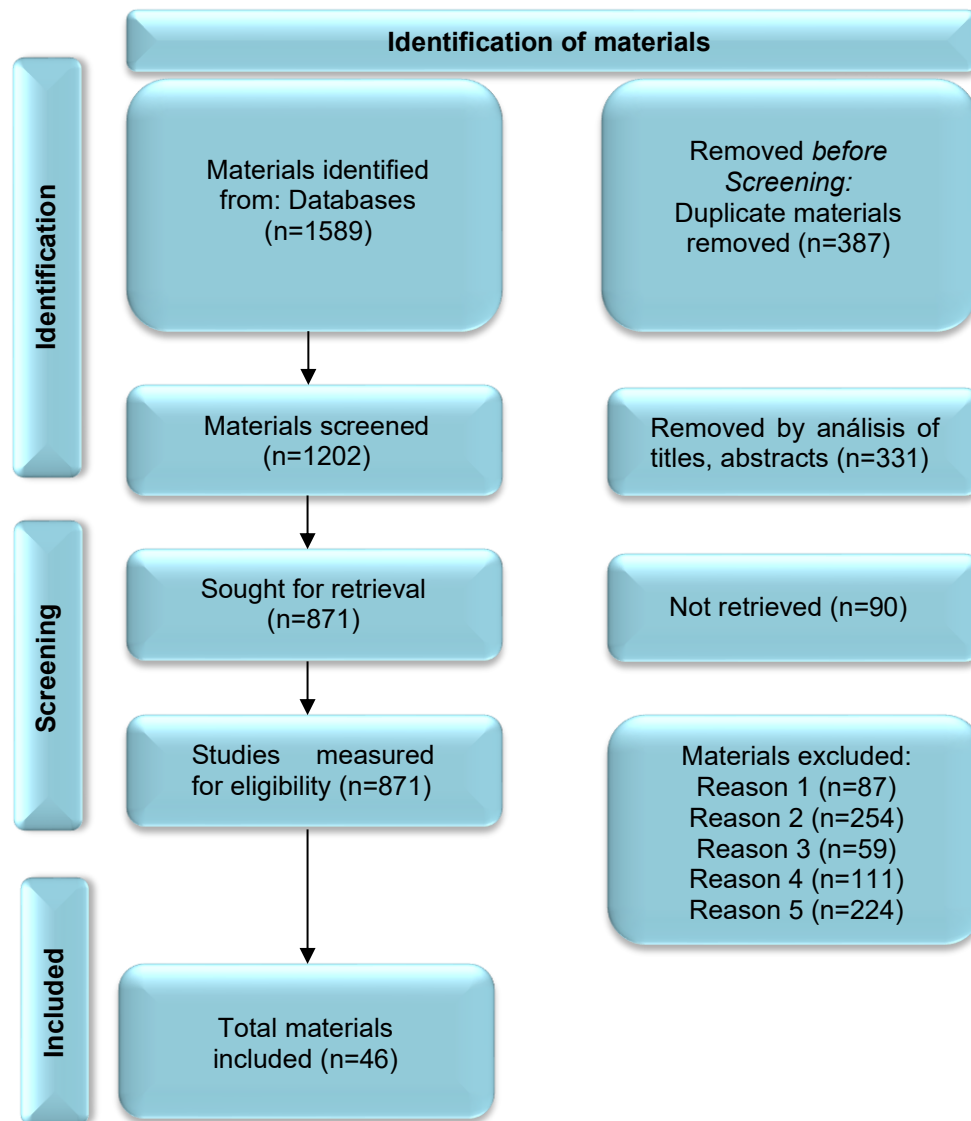
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adaptation, technologies, platforms, digitalization, crisis, management, and war were entered into the database search engine. A total of 1,589 results were obtained. First, all duplicates were removed (387 in total). Next, all irrelevant sources that did not relate to the selected topic were rejected (-331). After that, the following exclusion criteria were applied:

1. Eliminated information from non-peer-reviewed sources, including blogs, conference abstracts, incomplete reports, or journal articles that are not peer-reviewed.
2. Articles that were simultaneously duplicated in several databases were eliminated. This situation, for example, is typical for journals that are simultaneously indexed in the Scopus and Web of Science databases.
3. Irrelevant studies, as determined by analysing the abstracts of the articles.
4. Articles that do not describe the role of digitalisation in education in Ukraine.
5. Publications that do not describe modern innovative technologies.

Figure 1 shows the collection and identification of materials in accordance with PRISMA.

Data analysis

To process the data, it was used a theoretical analysis method that focused on studying the technological reform of education and science in Ukraine during the humanitarian crisis. First, we figured out the main research question: how does the humanitarian crisis (especially the war) affect the digital transformation in education. Initially, the information field was structured by identifying the main thematic areas: digital transformation of education, educational policy in times of crisis, educational inequality, the role of EdTech solutions, and management of higher education institutions in emergency situations. Within each theme, a number of sub-themes were analyzed that reveal specific aspects, in particular, types of tools, digital platforms, the level of digital literacy of participants, the level of access, user adaptation, barriers to application, and the challenges of war. The identified components were integrated into a systemic model that describes the relationships between digital processes, the crisis context, and the results of educational transformation. Triangulation of sources was used to confirm the validity of the identified topics and subtopics. In particular, the main theoretical propositions were tested by comparing them with practical examples, government data, and educational reports. Interpretation control was also carried out by reanalyzing the terms and propositions used in several sources.

Identification of materials

Identification

Materials identified
from: Databases
(n=1589)

Removed *before
Screening:*
Duplicate materials
removed (n=387)

Materials screened
(n=1202)

Removed by análisis of
titles, abstracts (n=331)

Screening

Sought for retrieval
(n=871)

Not retrieved (n=90)

Studies   measured
for eligibility (n=871)

Materials excluded:
Reason 1 (n=87)
Reason 2 (n=254)
Reason 3 (n=59)
Reason 4 (n=111)
Reason 5 (n=224)

Included

Total materials
included (n=46)

Figure 1. *The collection of sources in accordance with PRISMA*
Source: Author's development

Results and Discussion

Following the Russian Federation's full-scale invasion of Ukraine in 2022, the country's education and science system underwent transformations. In particular, digital transformation has become the main tool for ensuring the continuity of the educational process and scientific activity, which involves the active introduction and use of electronic platforms, remote technologies, and blended learning. Since then, remote platforms have been actively used for conducting classes, in particular, Zoom, Moodle, Google Classroom, etc. Zoom began to serve as the primary means of synchronous communication between teachers and students. Its widespread implementation made it possible to conduct online lectures, seminars, conferences, and individual consultations in real time. At the same time, Moodle was used mainly in higher education institutions. This platform made it possible to create structured online courses, organize testing, forums, and assessments. On the other hand, Google Classroom became widespread among schools,

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particularly during the initial phase of the COVID-19 pandemic and the war. The platform provided quick organization of the learning process, access to assignments, communication, and assessment. Thanks to its integration with Google Docs, Drive, and Meet, it creates an ecosystem for learning. In the university system, the Prometheus national course platform began to play an important role in ensuring access to quality education under restrictions. This platform actively hosts courses on relevant topics, including digital literacy and psychosocial support. Дія.Освіта is the educational component of the Дія ecosystem, focused on improving citizens' digital skills. In the context of war, the platform has become an important means of supporting digital inclusion, as it provided free courses for a wide range of users. The international MOOC platform Coursera became particularly important after the Ukrainian government obtained free access to it for educational institutions. It allowed Ukrainian students and teachers to gain knowledge from leading universities around the world. The platform expanded opportunities for academic development, but language accessibility remains a barrier, as most courses are conducted in English.

Table 1.
*Typology of technological solutions used in Ukraine during the war*

Name	Type	Purpose	Audience	Main advantages	Limitations of use
Zoom	Synchronous Online Communi-cation	Conducting online classes, consultations	Students, teachers	Simplicity, convenience, high-quality communication	Internet requirement, vulnerability
Moodle	Course Platform	Course construction, assessment	Universities, teachers	Flexibility, adaptability	Difficult to implement
Google Classroom	Cloud Learning Ecosystem	Homework, communication, assessments	Schools, lyceums, teachers	Speed, integration of Google services	Dependency on Google accounts
Prometheus	Online Courses	Self-education, preparation for external examinations	Schoolchildren, students, adults	Ukrainian-language courses, adaptation to the realities of war	Limited number of specialized courses
Diia. Education	Digital Education Platform	Development of digital skills	Wide audience	Free, localized content	Limited specialization
Coursera	MOOC	Access to courses from leading universities	Students, teachers, scientists	High quality courses, certification	Language barrier, difficult to navigate

Source: Author's development

Therefore, in the face of challenges such as war and growing migration flows, technology has ceased to be an optional extra and has become the main channel of interaction between participants in the educational process. In this context, the concept of technological mediation has taken on a particularly prominent role. Technological mediation is a process in which digital interfaces, platforms, and algorithms act as intermediaries in communication between teachers, students, and educational administrative structures. Technological mediation involves the automation of communication and assessment, the mediation of interfaces in feedback, the adaptation of content through artificial intelligence algorithms, and the digital administration of learning. EdTech (Educational Technology) is an important medium for mediation. In the Ukrainian educational context, the most common EdTech environments include LMS platforms, cloud services, MOOC platforms, AI and adaptive learning systems, and digital libraries. The use of artificial intelligence is another important area that has begun to be actively used in Ukraine. This tool is aimed at automating assessment, translation, and adaptive learning. Some universities in Ukraine have already introduced automatic assessment of student work, adaptive learning systems that consider individual learning speeds, and language support based on automated translation of materials. However, this area is still new in Ukrainian education and requires significant financial investment. Expert assessments have shown that the digital transformation of education in Ukraine places particular emphasis

on personalization and analytics technologies, as well as the application of artificial intelligence language models. Visual technologies and voice interfaces are also used, but their impact is still somewhat lower (see Figure 2).
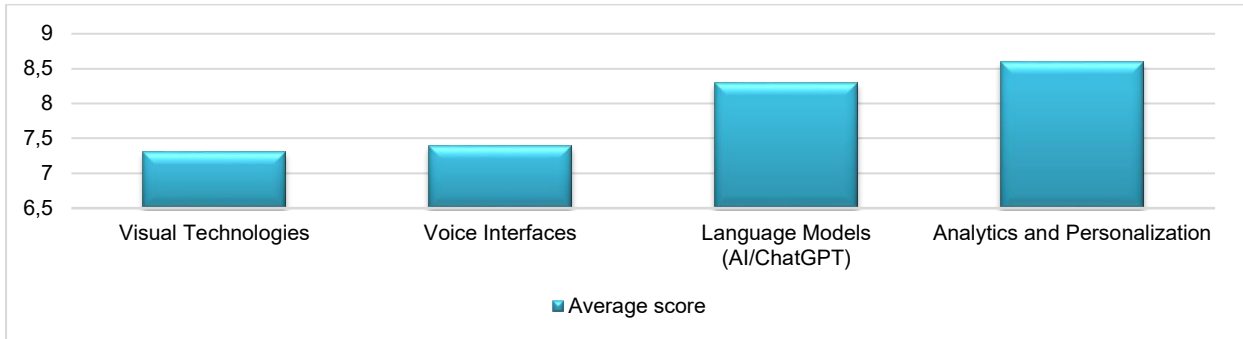

Figure 2. *Assessment of the impact of EdTech technologies on education (on a scale of 1 to 10)*
Source: *Author's development*

The advantages of technological mediation are that learning is possible anywhere and anytime, without territorial restrictions. In addition, personalization is implemented, and data analytics is carried out qualitatively. In particular, the collection of data on progress allows for a more accurate diagnosis of educational problems. An important advantage is automation (releasing the teacher from routine tasks (assessment, documentation) and digital inclusion (access to resources for people with disabilities, IDPs, and combatants). Therefore, some educational institutions in Ukraine are actively implementing modern technologies. Figure 3 presents a scheme of the functioning of technologies in Ukrainian education in times of crisis.
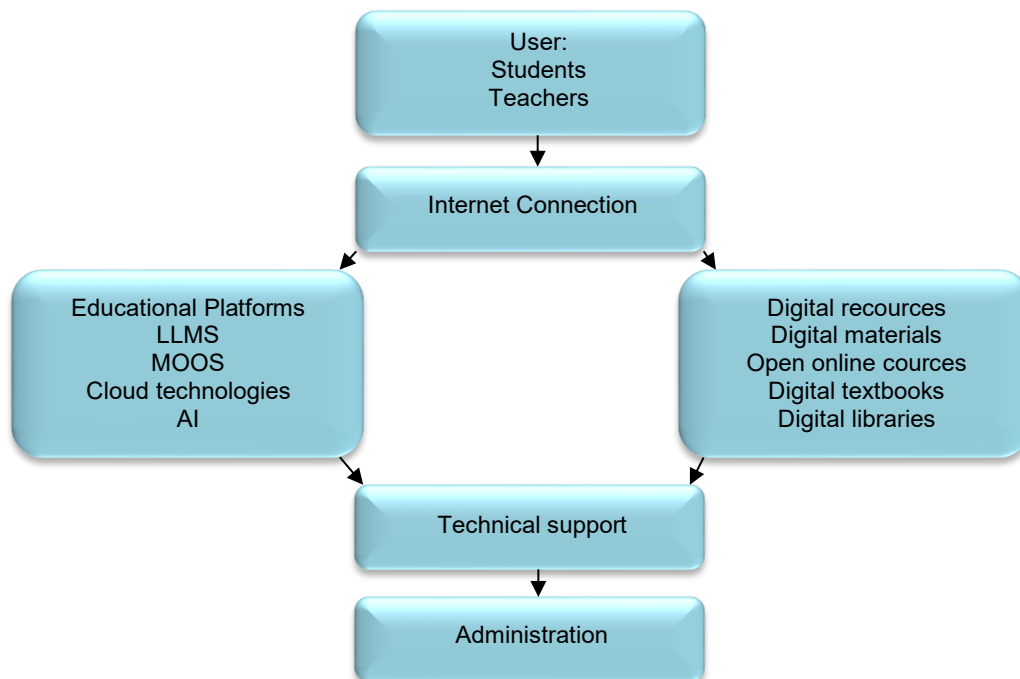
Figure 3. *Scheme of the functioning of educational platforms in times of crisis.*
Source: Author's development

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Therefore, as can be seen from Figure 3, in times of crisis, it is important to provide all participants in the educational process with technological means for effective digital learning. A significant role is played here by the network infrastructure that ensures data transmission. Reliable and accessible Internet is a key condition for connecting users to educational resources. Learning management systems (LMS), such as Zoom, Moodle, and Google Classroom, are the main ones for organizing the educational process and communicating between students and teachers. Electronic catalogs, databases, and educational literature available online should complement the main educational materials. However, the availability of technical support is especially important, as many difficulties may arise. However, not all educational institutions have the appropriate capabilities to implement these technologies. Therefore, many educational institutions in Ukraine plan to actively implement EdTech technologies. The largest share of Vision and Voice technologies is at the "Not planned" stage (38-39%). This indicates that many educational institutions have not yet begun their implementation. Analytics technology has the largest share at the "Planned" stage (35%), i.e. its active application. The share of "Embedded" is more noticeable in the areas of Language and Analytics. This generally indicates an advanced use of these technologies. The low percentage of "Abandoned" (implementation stopped), which indicates a general positive trend and interest in using EdTech/AI (See Figure 4) presents a diagram of the functioning of educational platforms in times of crisis.
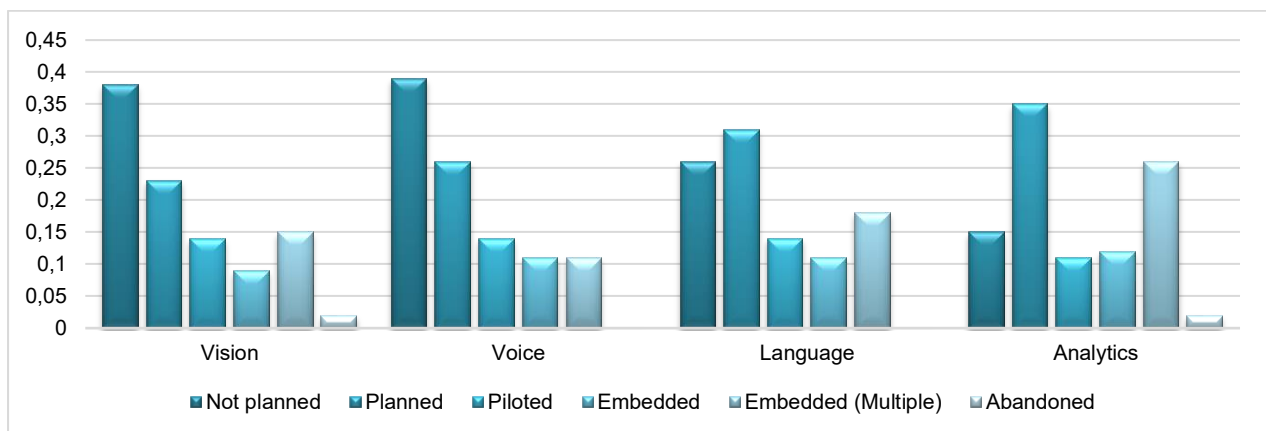

Figure 4. *Infographics on the implementation of EdTech in Ukrainian universities*
Source: Author's development

Overall, the figure shows that Ukrainian educational organizations are in the process of active planning and initial implementation of EdTech/AI, with some technologies already integrated into educational processes. According to USAID, in 2023, more than 100 EdTech projects were operating in Ukraine, most of which were integrated into the official education system. Among the most notable initiatives is the Prometheus platform, which is the first Ukrainian massive open online platform (MOOC), offering free courses in various fields of knowledge, including information technology, management, and the humanities. Another example is EduPay, which integrates distance learning with electronic journals and an online payment system, which optimizes the management of educational institutions and increases the efficiency of the educational process. It is also worth noting the Lingva. Skills project, which uses artificial intelligence methods for adaptive learning of foreign languages. In addition, an important element of the digital education infrastructure in Ukraine is the development of digital libraries. In particular, the electronic library of Ukraine (eLibraryUA) provides access to scientific, educational and artistic materials, which is an important resource for students and scholars. Similarly, the National Library of Ukraine named after V. I. Vernadsky digitizes unique archival materials and provides access to them through its own digital catalogs. However, there are also certain risks of implementing Edtech, in particular, a noticeable risk is the fragmentation of the educational space and the lack of a unified strategy for digital integration. In addition, some scientists emphasize the decrease in the quality of education in digital education. Digital inequality is also highlighted. Some works indicate that access to technology is uneven among different social groups. It is indicated that richer households have the opportunity to provide children with laptops, tablets and high-speed Internet,

which contributes to uninterrupted learning. For many families with lower incomes, the acquisition of digital technology remains unattainable, which causes a digital divide. Infrastructure limitations are also becoming noticeable. Even with financial resources, some regions of Ukraine experience problems with access to stable internet, especially in rural areas and frontline areas. These barriers complicate the implementation of innovative technological solutions, which contributes to the emergence of a digital divide.
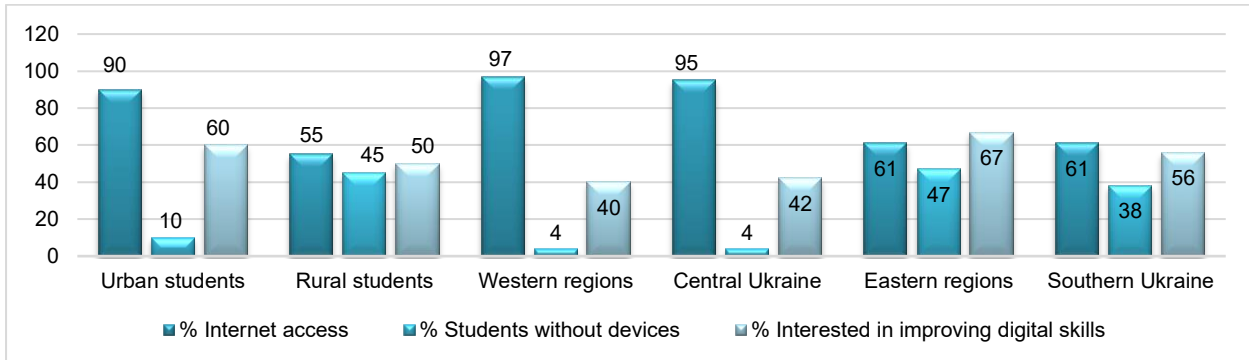
Figure 5. *Diagram of digital inequality among education seekers*
Source: created based on indicators from reports and surveys Ministry of Digital Transformation of Ukraine

In response to these challenges, a number of effective technological platforms, tools and approaches have begun to be developed and implemented in Ukraine, which have shown high efficiency in wartime conditions. The development of hybrid learning models, STEM centers, EdTech incubators and support for open educational platforms have become key components of the strategy for the digital reconstruction of education. These solutions contribute not only to ensuring the continuity of learning in times of crisis, but also to the formation of new opportunities for the development of digital competencies among students and teachers. At the same time, great emphasis is placed on the use of localized educational platforms, digital libraries with offline access and modern technical support tools. A significant role is played by the Moodle and Google Classroom platforms, which are widely used in educational institutions, as well as digital solutions developed by Ukrainian startups in the EdTech sphere. Ensuring cybersecurity and protecting personal data in conditions of heightened threats is also an important aspect (See Table 2).

Table 2.
Policy table with specific technological solutions that can be applied in similar humanitarian conditions

Category	Platforms/Tools	Description	Policy Recommendations
Hybrid Academies	Moodle, Google Classroom, Zoom, Microsoft Teams	Blended learning with online and offline components	Deploy local training centers with access to technology
STEM Centers	Arduino, Raspberry Pi, Ukrainian educational kits	Practical training in programming, robotics, engineering	Support state and public initiatives for logistical equipment
EdTech Incubators	EdTech Ukraine, 1991 Open Data Incubator	Support platforms for Ukrainian startups in the field of education	Attract international grants and donor assistance
Digital Libraries with Offline Access	Kolibri, Prometheus, National Electronic Library	Access to educational materials without stable internet	Expand localized content and training courses
24/7 Technical Support	AI chatbots (BotkinAI, "Diya"), Call centers	Real-time user support	Develop multilingual support services and operator training
Monitoring and Analytics	Google Analytics, own systems of the Ministry of Education and Science of Ukraine	Tracking the quality of distance learning	Use data to quickly adapt educational programs
Data Security and Protection	VPN services, two-factor authentication, encryption	Personal data protection, cybersecurity	Implement GDPR standards and local cybersecurity regulations

Source: Author's development

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Therefore, as can be seen from the summary table, the recommendations for countries that may find themselves in conditions of war or other systemic crises include several important points. In particular, it is necessary to make a rapid transition to digital platforms, in particular, to introduce national LMS and actively use cloud services. Another important direction is the development of digital education infrastructure, in particular, to invest in reliable Internet connectivity in schools, universities, especially in rural and remote regions. It is also important to create educational hubs with access to technology for children, IDPs, and vulnerable groups. However, an especially important direction is investment in EdTech. In particular, it is worth creating EdTech incubators to support startups that develop educational solutions and supporting such a direction as STEM education, which will allow implementing access to programmable platforms (Arduino, Raspberry Pi) in educational institutions. It is also necessary to expand digital inclusion, in particular, to ensure the availability of devices and access to the Internet for children from socially vulnerable families.

Therefore, given the main problem of the study, namely determining the impact of digital transformation in education and science in the context of the humanitarian crisis of the 21st century caused by the war in Ukraine, it was determined that in Ukraine there is a noticeable transition to distance and blended learning, digital innovative solutions are actively used. These transformations are not unique to Ukraine: similar challenges and ways to overcome them are observed in other countries (Cotán et al., 2021). Of particular importance are the studies that analyze the humanitarian crises in Syria and Iraq, as well as in education systems that have adapted to the consequences of the COVID-19 pandemic (Ali et al., 2023). The results indicate that the main tools of digital transformation have become the platforms Zoom, Moodle, Google Classroom and national resources, in particular Prometheus and Action.Education. Similar technological solutions are also observed in the Syrian and Iraqi education systems, where conflicts have also complicated the traditional educational process (Salha et al., 2023; Truba et al., 2023). For example, in Saudi Arabia, Syria, and Iraq, the active use of distance learning platforms has been a response to the destruction of school infrastructure and mass population displacement (Rajab, 2018). However, as evidenced in other works, there is a greater dependence on mobile phones and applications with low system requirements due to limited access to powerful computers and stable internet (Salha et al., 2023; Domínguez-Martínez & Robles, 2019). Similarly, in Iraq, where education has been significantly disrupted by years of conflict, the implementation of EdTech solutions has faced infrastructure problems, unequal access to technology, and the lack of a centralized digitalization strategy (Almasri et al., 2018; Ahmed et al., 2021). Accordingly, a comparison with the Ukrainian experience indicates similar challenges, especially in terms of digital inequality, which is manifested in access to the Internet and technical equipment. In addition, the problem of heterogeneity in the level of digital literacy among students and teachers has been emphasized by other scholars.

At the same time, in Ukraine, unlike most regions of Syria and Iraq, local EdTech startups and incubators are actively developing, offering innovative solutions that are adapted to the specifics of war conditions. This indicates a high level of volunteer and professional mobilization of the educational community, as well as greater support from state and international institutions. n turn, this, as presented in other works, affects the formation of the basis for a more systemic approach to the digital reconstruction of education. In contrast, some Latin American countries, while facing fewer military threats, have demonstrated slower institutional responses. According to Pedraja-Rejas et al. (2023), edtech startups in Latin America have often lacked government support or scale-up funding, leading to fragmentation of innovation ecosystems. This comparison highlights Ukraine's relative success in mobilizing both grassroots and institutional resources during the crisis.

Regarding the post-pandemic experience, many countries of the world after COVID-19 found themselves faced with the need to quickly adapt their education systems to digital technologies. Accordingly, making a comparison with works that cover education during the COVID-19 period is also important. In Latin America, where COVID-19 has exposed structural weaknesses in education systems, a similar trend has been observed. For example, in Brazil and Peru, the epidemic has exposed significant inequalities in access to digital technologies and forced schools to communicate with students using mobile phones and WhatsApp

(Tani et al., 2020; Mello et al., 2020). Despite their widespread availability, these resources have lacked pedagogical depth and have widened the gap between urban and rural areas in terms of access to high-quality educational resources. According to other researchers, the pandemic significantly accelerated the digitalization of education worldwide, while emphasizing the importance of inclusion and overcoming digital inequality (André et al., 2019), which is also reflected in the Ukrainian context. Ukrainian initiatives to develop digital libraries, offline access platforms, and technical support for users are examples of practical measures that meet the recommendations of international organizations on sustainable digital education. Similar cases of inequality have been documented in Latin America, where scholars have described the fragmented implementation of digital learning initiatives. In Colombia and Argentina, efforts to deploy national platforms have encountered technical, economic, and social barriers, especially in rural areas and among indigenous populations (Gómez Niño et al., 2024; Filho et al., 2021). These cases demonstrate that digital inequality is a global phenomenon that is not limited to conflict zones.

At the same time, as in many other countries that have experienced periods of crisis, Ukraine faces serious challenges related to the fragmentation of the educational space, the lack of a unified digital strategy, and the heterogeneity of the use of technologies at the regional level. These problems are consistent with the results of other scholars who have pointed to the problem of the weakness of central management structures. These results provide insight into important macroeconomic factors that influence social development, including the educational sector. Currently, the connection between migration processes and the educational environment is particularly important in the context of educational transformation. Similarly, as shown in other works in the post-pandemic world, many education systems are experiencing similar difficulties. This suggests that student mobility, academic migration, and the brain drain effect require further development in future research. Therefore, universal EdTech strategies, which are recognized as effective in other works, also find their application in the Ukrainian educational space. Other studies have also confirmed that the use of these approaches allows overcoming key barriers, including limited access to the Internet, lack of technical equipment and the need for technical support (Rajab, 2018). Therefore, the Ukrainian experience of digital transformation of education in wartime is an important example of adaptation to humanitarian crises using universal EdTech strategies.

The study has some limitations. In particular, the main focus of the work is on the analysis of the digital adaptation of education in Ukraine during the specific period of wartime (since 2022). Due to the limited time frame, it is difficult to draw predictive conclusions about the long-term impact of digitalization on the education system. Another important drawback is the availability of data, since the war has made it difficult to obtain up-to-date statistical information. Many official sources are not updated in a timely manner or contain incomplete data.

Conclusions

Digital adaptation of the educational environment in Ukraine is an important direction for ensuring the continuity of the educational process and scientific activity. Educational institutions have actively adapted to new realities, as they have introduced modern EdTech solutions, in particular the platforms Zoom, Moodle, Google Classroom, Coursera, Prometheus, Diya.Osvita, etc. These technologies have not only replaced traditional learning formats but also initiated a new paradigm – the so-called technological mediation, in which digital platforms act as intermediaries between participants in the educational process.

Particular attention in the digital transformation was paid to the development of personalized learning, automation of assessment, the use of language models of artificial intelligence and analytical tools. In general, EdTech analytics has the highest potential for scaling: 35% of institutions are already planning their implementation, 26% have them fully integrated. However, visual interfaces and voice solutions demonstrate the highest share of "not planned" (38–39%), which indicates a low readiness of institutions to use complex innovative interfaces. AI has begun to be used in adaptive learning, automatic assessment, and translations, but remains under-implemented, due in part to financial and technical problems.

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However, the study identified a number of challenges and limitations. The most critical are digital inequality, weak infrastructure in rural and frontline regions, fragmentation of the educational space, lack of a unified digital integration strategy, and cybersecurity risks. Therefore, it is indicated that the further development of the EdTech sector should be based on supporting state and public initiatives, attracting international assistance, developing STEM areas, providing technical support and cyber protection.

Considering these findings, several pedagogical recommendations can be proposed that are relevant for both Ukraine and Latin America. For example, develop teacher training programs focused on digital pedagogy, including inclusive and culturally sensitive practices, is a relevant scientific issue both for Ukraine and Latin America's countries. Also, implementation of AI-driven diagnostic tools to identify gaps in learning and personalize feedback, especially in underserved communities, is very important too.

The study identified a number of challenges and limitations. The most critical are digital inequality, weak infrastructure in rural and frontline regions, fragmentation of the educational space, lack of a unified digital integration strategy, and cybersecurity risks. Therefore, it is indicated that the further development of the EdTech sector should be based on supporting state and public initiatives, attracting international assistance, developing STEM areas, providing technical support and cyber protection.

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