UDC 37.018.43:004.01(477)

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PROVIDING DISTANCE EDUCATION DURING THE WAR: THE EXPERIENCE OF UKRAINE

Abstract. The sphere of education is multidimensional, it forms economic, political, and cultural impacts on society. Interruption (or complete stoppage) of the educational process in emergency situations caused by natural disasters, epidemics, and man-made disasters, results in extremely negative social consequences for society. The most negative impact on education occurs in the context of the war, as students are deprived of opportunities to learn. Destroyed schools and forced displacement can result in students no longer being able to learn in their typical learning environments. Even for students who are not affected by flight and displacement, learning opportunities in war zones can be limited because of newly dangerous circumstances. In such cases, distance education can offer students the opportunity to use distance learning technologies even under extremely difficult and challenging conditions and, in this way, contribute to a stable learning environment for students in times of war. However, little is known about distance education, the conditions for ensuring the continuity of the learning process during wartime, and how educational systems can be prepared to provide distance learning opportunities in such adverse conditions. Therefore, we explore how Ukraine is using distance education during the Russian war against Ukraine, in particular, by introducing IT innovations in distance learning. We also analyze the impact of digital technologies and educational IT infrastructure on the viability of the educational process under unfavorable social conditions. In addition, by constructing an educational regression model, we investigate various factors that may have influenced students' achievement before the war (e.g., the availability of computers for students and teachers, schools' access to high-speed internet, etc.), and identify the relationships between these factors. Our findings provide the first insights into the social implications and how countries can prepare to create distance-learning opportunities for their students during wartime and highlight the relevance of IT infrastructure in this context.

Keywords: innovations in distance education; distance learning technologies; educational IT infrastructure; educational model construction; analysis of education under social emergencies; social implications.

1. INTRODUCTION

The problem statement. The field of education is responsible for transmitting the social knowledge and valuables accumulated by previous generations to the next generations, creating a vision of the meaning of life, and understanding the ways of future development of society in the current and forthcoming conditions. The field of education is multifaceted and has an economic, political, and cultural impact on society. Interruption of the educational process due to adverse conditions caused by natural or social emergencies has very negative social consequences. Unfortunately, man-made and natural disasters, pandemics, and wars are

becoming an inherent part of the current stage of human development. World Vision International estimates that the number of emergency situations worldwide has doubled over the past decade and the number of people in need of humanitarian assistance for survival, half of whom are children, has increased dramatically during this period. In 2022, there were 274 million such persons, 39 million more than in 2021 and 106 million more than in 2020. One of the consequences of social crises has always been hunger: today, 45 million people worldwide are at risk of hunger (i.e., 18 million, or 60%, more than in 2019 [1]).

Education systems are particularly vulnerable under such circumstances because they must cover an entire country, including those areas where adverse processes, i.e., warfare or hunger crises, take place. Children are the object of the educational process and the most vulnerable part of any society. Accordingly, children suffer most under such conditions [2].

Ukrainian children have experienced many difficulties, which have had a negative impact on their physical and psychological well-being and changed the way they live and learn. The worst examples were the Chornobyl disaster; the COVID-19 pandemic; and Russia's permanent hybrid war – a blending of conventional and non-traditional tactics to achieve political-military objectives – which began in 2014 and escalated into full-scale armed aggression in 2022 [3] – [4]. However, the educational process in Ukraine was not interrupted even during the war.

Thus, the interest of researchers in the subject of education in crisis situations, as well as the creation and provision of new educational technologies using the achievements of scientific and technological progress, is obvious. At the same time, the practical experience of schooling in the context of social upheavals has not been sufficiently studied. Therefore, its generalization based on the example of Ukraine can provide a further impetus to deepen our knowledge about the functioning of education in hostile environments.

Analysis of recent research and publications. War interrupts educational biographies and has lifelong consequences [5]. Understandably, the problems of the education sector in the context of armed conflicts have been the subject of numerous scientific studies and attracted significant attention in recent years. However, there is timely data on school education from conflict-affected countries worldwide [6]. Data are mostly reported retrospectively, and analyses are mostly conducted retrospectively as well. For instance, McCulloch and Brewis [7] show that the topic of education in times of war is attracting more and more attention on the part of researchers and international organizations. Thus, the «Education, War and Peace» conference [8] was devoted to the results of studies of educational processes in European countries since the beginning of World War I. Researchers focused, in particular, on such sub-themes as education for war, education for peace, the impact of war on education, the presentation of war and peace in the media and educational materials, and the role of war and peace in cultural values. They highlight the key mediating role of education in matters of war and peace in the last century and emphasize that this historical experience can play a strategic role today.

Weinstein et al. [9], in their study, concentrated on defining the role of education in the process of social repair in four countries, Croatia, the UN-administered province of Kosovo in Serbia-Montenegro, Bosnia and Herzegovina, and Rwanda, after the mass conflicts of the 1990s. The study they conducted proved that schools are uniquely necessary for a long-term vision of the future and can contribute to reconciliation processes.

Kekmanovic [10], in turn, examined the consequences of the Croatian War of Independence, 1991 – 1995, for interrelated components of public life, such as education, employment, and income dynamics, among men born in 1971 and recruited into the armed forces. Comparative studies have shown that the war had a negative impact on their educational outcomes but a slightly positive impact on their future work and earnings. The results of the study were influenced by the fact that Croatia won the war and the people involved in the hostilities gained public recognition and credibility.

A study by Shakya [11] deals with the problems of children, including child soldiers, who were directly affected by armed conflicts in various parts of Nepal during the 2005 – 2009 period. The sample used in the study included 400 children aged 12 to 18 and allowed the author of that study to collect primary information about the real-life stories of children who suffered because of military operations. The author of the study draws attention to the fact that the reasons for the involvement and use of child soldiers differed. In some cases, it was the children's voluntary choice, made for ideological reasons, while in others, it was a method of survival. The author provides information on the abduction and deportation of children, as well as their forcible enrollment into the so-called «one house one person policy». However, the impacts on children were equally negative: gender-based violence; bullying in schools and communities; psychological trauma and its consequences such as depression and unbalanced behavior; and the abuse of psychotropic substances. The author also discusses the reintegration of child soldiers and their need for psychological support, including comprehensive measures for the return of children to public life, which can be taken by the community, religious centers, psychologists, families, and schools. The UN highlights the use of child soldiers as a serious violation of these children's rights, documenting almost 10,000 cases of child recruitment in more than 20 countries in 2017.

In Ukraine, as a result of the hybrid war with Russia that began in 2014, part of Ukraine's territory was annexed by the Russian occupiers, the national economy suffered a decline, and the social and educational infrastructure was also affected. At the same time, these processes accelerated the implementation of social reforms, especially education reform, which slowed down significantly with the outbreak of full-scale war in February 2022.

Angrist et al. [12] show, based on empirical data, that interruptions in learning due to the transition to distance education, which began in 2020 because of the COVID-19 pandemic and continued during the Russian-Ukrainian War, may have led to learning losses of at least one school year for school-aged children in Ukraine.

The research goal. Accordingly, the present study aims to analyze the functioning of school education in Ukraine under martial law, summarize this knowledge, and seek ways to improve the management of the educational process under such conditions.

2. THE THEORETICAL BACKGROUNDS

It is astonishing that there are almost no reliable data or studies regarding whether and how teaching can succeed under wartime conditions. Nonetheless, there has been a recent increase in studies that address the COVID-19 pandemic and, therefore, show initial approaches to effective education under crisis conditions.

The outbreak of the COVID-19 pandemic has created new challenges for educational systems and triggered the further development of alternative forms of learning, especially distance learning. UNICEF [13] estimates that, since the beginning of the pandemic, nearly 405 million school students from 23 countries have lost access to full-time education due to the complete or partial closure of schools. In two years, nearly 147 million children around the world have missed more than half of their full-time education, with more than 27 million of them having missed three-quarters of their full-time education, which is equivalent to a loss of 2 trillion hours of face-to-face education.

In this regard, the Organization for Economic Co-operation and Development (OECD) generally indicates the crucial role of teaching staff and school administrators in supporting and organizing the educational process: «It is a given that the quality of the educational system cannot exceed the quality of its teachers» [14].

The high level of education in the modern world is based on the maintenance of continuous professional development on the part of teachers and principals throughout all

school activities, participation in which is an indicator of the United Nations Sustainable Development Goals. The quality of education and the qualifications of teachers are important factors influencing the results of student success.

In this context, a significant role is assigned to increasing the level of information and digital competence of participants in the educational process, especially teachers. Compliance with the continuity of education under extraordinary circumstances, which is carried out mainly in distance or blended forms, can be ensured in the information and digital environment of the institution of general secondary education (availability of modern educational technologies, relevant IT resources, educational and methodological support, etc.) [15, 16].

In particular, the leadership of school principals plays a significant role in improving the functioning of educational institutions under crisis conditions. As shown in Germany [17], thanks to the principals of educational institutions, their flexibility and ability to quickly respond to demands and challenges, and their readiness to anticipate and apply the necessary innovations, schools had the reserve of strength they needed to function in turbulent environments.

Another aspect of solving this problem is the wide use of advanced educational technologies because it is through the development of a powerful IT infrastructure and the creation and use of the latest educational tools that it becomes possible to introduce effective online learning and increase the sustainability of educational institutions during the post-crisis period.

The need for online learning has intensified the introduction of modern digital technologies into the educational process and highlighted the growing gap in access to education, particularly due to the lack of adequate internet networks. According to UNICEF [13], as of 2020, 2.2 billion people in the category of «children and youth under the age of 25 years», or two-thirds of the total in that category, did not have access to the internet at home. However, internet development has been found to be closely linked to a country's level of socio-economic development (only 6% of children and youth have such access in low-income countries, as compared to 87% in high-income countries); the material situation of the family; and locality type.

It is not surprising, therefore, that the identified problems were among the main issues discussed at the UN Transforming Education Summit in September 2022 and reflected in the adopted decisions. In the context of the follow-up to the summit, a number of global initiatives were launched to address the education crisis. In particular, the International Finance Foundation for Education (IFFEd) and the Gateways to Public Digital Learning initiative on the part of UNESCO and UNICEF, respectively, indicated their support for countries attempting to overcome inequalities in access to digital learning resources. One of the «six calls to action» launched at the summit was digital learning for all, which comprehensively addresses the three following challenges [18]:

- provide access to high-quality, curriculum-adapted digital content for students and teachers through digital learning platforms;
- increasing the opportunities for participants in the educational process to use digital technologies and tools;
- enabling the expansion of lifelong learning opportunities through digital connectivity by eliminating inequalities in access to quality internet.

This article combines the subject of those scientific studies that are aimed at studying, systematization, and generalizing the use of the best experience of the organization of the educational process in dangerous conditions, including the military, in particular through wider use of new technologies and changes in education management.

3. RESEARCH METHODOLOGY

Our article has four aims: 1. To give an overview of distance education measures using distance learning technologies during the Russian war in Ukraine (hybrid & and full-scale armed). 2. To show how IT infrastructures for schools, students, and teachers in Ukraine have changed in recent years. 3. To investigate how this relates to student performance at the regional level within Ukraine. 4. To give indications on how to educate students on the move even under the most adverse circumstances, i.e. warfare and flight.

In order to fully solve the main tasks and obtain the objective results envisaged by this study, we applied a comprehensive strategy using both quantitative and qualitative approaches (methodological triangulation). The research process used a mixed (QUAN-qual) methods design [19].

For the purposes of the present study, the necessary data on the functioning of schools during the 2019 – 2022 period, were collected both in Ukraine as a whole and in each of its regions. The main information was obtained from the website of the State Statistics Service of Ukraine and the software and hardware complex known as the Automated Information Complex of Educational Management (AICEM) database, which belongs to the Ministry of Education and Science of Ukraine and is administrated by the Institute of Educational Analytics [20]. The Automated Information Complex of Educational Management is a national educational management information system for the collection, processing, storage, and dissemination of educational information on preschool, out-of-school, school, and vocational education. During the same period, the Ukrainian Centre for Educational Quality Assessment [21] provided open data on the results of the training of school graduates as part of national external independent testing on compulsory subjects, specifically mathematics, and Ukrainian.

In this way, the set of data needed for the study was created, from which the following indicators were derived (Table A):

1) The share of schools connected to the internet via cable with a speed of 100 Mbit/s or more (%); this indicator is calculated by dividing the number of schools with the appropriate internet connection in the region by the total number of schools (these data are available in the official statistical report of general secondary education institutions).

2) The share of schools wirelessly connected to the Internet with a speed of 100 Mbit/s or more (%); this indicator is calculated by dividing the number of schools with the appropriate Internet connection in the region by the total number of schools (data availability as above).

3) The number of teaching staff per school portable device (persons); this indicator is calculated by dividing the number of teachers in the school (these data are available in the official annual report on the number and structure of teaching staff in general secondary education institutions) by the number of school portable laptops and netbooks (these data are available in the official statistical report of general secondary education institutions).

4) The number of students per school computer connected to the internet, (persons); this indicator is calculated by dividing the number of school students by the number of school computers connected to the internet that are used to educate school students (data availability as above).

5) The average salary of school teachers in the regional context in the national currency (hryvnias); this indicator is calculated by dividing total cash expenditures (these data are available in the official reporting data of the State Treasury Service of Ukraine on the amount of educational subvention funds (transferred from the state budget to the local budgets of a certain region) and the amount of corresponding own funds in local budgets of that region) by the number of teachers in the region (these data are available in the official annual report on the number and structure of teaching staff in general secondary education institutions).

6) The average external independent testing scores of school graduates of a certain region in two compulsory subjects, mathematics and Ukrainian.

The resulting dataset is shown in Table A in the appendix.

These data were collected to answer the main research question formulated above. Because distance learning, specifically online learning, is more widely used for continuing education in emergencies, its results will depend on factors such as school internet parameters, the availability of gadgets and computers among students, the provision of teachers with the necessary computer equipment, and encouraging resource support for teachers in the form of their salaries. As an indicator of the educational efficiency of school students, we chose their average scores for mathematics and their native language, Ukrainian, based on mandatory external independent testing.

The geographic (re-) location of school students because of forced internal or external displacement can also affect learning outcomes. In this context, identifying students' locations using direct and indirect research methods is very important. Direct methods of identifying their geographic locations (e.g., collecting statistics from embassies) are reliable and accurate but also expensive, time-consuming, and difficult to apply. After all, the collection of such data in many countries via diplomatic agencies and migration services is difficult. For example, information from the temporarily occupied territories is not directly available. The indirect peer review method is more appropriate for rapid assessment purposes in emergencies, thus reducing the costs of obtaining information.

In this context, we suggest the following approach. Indirect assessment can be based on electronic statistics created when students use popular e-learning resources. One such resource in Ukraine is the online educational platform All-Ukrainian School Online (E-School.net.ua), which is used for distance and blended learning for grades 5 – 11. Another source of such information could be school E-Journal websites. For example, the electronic school journals of the LLC New Knowledge (E-Journal) are very common among school students in all regions of Ukraine. In such a journal, students' attendance of classes and academic results are recorded.

When visiting the websites of the above-mentioned online resources, the number of unique IP addresses that have visited a website over a certain period is recorded, and the countries of residence can also be identified. To estimate the number of school students in different countries, it is possible to rank the relative number of IP addresses in these countries and assign this relative value to the nominal value of the number of persons if the total number of students living abroad is known. In Ukraine, this total number is periodically assessed by the Ministry of Education and Science of Ukraine.

In addition to presenting descriptive statistics, we use linear regression models [22] and thermal matrices [23] in our study. Thus, the generated dataset can be used to formalize a linear regression model of the dependence of learning outcomes (e.g., average test scores) in a specific region (dependent variable Y) on independent factor variables (variables X_i), such as the presence of an internet connection, the availability of necessary computer equipment for students and teachers, and teachers' salaries in the region (regions can contribute additional funds to the national educational subvention). One advantage of multi-factor modeling is the ability to compare the relative influences of various factors, draw conclusions, and justify proposals for priority management measures, which may have a significant impact under the present circumstances.

Another tool for use in studying the state of education for management purposes is the thermal matrix, in which relative educational indicators are calculated on the basis of the formed dataset and the educational level of a certain region relative to others is also assessed. Furthermore, the use of a risk-oriented visualization identifies regional educational problems in the functioning of the network of institutions and determines the priority of managerial tasks so as to eliminate these problem areas.

4. THE RESULTS AND DISCUSSION

In Ukraine, before the beginning of the pandemic, a certain level of digital support for the education sector had already been established, allowing for the continuation of the educational process and the creation of conditions for more sustainable functioning in subsequent crisis situations, including wartime conditions. According to PISA-2018, in the category of providing students with computers in school, which was measured using the number of computers per student, Ukraine took 28th place among 78 countries.

Under wartime conditions, the Ukrainian education system intensified its efforts to continue the educational process, using practical experience gained by solving key problems in previous turbulent environments. Opportunities for the digital support of distance learning were expanded. To this purpose, the Ministry of Education and Science of Ukraine has actively attracted international partners who are representatives of Ukrainian businesses and patrons. The work has included providing participants in the educational process with the technical means of online training, providing internet access, expanding online educational platforms and methodological support for distance learning, and improving digital literacy among teachers and students.

4.1. IT Infrastructure in Ukrainian Schools

Fig. 1 shows the dynamics of the indicators characterizing the development of IT infrastructure in Ukrainian schools. With the spread of the COVID-19 pandemic and the forced shift to distance and blended learnin, schools' access to the internet has increased. The percentage of schools connected to high-speed internet, with a speed of 100 Mbit/s or more, has increased from 18 to 27%, over the 2019 – 2022 period for both cable and wireless connections. The technical supply of computer equipment and general internet access to schools has improved. During this period, the teacher load per portable IT device located in school decreased from 3.87 to 1.79, and the number of students per computer with an internet connection at school decreased from 17.51 to 16.21 persons. Overall, more and more teachers and students were able to access digital devices during the period under review.

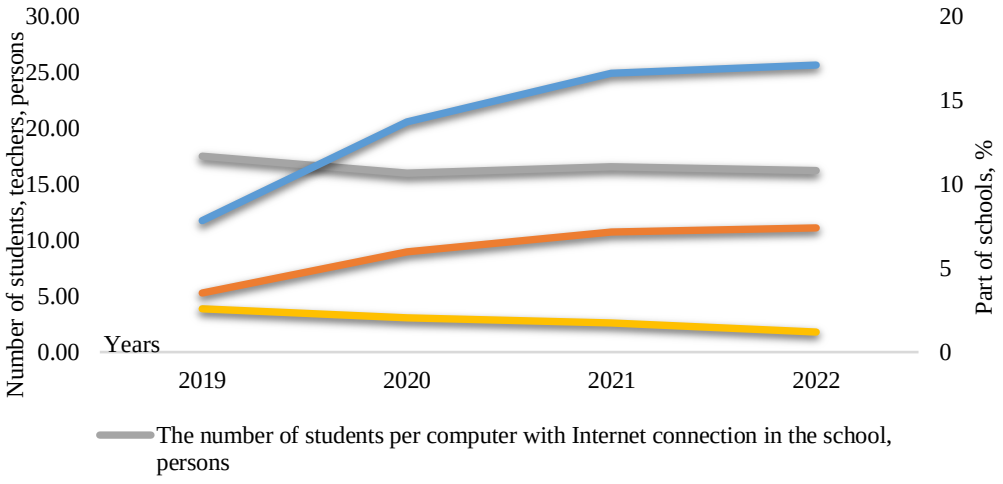

Fig. 1. Dynamics of change for indicators characterizing the development of IT infrastructure in general secondary education institutions in Ukraine

In 2022, Russia's invasion of Ukraine led to the partial destruction of its educational infrastructure. However, alternative options have been pursued. In particular, the network of educational institutions in Ukraine, including schools, received Starlink equipment in the form

of terminals and satellite antennas to provide access to high-speed, highly reliable satellite communications, especially in those areas where alternatives are limited, such as remote mountainous areas.

The military actions of the Russian Federation in Ukraine have also caused flows of internally displaced persons and refugees abroad, including many school students and teachers. In addition to humanitarian problems, these participants in the educational process were left without educational facilities and computer equipment.

In May 2022, the Ministry of Education and Science of Ukraine, the SSI known as the Institute of Educational Analytics, UNICEF-Ukraine, and the NGO known as Save the Children International conducted a national survey to determine the educational needs of Ukraine under martial law [24]. According to estimates, at the beginning of May 2022, there was a need for 165,309 laptops for teaching staff and 202,562 tablets for students. Within the month, confirmation of the availability of digital devices from international partners was received, including UNICEF's 5,000 notebooks and Google's 43,000 Chromebooks.

At the beginning of November 2022, about 39,000 devices were delivered to Ukraine. The Chromebooks are equipped with a specialized operating system, Chrome OS. Thus, clear instructions regarding their connection and configuration have been developed within the framework of the Google Digital Tools for Education program. The training was conducted during the 2022/2023 school year via a separate module on the use of Chrome OS in the educational process (https://bit.ly/3yQoDqe). Based on the results of this training, teachers are awarded Certificates of Skills Development.

Google has provided free access to the advanced features of the Google Workspace for Education service. The use of Google Workspace for Education services allows you to significantly improve the organization and management of the educational process in alternative forms (distance, blended) thanks creation of a single information space of an educational institution [25]. Free access to several Microsoft, Google, and Zoom products was also provided. Almost 5 million licenses for the Microsoft Office 365 A1 package for schools and more than 100,000 MS Office and Windows for Education licenses were granted to educational institutions in Ukraine. The technical team worked on the implementation of Microsoft Office 365 in educational institutions and provided free access to 38,000 Office 365 - A3 licenses.

4.2. Associations between IT Infrastructure and Student Achievement

Taking this information into account, the data analysis for the pre-war period of 2019 – 2021 was conducted. It is necessary to note that this period began shortly before the outbreak of the COVID-19 pandemic, in 2020, and covers roughly the period until Russian troops invaded Ukraine at the beginning of 2022. The statistical model may be presented as follows:

$$Y = f(X_1, X_2, \ldots, X_n) + \varepsilon, \quad (1)$$

where Y is the dependent, resulting variable; $X_1, X_2, \ldots, X_n$ are the independent, factor variables; f is function type for the model; and ε is the model error.

The uncertainty regarding the type of relationship between the factor and dependent variables is high in our case, so we will first hypothesize whether there is an appropriate linear relationship. In this case, the model is as follows:

$$Y = a_0 + a_1X_1 + a_2X_2 + \ldots + a_nX_n + \varepsilon. \quad (2)$$

As the dependent variable Y, we choose the indicator of the average score in a certain Ukrainian region. It will depend on several variables that will be selected from the set of indicators created above. It is known from modeling theory that the number of factor variables should not exceed a certain value, which correlates with the length of the series of values for the dependent variable Y. In particular, to obtain an unbiased, reasonable, and efficient

estimation of the coefficients a_0, a_1, a_2, …, a_n, the length of the series must exceed the number of variables by at least seven times. As we have collected the values of Y for 25 regions of Ukraine (see Appendix), there should be no more than three independent (factor) variables. The overall model will be as follows:

$$Y = a_0 + a_1X_1 + a_2X_2 + \ldots + a_3X_3 + \varepsilon. \quad (3)$$

To select independent variables for modeling, we estimated the pairwise correlation between the five indicators mentioned above and then selected the three indicators with the lowest pair correlations as independent variables: X_1 – share of schools with broadband Internet access with a speed of 100 Mbit/s or more (%); X_2 – number of teachers per portable device (persons); X_3 – average salary of school teachers (educational subvention + funds from local budgets; hryvnias).

Microsoft Excel tools were used to find the a_0, a_1, a_2, and a_3 values. In particular, the Linest functionality and the Solver program for finding the optimal solution were used. The modeling was carried out via a gradual iteration to increase the statistical parameters of the model elements in the form of pairs, dropping the regional indicators from the model value that deviated the most in the positive and negative directions. The second requirement was that the regions excluded from consideration be equally distributed throughout the country.

The conducted modeling for the data from 2019 and 2020 did not allow us to establish dependence with an acceptable coefficient of determination, which would have affirmed the significance (adequacy) of the model equation.

For the 2021 data modeling, the following model equation was obtained:

$$Y = 125.546 + 0.027X_1 - 0.090X_2 + 0.001X_3 + \varepsilon. \quad (4)$$

In this case, the coefficient of determination was $R^2 = 0.54$; Fisher's statistic was $F = 5.83$. The comparison of this value with the critical tabular value confirms the adequacy of the created model. The necessary testing of the model for the presence of multicollinearity and heteroscedasticity was conducted.

The Goldfeld-Quandt test was used to check for the presence of heteroscedasticity. The residuals of the model were ranked, and each residual was squared. In the middle of a series of 19 values, five values were removed. For one part of the remaining series of seven values, the sum of the squares of residues was found, and this value was 17.24. For another part, a value of 11.02 was obtained, so the ratio $F = 1.565$. The hypothesis that the variance of both parts of the series is equal was then tested using F-statistics. The appropriate critical value for Fisher's F-criterion for $p = 0.95$, $n = 7$, and $k = 3$ is 4.35. The value we obtained, 1.565, is less than the critical value. Therefore, the hypothesis regarding the equality of variances for both parts of the comparable series can be confirmed, so there is no heteroscedasticity in our model.

The method of comparing the pairwise coefficients of correlation for each independent variable with the coefficients of correlation for a dependent variable, which are combined in the matrix, has been used to check for multicollinearity. The model showed no strong multicollinearity. There is also no moderate multicollinearity in the model, as the smallest value among the pairwise correlations was less than the smallest value among the correlation coefficients for the dependent variable with each of the independent variables. Thus, if there is multicollinearity in the model, it is very weak.

As shown in formula (4), the coefficient $a_1 = 0.027$, which indicates that an increase of one percent in the share of schools with cable internet connections at 100 or more Mbit/s leads to an increase of 0.027 in the regional average score. In turn, improving the provision of portable devices to teachers, that is, reducing the number of teachers per portable device per unit, increases the average score on the part of school students by 0.090. Finally, an increase in teacher salaries of one hryvnia leads to an increase of only 0.001 in the average score, indicating a weak effect.

4.3. Managing Online Education During War

Thus, during the COVID-19 pandemic period, there was a relationship between available IT infrastructure and student performance aggregated at the regional level. However, particularly in emergencies, effective management tools are needed to reduce decision-making time and increase decision-making validity. In order to strengthen the informational soundness of managerial decisions at the level of the Ministry of Education and Science of Ukraine and the heads of the Departments of Education and Science of Regional State Administrations in Ukraine, through the joint efforts of a special working group consisting of specialists from the SSI known as the Institute of Educational Analytics, the Ministry of Education and Science of Ukraine, and employees of regional education departments, a set of indicators of management information for the development of education, the so-called Solid Info, was created. On the basis of these indicators and a risk-oriented approach, the thermal matrix information-management tool was visualized, which allows for the fast identification of educational problems and determines the priority of tasks so as to overcome or minimize them.

In our study, by analogy, a thermal matrix was also constructed using indicators describing the state of computer and infrastructure provision for distance learning, as well as the average salary of teachers. The data processing algorithm (Fig. 2) was chosen by us according to option *b* because the distribution of the values used in our study is not normal; therefore, option *a*, which is used with a normal distribution, was not applicable.

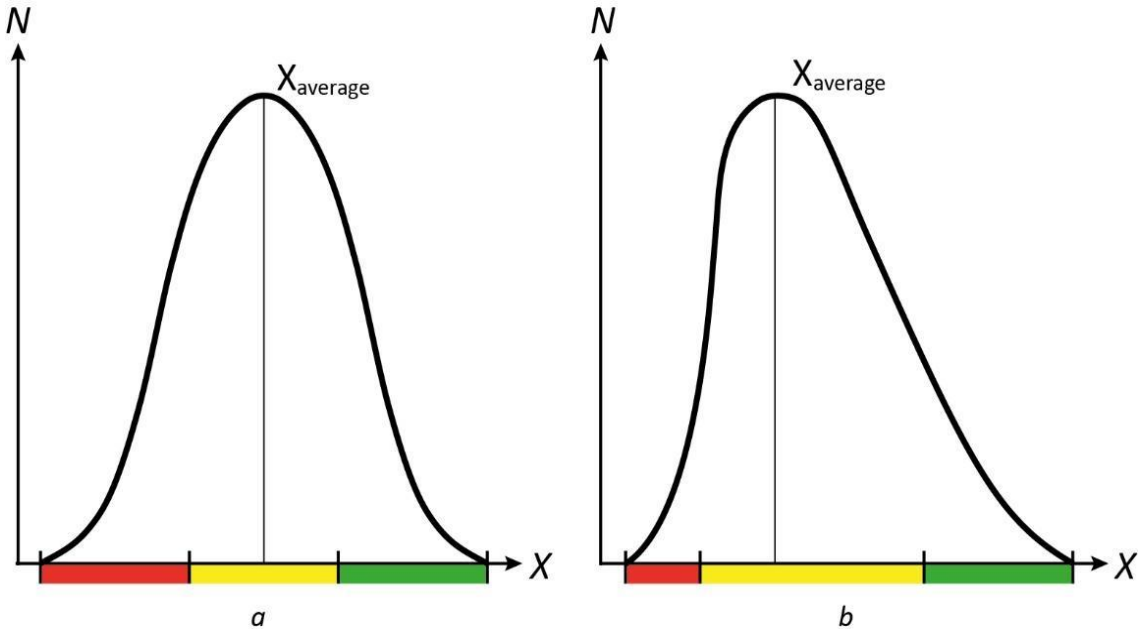

Fig. 2. Data-processing options

The average value of the indicators was chosen for Ukraine as a whole. The ranges of changes, from the lowest to the middle and from the middle to the highest, were divided into two subranges. From the two central subranges, the area near the average was created, which was assigned a yellow color (see Fig. 2). The other subranges were given green and red colors. A general matrix for all indicators was then visualized (see Table 1).

The analysis of the thermal matrix on the selected indicators showed that, among the 25 regions of Ukraine for the analyzed period, 2019 – 2022, the best conditions for distance learning in Ukraine occurred in several regions. According to the indicators of IT infrastructure development, the leading regions are Kyiv city and the Kyiv and Kirovohrad regions (see Table 2). The values for these regions are in the above-average or close-to-average subranges.

Table 1

«Thermal matrix» on educational indicators in the dynamics for 2019 – 2022

Years	2019					2020					2021					2022				
Region / Indicators	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
Ukraine	*7.83*	*3.52*	*17.51*	*3.87*	*9,621*	*13.7*	*5.96*	*16.00*	*3.07*	*12,855*	*16.61*	*7.15*	*16.56*	*2.63*	*14,972*	*17.10*	*7.4*	*16.21*	*2.45*	*11,563*
Vinnytsya	3.76	1.42	18.10	3.96	9,570	7.10	2.28	16.26	3.12	11,494	7.95	3.82	16.45	2.37	14,519	8.40	3.80	16.04	2.25	11,356
Volyn	4.58	2.29	19.54	4.11	8,534	10.10	2.53	16.35	3.22	12,335	11.59	0.71	19.87	3.22	14,734	12.30	0.90	18.53	2.78	12,293
Dnipropetrovsk	11.51	7.48	19.81	3.27	11,322	16.63	13.58	18.29	2.50	13,185	16.51	11.67	17.65	2.27	14,906	17.40	12.20	17.18	2.00	11,030
Donetsk	13.87	4.69	17.73	3.15	8,694	15.98	8.68	15.77	2.50	10,922	16.99	10.59	16.71	2.15	13,049	17.70	10.70	16.32	1.80	9,911
Zhytomyr	4.75	2.22	21.74	4.25	9,033	7.32	2.76	20.46	3.64	12,066	11.76	5.19	19.44	3.28	14,660	11.70	5.40	19.25	2.73	11,548
Zakarpattya	3.61	2.11	24.80	6.36	9,299	16.90	11.85	21.76	4.91	13,493	18.6	14.16	23.10	4.08	15,927	19.40	15.50	22.77	4.05	12,352
Zaporizhzhya	11.42	4.31	12.91	3.85	11,018	16.73	5.83	12.19	3.28	12,021	17.74	9.68	12.60	2.40	14,711	18.60	10.10	12.00	2.07	10,252
Ivano-Frankivsk	3.36	0.00	19.40	6.86	11,164	3.93	0.00	17.75	5.56	14,169	6.77	0.00	18.86	4.56	15,319	6.80	0.00	18.70	4.58	12,185
Kyiv-region	21.55	10.78	15.96	3.06	9,832	32.19	17.74	14.58	2.56	16,047	32.47	17.38	17.15	2.12	14,880	32.70	17.40	16.91	2.20	11,738
Kirovohrad	15.72	11.01	16.15	4.93	9,322	23.45	10.42	14.76	3.48	12,186	24.42	13.86	14.40	3.05	14,183	25.90	15.30	14.24	2.68	12,195
Luhansk	6.91	2.18	14.35	3.21	8,405	8.42	2.93	12.74	2.73	12,202	11.02	0.79	13.23	2.36	13,850	11.10	0.80	12.86	1.92	9,636
Lviv	3.52	1.42	19.36	4.89	9,626	7.54	2.79	16.92	3.69	12,275	10.88	6.19	17.74	3.25	15,194	11.30	6.50	17.43	3.18	10,702
Mykolayiv	6.26	2.51	13.60	2.98	9,290	8.46	4.44	12.65	2.51	12,402	11.26	2.87	12.66	2.34	14,555	11.50	3.10	12.38	2.16	12,444
Odesa	6.80	1.76	19.78	4.26	9,455	8.67	3.06	18.79	2.90	13,183	20.92	7.88	19.84	2.42	14,765	21.50	8.00	19.42	2.31	12,522
Poltava	6.48	3.32	13.38	3.53	10,722	15.66	12.56	12.03	2.82	11,661	20.79	12.55	12.23	2.14	14,665	20.80	12.50	12.06	2.07	11,984
Rivne	8.52	1.19	21.76	4.07	9,389	37.03	3.92	19.98	3.33	13,620	21.88	0.18	21.59	2.81	15,198	22.20	0.20	21.04	2.68	13,475
Sumy	10.10	2.16	14.30	2.97	9,623	15.46	3.99	12.97	2.55	11,395	14.67	3.47	13.04	2.27	13,598	15.50	3.50	12.78	2.06	10,833
Ternopil	7.73	4.01	15.58	5.35	8,860	12.23	3.35	13.96	4.37	12,310	16.39	0.77	15.00	3.55	14,176	16.50	0.80	14.88	3.46	11,203
Kharkiv	6.53	3.81	20.70	3.69	8,849	15.78	5.21	19.28	2.99	12,323	18.32	4.90	17.44	3.28	13,813	18.90	5.20	17.15	2.94	13,637
Kherson	5.54	2.41	18.17	2.76	9,364	9.18	5.36	16.64	2.09	12,644	12.24	5.99	17.64	1.93	14,538	12.50	6.00	17.31	1.65	6,943
Khmelnytskiy	4.01	2.62	14.74	4.02	9,219	6.61	4.03	13.33	3.35	11,740	11.25	6.23	13.84	2.77	14,421	11.60	6.40	13.60	2.69	11,949
Cherkassy	7.73	2.16	12.43	3.39	8,826	11.82	3.94	11.76	2.92	12,822	12.58	6.49	12.17	2.20	14,072	12.60	6.50	11.89	2.13	12,274
Chernivtsi	8.71	7.46	17.02	4.25	9,430	25.57	9.37	16.08	3.39	13,483	22.06	10.03	17.81	2.81	15,259	22.60	10.00	17.51	2.74	11,489
Chernihiv	4.73	0.82	16.91	4.03	8,508	7.84	2.75	14.51	3.32	12,899	9.86	2.35	15.73	2.64	13,897	10.10	2.30	15.57	2.49	9,326
Kyiv-city	16.92	6.65	17.93	3.04	13,156	11.09	6.44	16.96	2.41	15,186	37.48	17.96	16.80	2.03	20,288	38.10	18.20	16.62	1.98	10,995

Note. A1 – the share of schools connected to the Internet by cable with a speed of 100 Mbit/s or more (%); A2 – the share of schools wirelessly connected to the Internet with a speed of 100 Mbit/s or more (%); A3 – the number of students per one school computer connected to the Internet (persons); A4 – the number of teaching staff per school portable device (persons); A5 – average monthly salary of teachers (the sum of educational subvention funds and own funds of local budgets) (hryvnias).

Table 2

Indicators of schools being connected to the internet

Regions/ Indicators	The share of schools connected to the internet via cable with a speed of 100 Mbit/s or more (%)				The share of schools wirelessly connected to the Internet with a speed of 100 Mbit/s or more (%)			
Years	2019	2020	2021	2022	2019	2020	2021	2022
Kyiv-region	21.55	32.19	32.47	32.7	10.78	17.74	17.38	17.4
Kyiv-city	16.92	11.09	37.48	38.1	6.65	6.44	17.96	18.2
Kirovohrad	15.72	23.45	24.42	25.9	11.01	10.42	13.86	15.3
Ukraine	*7.83*	*13.7*	*16.61*	*17.1*	*3.52*	*5.96*	*7.15*	*7.4*

According to the indicators of teachers being provided with portable devices, the best out of the 25 regions are Kyiv city and the Kyiv and Dnipropetrovsk regions. In 2022, as compared to 2019, the values improved by 1.5 times in Kyiv-city, 1.4 times in the Kyiv region, and 1.6 times in the Dnipropetrovsk region, and these are mainly in the subranges above the average value.

At the same time, the matrix shows that some regions have been in a critical situation for several years. In the Ivano-Frankivsk and Zakarpattya regions, indicators of the availability of educational facilities for students and teachers suggest a risk: for the provision of teachers with portable devices during the analyzed period, the indicators for the Zakarpattya region are more than 1.6 times lower than the average values for Ukraine, and in Ivano-Frankivsk region, they are more than in 1.8 times lower.

Difficulties regarding the development of IT infrastructure (school access to the internet) were noted in the Lviv, Zakarpattya, Ivano-Frankivsk, and Khmelnytskiy regions. The mountainous terrain; the smallness of local budgets; and, accordingly, the co-financing of the educational sector have had negative impacts on such development. The dynamics of the indicators provide policymakers, especially at the regional level, with a clear picture of the state of education in some respects and improve the provision of affordable, quality education services. In particular, under conditions of martial law, education authorities took into account the problems of cable internet access in these areas, with a particular focus on wireless internet access. Most Starlink kits were directed specifically to schools in mountainous areas (Fig. 3).

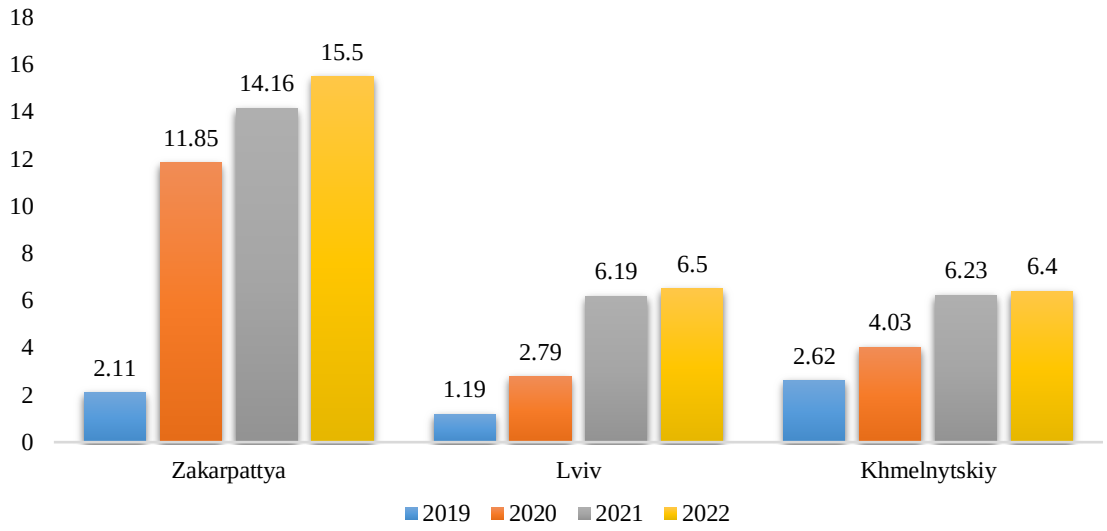

Fig. 3. Dynamics of change of indicators characterizing the share of schools wirelessly connected to the internet with a speed of 100 Mbit/s or more (%)

long with the IT provisions for schools, another important factor is the development of electronic learning platforms that can provide organizational support and meaningful education in emergencies. Even before the onset of the COVID-19 pandemic in 2018, Ukraine ranked 26th in the world in providing educational platforms for schools and 11th in professional resources for teachers regarding digital literacy [26].

In Ukraine, in December 2021, the electronic learning platform known as All-Ukrainian School Online (E-School) began operating, with the aim of ensuring equal access to quality school education for grades 5 – 11. This platform was launched by the Ministry of Education and Science of Ukraine, together with the Ministry of Digital Transformation of Ukraine. The need to create a national educational platform was instigated by the spread of COVID-19.

Educational materials posted on the E-School platform meet state educational standards. Students have access to video explanations, notes, and tests and can track their learning progress. In addition, they can use this platform to learn about topics that they missed. In turn, teachers were given access to the necessary methodological recommendations, as well as examples of the use of modern educational IT technologies.

Also, via an order on the part of the Ministry of Education and Science of Ukraine, electronic applications such as e-diary and e-journals were launched. These solutions make it possible to switch to electronic document circulation in the context of distance learning and thus provide students with 24-hour access to information about tasks and schedules and give parents and teachers the opportunity to monitor students' attendance and successes, as well as teachers' comments.

The Russian invasion caused a social shock in Ukraine. However, the IT tools provided became an important component of the educational process despite Russian aggression. Later, especially at the beginning of the war, the portfolio of online tools was expanded through both the efforts of the Ukrainian government and the support of Ukraine by international partners. Thus, educational IT applications, such as Diia Digital Education, All-Ukrainian School Online, Prosvita, Smart Osvita, Ukrainian Education in Emergencies, and Together to Education, have begun to work.

4.4. Educating Students on the Move

The war affected the safety of students and teachers. According to official data [27], as of November 4, 2022, more than 1,255 children had suffered in Ukraine as a result of armed aggression by Russia: four hundred thirty children were killed, and 826 suffered injuries of various severity levels, without considering areas with active hostilities and temporarily occupied and liberated territories. The fates of 10,570 deported and 263 missing children are unknown. Children in the Donetsk, Kharkiv, Kyiv, Mykolaiv, Zaporizhzhya, Chernihiv, Luhansk, Kherson, and Dnipropetrovsk regions have suffered the most.

At the beginning of the 2021/2022 school year in Ukraine, the network of general secondary education institutions consisted of 13,991 schools: five thousand five hundred and forty-five in urban areas and 8,446 in rural areas. As of November 4, 2022, because of shelling and bombing, the total number of damaged educational institutions reached 2,719, including 332 schools that were completely destroyed. At the same time, there were 1,070 schools in the occupied territories, including 158 in the Donetsk region, 265 in the Zaporizhzhya region, 252 in the Luhansk region, 26 in the Kharkiv region, and 359 in the Kherson region.

The hostilities have also generated massive flows of Ukrainian residents within the country. These are internally displaced persons (IDPs; i.e., students who were forced to leave their homes within Ukraine to avoid dangerous threats) and those forced to travel abroad (i.e., students who crossed an international border due to a well-founded fear of persecution and are considered refugees). Of course, most of these children moved with their parents.

As mentioned above, today, it is extremely important to collect information about the whereabouts of displaced children. Such information can be obtained through the country's embassies in other countries. But it's a costly and slow method for emergencies. We used the already available IT technologies to assess the distribution of Ukrainian school students abroad, in particular, Google Analytics service to analyze the IP addresses of students visiting popular Ukrainian educational resources. For example, the total monthly attendance of the most famous learning platform All-Ukrainian School online is about 1.5 million visitors; the monthly attendance of the E-Journal website is 0.9 million users. Using Google Analytics, the relative distribution of Ukrainian school students in the context of foreign countries, which was imposed on the total number of school students abroad, as determined by the military and civil

administrations of the regions of Ukraine, was evaluated within a few months. Since September 2022, this indicator has stabilized at around 500,000 persons (Fig. 4).

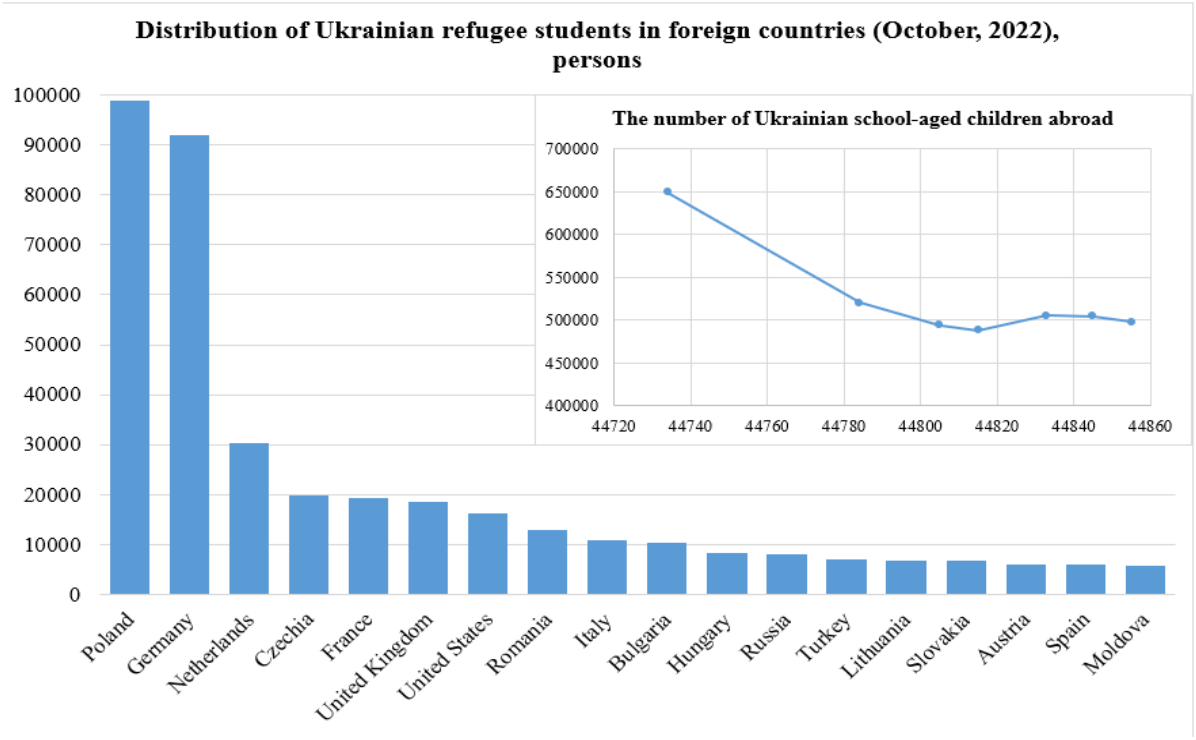

Fig. 4. Ranking of countries by number of Ukrainian school students abroad

Fig. 4 demonstrates the distribution of Ukrainian students who fled abroad because of the war and became refugees. Most are in the EU countries, and Poland and Germany are hosting the lion's share of Ukrainian school students. Other countries that have sheltered many Ukrainian refugees from the war are the Netherlands, the Czech Republic, France, and the United Kingdom, which can be explained by not only their geographical proximity to Ukraine but also the fact that these nations can provide social support.

For the period from the end of May to October 2022, the downward trend in the total number of Ukrainian school students, which is periodically monitored by regional civil-military administrations in Ukraine, may be attributed to the following factors. During the summer, some of the parents were able to return to their homes in Ukraine, so the children from these families continued their education in Ukrainian schools. The number of students in EU countries attending Ukrainian online platforms also decreased due to their need to attend schools in their country of residence abroad and the impossibility of parallel online learning in Ukrainian schools. Sometimes, the situation in the foreign country chosen for a temporary stay has changed for various reasons.

The war also led to the significant internal displacement of Ukrainian school students from dangerous to more peaceful regions. According to a nationwide survey conducted by the Ministry of Education and Science of Ukraine, specifically the Institute of Educational Analytics and the Ukrainian Education Cluster, with the support of UNICEF, on the educational needs of Ukraine at the community level after February 24, 2022, the total number of IDP students was about 164,000 as of May 6, 2022 [24].

As military operations intensified, both the number of IDP school students and the number of regions in which they were most displaced changed (Fig. 4). Thus, as of 2021, IDP school students who escaped the consequences of the Russian hybrid war in eastern Ukraine

were concentrated near their places of permanent residence, in the Ukrainian-controlled territories of the Donetsk (10,802 persons) and Luhansk (3,567 persons) regions, as well as in the Kharkiv (6,326 persons) and Dnipropetrovsk (4,196 persons) regions and Kyiv city (10,222 persons).

After the beginning of the Russian invasion, the largest share of IDP students continued their educations in schools in Lviv (21,092), Dnipropetrovsk (8,392), Poltava (6,626), and Ivano-Frankivsk (6,144 people) regions, according to operational data obtained from the Ministry of Education and Science of Ukraine as of June 22, 2022 [20].

Fig. 5 illustrates the distribution of IDP students in schools in certain regions in Ukraine for the period from September 2021 to October 2022.

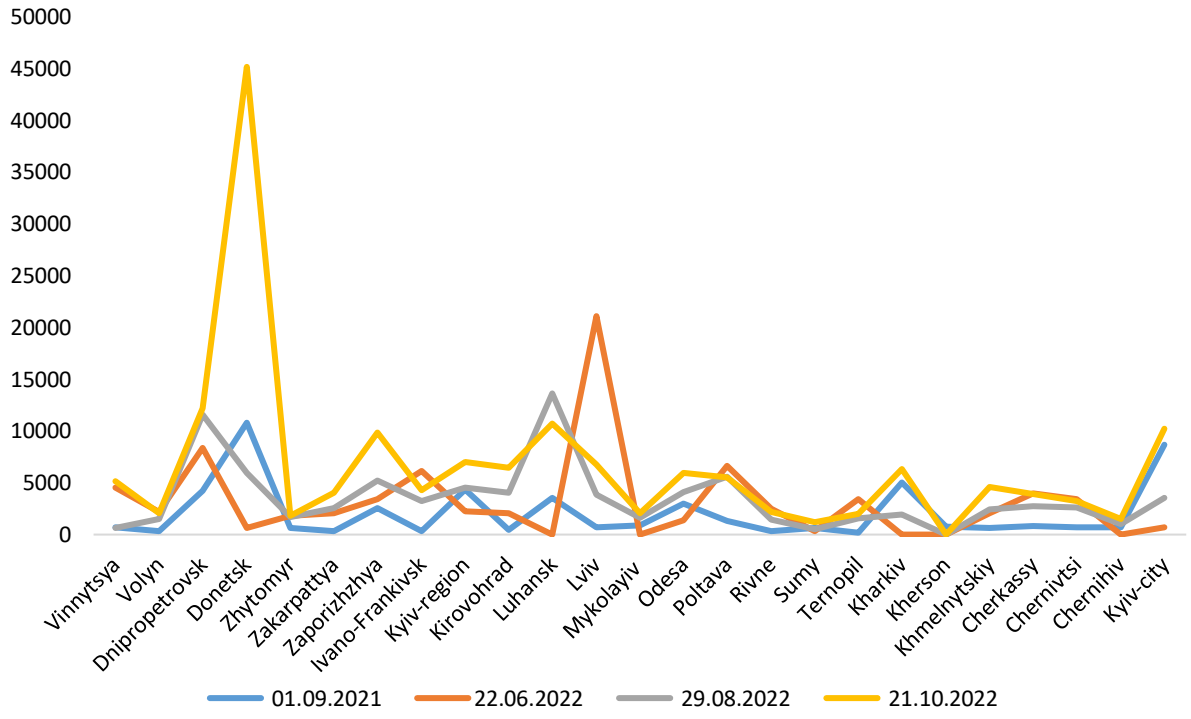

Fig. 5. Dynamics of the distribution of IDP school students enrolled in schools in a certain Ukrainian region (2021/2022 academic year) (persons)

The attention is drawn to changes in the dynamics of the number of IDP school students in selected regions, according to the data as of August 29 and October 21, 2022. In particular, a significant decrease in the number of IDP students in the Lviv region, 5.5 times by the end of August as compared to the data as of June 22, 2022, may be due to the proximity of the border and their subsequent departure from the country, as well as the return of some of them to their homes in the unoccupied territories of Ukraine. The increase in the number of IDP students in the Dnipropetrovsk region to 12,220 as of October 21, 2022, may have been caused by their further displacement to this region from the nearby areas, where hostilities intensified.

A significant increase in the number of IDP students in the Donetsk and Luhansk regions during August-October 2022 may be due to the success of the Ukrainian military on the front and the liberation of some of the occupied settlements. According to official statistics, as of early October 2022, 1,534 Ukrainian settlements had already been liberated in the Donetsk, Luhansk, Mykolaiv, Kharkiv, and Kherson regions.

The stability of the Ukrainian educational system under conditions of war is largely explained by the processes that occurred in 2019 – 2021, during the COVID-19 pandemic.

During this period, the stability of the Ukrainian educational system under conditions of war is largely explained by the processes that occurred in 2019 – 2021, during the COVID-19 pandemic. During this period, important steps were taken to increase the use of distance-learning technologies. The legal basis for such has been created, and educational and methodological support suitable for distance learning has been developed for students in grades 5 – 9, as well as those in high school.

In 2018, Ukraine ranked 54th out of 78 countries in school computers connected to the Internet [26], and in the context of unfolding pandemics and martial law, the introduction of educational IT has been significantly intensified. The share of schools connected to high-speed internet has more than doubled in the 2019 – 2022 period. During this period, the teacher load per laptop computer in schools decreased from 3.87 to 1.79, and the number of students per school computer connected to the internet decreased from 17.51 to 16.21.

The regression analysis of the dependence of the educational results of general secondary school graduates on the computer equipment of schools and internet access showed a significant relationship, which confirms the hypothesis regarding the influence of these factors on the educational results at the aggregate level. The results obtained show that it is very important to improve the accessibility of portable devices, especially for teachers. This suggests that the most effective management measure via which to improve learning outcomes is improving the provision of portable devices to teachers. This is precisely what is being done in Ukraine in 2022.

However, other factors that required further study were not currently being considered in the statistical models. There are other factors affecting learning outcomes that may be important, such as providing students with home Internet and home IT devices suitable for distance learning.

This is also a consequence of the data. On the one hand, the large number of available data, which is also a consequence of digitalization in education, provides us with an insight into the education of students in times of war. This means that our study goes far beyond all other studies that have been conducted on the topic to date, as data on the educational pathways, learning experiences, learning results, and outcomes of displaced and refugee students are usually scarce [28]. Because protecting children on the move begins with better data, the availability of this information is likely to positively contribute to evidence-based decision-making in educational policy and administration, thus improving the learning of children in times of war in general. On the other hand, these data cannot be used for evidence-based decision-making at the individual student level, as individual displaced children are not visible in such education statistics. Thus, there is neither the possibility of determining if, how, and where interruptions in an individual's learning process have occurred nor an opportunity for timely and focused intervention at the individual student level [29], [30].

5. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

In this study, the created thermal matrix of indicators of school provisioning with computer equipment and internet access, which was calculated based on education statistics, is an educational management tool. This tool was crystallized by the practice of education management in Ukraine during the war. It visually demonstrates the relative positions of the regions of Ukraine in terms of such provisions and shows the dynamics of change for these indicators over the selected period, 2019 – 2021. This tool also allows decision-makers at the regional and central levels to quickly identify problem areas and allocate available educational resources, which are always limited in nature, in a balanced and rational manner.

One very important component of maintaining the educational process during emergencies is the creation of national electronic learning platforms, within which electronic

educational and methodological support accumulate. Access on the part of school students and teachers to educational materials from any place where there is access to the Internet significantly enhances the sustainability of the educational process and ensures its flexibility and resilience under adverse circumstances. It should be noted that the use of such e-learning platforms (in Ukraine, it is primarily the All-Ukrainian Online School that is used) has made it possible through the use of the Google Analytics service to obtain an empirical assessment of the distribution of students by country of residence using their IP addresses. This is a cost-effective way of obtaining important management information, although it is not as accurate as the direct collection of information, for example, from the embassies of the countries in which students are staying.

Thus, our study demonstrates the importance of using educational IT technologies, due to which education in Ukraine did not stop during wartime.

- IT infrastructure is an important prerequisite to enable distance education during war. However, further research is needed regarding how to make distance learning under wartime conditions more technologically, geographically, and financially accessible without decreasing the quality of learning. In this context, Ukraine has already experienced providing educational access to the internet under periodic blackouts (e.g., the development of an uninterrupted power supply of sufficient capacity; the possibility of connection to electrical inputs from various substations; and the decentralization of generating capacity, such as solar batteries and other electric generators). It is also desirable to use at least two alternative methods to access high-speed internet (e.g., cable internet and Starlink internet).
- In times of war, digital technologies make it possible to locate displaced students, address their educational needs, and develop interventions to provide support.
- Distance learning enables both internally displaced and refugee students to learn.
- The better teachers in a region are equipped with portable devices, the higher the regional student achievement.
- Data at the aggregate level is helpful for the governance of education systems in war, but individual students cannot be addressed. Whether and to what extent the application and use of these measures are reflected in educational achievement and student outcomes will be seen in the coming years.

ACKNOWLEDGMENT

The author(s) disclosed receipt of the following support for the research: Marcus Pietsch is supported by a Heisenberg professorship of the German Research Association (DFG - Grant: 451458391, PI 618/4-1) and by the Lower Saxony “Vorab” of the Volkswagen Foundation and the Ministry for Science and Culture of Lower Saxony (Grant No. 15-76251-3-25-/5402/2022).

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The text of the article was accepted by Editorial Team 27.09.2023

ЗАБЕЗПЕЧЕННЯ ДИСТАНЦІЙНОЇ ОСВІТИ ПІД ЧАС ВІЙНИ: ДОСВІД УКРАЇНИ

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Анотація. Сфера освіти є багатовимірною, вона формує економічні, політичні та культурні впливи на суспільство. Переривання (або повна зупинка) освітнього процесу в умовах надзвичайних ситуацій, спричинених природними катаклізмами, епідеміями, техногенними катастрофами, зумовлюють вкрай негативні соціальні наслідки для суспільства. Найбільш негативний вплив на освіту відбувається в умовах війни, оскільки учні позбавлені можливості навчатися. Зруйновані школи та вимушене переміщення можуть призвести до того, що учні більше не зможуть навчатися у звичному для них освітньому середовищі. Навіть для учнів, які не постраждали від втечі та переміщення, можливості навчання в зонах бойових дій можуть бути обмежені через нові небезпечні обставини. У таких випадках дистанційна освіта може запропонувати учням можливість використання технологій дистанційного навчання навіть у надзвичайно складних і напружених умовах і в такий спосіб сприяти створенню стабільного навчального середовища для учнів під час війни. Однак про дистанційну освіту, умови забезпечення безперервності навчального процесу у воєнний час, а також про те, як можна підготувати освітні системи до надання можливості навчатися дистанційно в таких несприятливих умовах, відомо небагато. Тому ми досліджуємо, як Україна забезпечує дистанційну освіту під час вторгнення Росії на її територію, зокрема, впроваджує ІТ-інновації в дистанційному навчанні. Ми також аналізуємо вплив цифрових технологій та освітньої ІТ-інфраструктури на життєздатність навчального процесу в несприятливих соціальних умовах. Крім того, побудувавши освітню регресійну модель, ми дослідили різні фактори, які могли впливати на успішність учнів до війни (наприклад, наявність комп'ютерів для учнів та вчителів, доступ шкіл до високошвидкісного інтернету тощо), та визначили взаємозв'язки між цими факторами. Наші висновки дають перше уявлення про соціальні наслідки і про те, як країни можуть підготуватися до створення можливостей використання в освітньому процесі дистанційного навчання для своїх учнів у воєнний час, а також підкреслюють актуальність ІТ-інфраструктури в цьому контексті.

Ключові слова: інновації в дистанційній освіті; технології дистанційного навчання; освітня ІТ-інфраструктура; побудова освітньої моделі; аналіз освіти в умовах надзвичайних ситуацій; соціальні наслідки.

Appendix A

Table A

Table of the indicators

Indicators	The share of schools connected to the Internet by cable with a speed of 100 Mbit/s or more (%)				The share of schools wirelessly connected to the Internet with a speed of 100 Mbit/s or more (%)				The number of students per one school computer connected to the Internet (persons)				The number of teaching staff per school portable device (persons)			
Region /years	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**
Vinnytsya	3.76	7.10	7.95	8.4	1.42	2.28	3.82	3.8	18.10	16.26	16.45	16.04	3.96	3.12	2.37	2.25
Volyn	4.58	10.10	11.59	12.3	2.29	2.53	0.71	0.9	19.54	16.35	19.87	18.53	4.11	3.22	3.22	2.78
Dnipropetrovsk	11.51	16.63	16.51	17.4	7.48	13.58	11.67	12.2	19.81	18.29	17.65	17.18	3.27	2.50	2.27	2.00
Donetsk	13.87	15.98	16.90	17.7	4.69	8.68	10.59	10.7	17.73	15.77	16.71	16.32	3.15	2.50	2.15	1.80
Zhytomyr	4.75	7.32	11.76	11.7	2.22	2.76	5.19	5.4	21.74	20.46	19.44	19.25	4.25	3.64	3.28	2.73
Zakarpattya	3.61	16.90	18.60	19.4	2.11	11.85	14.16	15.5	24.80	21.76	23.10	22.77	6.36	4.91	4.08	4.05
Zaporizhzhya	11.42	16.73	17.74	18.6	4.31	5.83	9.68	10.1	12.91	12.19	12.60	12.00	3.85	3.28	2.40	2.07
Ivano-Frankivsk	3.36	3.93	6.77	6.8	0	0	0	0	19.40	17.75	18.86	18.70	6.86	5.56	4.56	4.58
Kyiv-region	21.55	32.19	32.47	32.7	10.78	17.74	17.38	17.4	15.96	14.58	17.15	16.91	3.06	2.56	2.12	2.20
Kirovohrad	15.72	23.45	24.42	25.9	11.01	10.42	13.86	15.3	16.15	14.76	14.40	14.24	4.93	3.48	3.05	2.68
Luhansk	6.91	8.42	11.02	11.1	2.18	2.93	0.79	0.8	14.35	12.74	13.23	12.86	3.21	2.73	2.36	1.92
Lviv	3.52	7.54	10.88	11.3	1.42	2.79	6.19	6.5	19.36	16.92	17.74	17.43	4.89	3.69	3.25	3.18
Mykolayiv	6.26	8.46	11.26	11.5	2.51	4.44	2.87	3.1	13.60	12.65	12.66	12.38	2.98	2.51	2.34	2.16
Odesa	6.80	8.67	20.92	21.5	1.76	3.06	7.88	8.0	19.78	18.79	19.84	19.42	4.26	2.90	2.42	2.31
Poltava	6.48	15.66	20.79	20.8	3.32	12.56	12.55	12.5	13.38	12.03	12.23	12.06	3.53	2.82	2.14	2.07
Rivne	8.52	37.03	21.88	22.2	1.19	3.92	0.18	0.2	21.76	19.98	21.59	21.04	4.07	3.33	2.81	2.68
Sumy	10.10	15.46	14.67	15.5	2.16	3.99	3.47	3.5	14.30	12.97	13.04	12.78	2.97	2.55	2.27	2.06
Ternopil	7.73	12.23	16.39	16.5	4.01	3.35	0.77	0.8	15.58	13.96	15.00	14.88	5.35	4.37	3.55	3.46
Kharkiv	6.53	15.78	18.32	18.9	3.81	5.21	4.90	5.2	20.70	19.28	17.44	17.15	3.69	2.99	3.28	2.94
Kherson	5.54	9.18	12.24	12.5	2.41	5.36	5.99	6.0	18.17	16.64	17.64	17.31	2.76	2.09	1.93	1.65
Khmelnytskiy	4.01	6.61	11.25	11.6	2.62	4.03	6.23	6.4	14.74	13.33	13.84	13.60	4.02	3.35	2.77	2.69
Cherkassy	7.73	11.82	12.58	12.6	2.16	3.94	6.49	6.5	12.43	11.76	12.17	11.89	3.39	2.92	2.20	2.13
Chernivtsi	8.71	25.57	22.06	22.6	7.46	9.37	10.03	10.0	17.02	16.08	17.81	17.51	4.25	3.39	2.81	2.74
Chernihiv	4.73	7.84	9.86	10.1	0.82	2.75	2.35	2.3	16.91	14.51	15.73	15.57	4.03	3.32	2.64	2.49
Kyiv-city	16.92	11.09	37.48	38.1	6.65	6.44	17.96	18.2	17.93	16.96	16.80	16.62	3.04	2.41	2.03	1.98
Ukraine	**7.83**	**13.70**	**16.61**	**17.1**	**3.52**	**5.96**	**7.15**	**7.4**	**17.51**	**16.00**	**16.56**	**16.21**	**3.87**	**3.07**	**2.63**	**2.45**

Average monthly salary of teachers (the sum of educational subvention funds and own funds of local budgets) (hryvnias)				**Average external independent testing score of school graduates in 2 main subjects (mathematics + Ukrainian)**				**Average external independent testing score of school graduates in Ukrainian**				**Average external independent testing score of school graduates in mathematics**			
2019	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**	**2019**	**2020**	**2021**	**2022**
9,570	11,494	14,519	11,356	137.4	139.4	138.8	150.05	139.3	143.1	143.0	153.4	135.4	135.6	134.5	146.7
8,534	12,335	14,734	12,293	142.2	142.4	142.4	152.90	142.9	145.3	146.7	156.7	141.4	139.5	138.1	149.1
11,322	13,185	14,906	11,030	138.7	139.7	138.5	149.30	139.4	141.5	139.9	151.6	137.9	137.8	137.1	147.0
8,694	10,922	13,049	9,911	138.4	138.4	139.3	151.95	139.3	140.4	141.6	154.5	137.5	136.3	136.9	149.4
9,033	12,066	14,660	11,548	138.6	139.8	139.5	149.25	141.1	144.0	144.3	153.1	136.1	135.5	134.6	145.4
9,299	13,493	15,927	12,352	135.2	135.9	135.8	147.55	132.4	136.0	138.3	151.3	138.0	135.8	133.2	143.8
11,018	12,021	14,711	10,252	137.8	137.5	137.5	150.20	138.2	138.9	139.8	152.9	137.4	136.1	135.1	147.5
11,164	14,169	15,319	12,185	140.1	142.1	139.5	151.35	140.3	145.4	143.9	155.9	139.9	138.7	135.1	146.8
9,832	16,047	14,880	11,738	141.4	140.9	141.6	150.05	144.2	144.3	145.2	153.5	138.6	137.5	138.0	146.6
9,322	12,186	14,183	12,195	137.1	138.1	138.5	148.25	139.8	141.4	141.4	151.5	134.4	134.8	135.5	145.0
8,405	12,202	13,850	9,636	136.8	137.7	137.9	153.10	138.6	140.9	141.2	156.1	135.0	134.4	134.5	150.1
9,626	12,275	15,194	10,702	145.0	147.0	146.5	155.80	146.8	151.4	151.0	159.6	143.2	142.6	142.0	152.0
9,290	12,402	14,555	12,444	136.6	136.6	137.4	148.90	137.9	139.0	139.7	152.1	135.2	134.1	135.1	145.7
9,455	13,183	14,765	12,522	137.1	138.2	138.8	149.85	137.6	140.7	141.0	152.5	136.6	135.6	136.6	147.2
10,722	11,661	14,665	11,984	139.4	140.0	139.8	149.40	141.1	143.1	142.5	152.6	137.7	136.9	137.1	146.2
9,389	13,620	15,198	13,475	139.8	142.3	141.0	151.80	139.1	145.5	144.1	155.1	140.5	139.1	137.9	148.5
9,623	11,395	13,598	10,833	140.5	141.6	141.6	150.45	140.9	145.1	145.1	153.7	140.0	138.1	138.1	147.2
8,860	12,310	14,176	11,203	141.1	141.6	140.1	150.05	141.2	144.7	144.3	153.6	140.9	138.4	135.8	146.5
8,849	12,323	13,813	13,637	142.5	142.6	143.7	153.15	144.1	145.5	147.1	155.6	140.9	139.6	140.3	150.7
9,364	12,644	14,538	6,943	137.0	137.2	139.1	155.20	137.7	139.0	141.5	158.1	136.3	135.3	136.7	152.3
9,219	11,740	14,421	11,949	139.7	140.8	140.1	149.25	140.5	144.2	144.2	152.7	138.8	137.3	136.0	145.8
8,826	12,822	14,072	12,274	141.2	140.7	141.0	149.50	142.1	143.4	144.8	152.9	140.3	137.9	137.2	146.1
9,430	13,483	15,259	11,489	134.8	138.9	138.0	150.20	133.2	141.0	142.1	153.7	136.4	136.8	133.9	146.7
8,508	12,899	13,897	9,326	141.2	141.0	141.4	150.55	143.2	143.8	144.2	154.2	139.1	138.2	138.5	146.9
13,156	15,186	20,288	10,995	147.7	148.2	146.7	155.20	148.0	150.5	149.4	158.0	147.3	145.9	144.0	152.4
9,621	**12,855**	**14,972**	**11,563**	**140.3**	**141.2**	**141.1**	**151.30**	**141.1**	**144.0**	**144.2**	**154.5**	**139.4**	**138.4**	**137.9**	**148.1**