

Digital transformation of secondary education of Ukraine and the quality of teaching natural and mathematical sciences in the conditions of war

Iryna P. Vorotnykova¹, Nataliia V. Morze¹ and Liliia M. Hrynevych¹

¹*Borys Grinchenko Kyiv University, 18/2, st. Bulvarno-Kudryavska, Kyiv, 04053, Ukraine*

Abstract

The article is devoted to the study of the possibilities of digital transformation of secondary education in Ukraine to ensure the quality of teaching natural and mathematical sciences in the conditions of war. The analysis of scientific and methodological literature on the digital transformation of secondary education has made it possible to single out tools for self-assessment by educational institutions of their activities and highlight the main indicators and recommendations for the introduction of digital technologies and ensuring quality science and mathematics education in war conditions. Empirical research methods such as the qualitative approach using interviews and focus groups as methods of data collection and statistical methods of processing the results have made it possible to draw conclusions about the levels of digital competence of teachers and students, their understanding of the digital transformation of education and the influence of its components on the implementation of quality science and mathematics education. During the study, hypotheses have been confirmed regarding the positive impact of increasing the level of digital competence of teachers on the attitude and readiness for digital transformation, the impact of digital transformation on the quality of science and mathematics education in war conditions, and the need to consider the characteristics of children to increase their positive motivation.

Keywords

digital technologies, digital transformation, quality of science and mathematics education, martial law conditions

1. Introduction

The Ministry of Education and Science of Ukraine considers digital transformation in the field of education and science as the creation of an ecosystem of digital solutions. Digital technologies can help intensify the educational process, make it mobile, diverse and adapted to today's realities. In addition, work on conflict transformation is one of the priority directions in the

DigiTransfEd 2023: 2nd Workshop on Digital Transformation of Education, co-located with the 18th International Conference on ICT in Education, Research, and Industrial Applications (ICTERI 2023), September 18-23, 2023, Ivano-Frankivsk, Ukraine

✉ i.vorotnykova@kubg.edu.ua (I. P. Vorotnykova); n.morze@kubg.edu.ua (N. V. Morze); l.hrynevych@kubg.edu.ua (L. M. Hrynevych)

🌐 <https://kpmot.ipk.kubg.edu.ua/12-2/> (I. P. Vorotnykova);

<https://fitm.kubg.edu.ua/struktura1/kafedry/kafedra-kompiuternykh-nauk/sklad/824-1.html> (N. V. Morze);


<https://partner.kubg.edu.ua/contacts/rectorate/vice-rectors/173-liliia-hrynevych.html> (L. M. Hrynevych)

🆔 0000-0003-1211-8885 (I. P. Vorotnykova); 0000-0003-3477-9254 (N. V. Morze); 0000-0002-5818-8259

(L. M. Hrynevych)



© 2023 Copyright for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

 CEUR Workshop Proceedings (CEUR-WS.org)

field of human rights education and intercultural dialogue. Therefore, the digital transformation of education can be an important direction of development in conflict zones, which can help improve the quality of education and ensure access to it [1].

The use of digital technologies in secondary education under the conditions of martial law can have several advantages: mobility and accessibility, diversity and adaptability, intensification of the educational process, and reduction of costs because digital technologies allow: to carry out learning from any place, which is especially important under conflict conditions, when access to education may be limited; create diverse and adapted materials to the needs of students, which can help ensure more effective learning; help make the educational process more intensive and effective, which is especially important in conflict situations, when time may be limited; help reduce training costs, which can be important in conflict settings where resources may be limited.

The system of school education in Ukraine during the war and the planning of its reconstruction faces new challenges. The community prepares children for an unpredictable future. On the one hand, this future is marked by the rapid development of digital technologies – from their immediate daily household use to artificial intelligence, which has become a part of everyone’s life. On the other hand, global threats and challenges are related to the war and the destruction of the educational environment of many educational institutions. The digital transformation of education, which is developing particularly rapidly, due to the need to transfer the educational process to distance or mixed forms of education during the war, requires the creation and effective use of appropriate educational electronic resources, tools and services and increasing the level of digital competence of students, teachers, and education organizers and parents. The “New Ukrainian School” reform, which is being implemented in primary and basic schools, provides for the formation of information and digital competence as a key competence in students during the acquisition of general secondary education [2]. It is the effective use of digital technologies in the educational process that can have a positive effect on the formation of mathematical competence, competences in the field of natural sciences and innovativeness, defined by the Law of Ukraine “On Education”. Particularly effective in this context are methods based on the application of information and educational, digital technologies, and their systematic use to replace routine operations with solving research applications.

“Under the conditions of the digital transformation of the education system, there are a sufficient number of forecasts regarding its results, including full personalization of the educational process, support of sustainable educational motivation at all stages of the educational process; provision of prompt feedback to each student, quick and objective assessment of educational results directly during the performance of educational tasks; ensuring the project nature of educational activities, the deepest possible integration of theoretical and practical training; significant shortening of the terms of development, deployment and mastering of educational programs; increasing informational openness and transparency of the education system” [3]

Most research on digital transformation concerns the conditions of Covid [4], in particular digital transformation in higher education institutions [5, 6, 7] and management of the educational sector [8], impacts of digital technologies on education and factors influencing schools’ digital capacity and transformation [9], learning strategies and pedagogy [10] and its examples [11], but the possibility of digital transformation of secondary education for the development of science-intensive, high-tech industries, which is especially important in the conditions of war

and post-war recovery, ensuring high-quality science and mathematics education of students, is overlooked. However, such changes require research, significant planning, staffing, and training.

There are three main political approaches to promoting the development of science-intensive and high-tech industries, aimed at encouraging children and young people to conduct research and master scientific and technical, engineering professions, namely: the development of effective and attractive methods of implementing educational programs with educational methods of science and mathematics education (STEM education); improving the training of teaching staff and ensuring their professional development; stimulating education seekers to choose scientific and technical activities [12].

Science and mathematics education is important in the conditions of war, and the use of digital technologies for its implementation can help improve the quality of education and ensure access to it, students' mastery of technological literacy and problem-solving skills, involvement in research, invention, project activities, which will make it possible to increase the share of those who seek to choose scientific and technical, engineering professions. The use of digital technologies in science and mathematics education is important for the intensification of the educational process, mobility, and adaptability to today's realities, which requires professional training of science and mathematics teachers for digital transformation.

Research questions or hypothesis:

- Can the digital transformation of general secondary education contribute to the quality of teaching natural and mathematical sciences?;
- Can increasing the level of digital competence of teachers, attitudes towards digital transformation have a positive effect on the quality of science and mathematics education in war conditions?

The purpose of the study is substantiation of the possibilities of digital transformation of secondary education in Ukraine to ensure the quality of teaching natural and mathematical sciences in war conditions.

The objectives of the study are:

- to analyse approaches to determining indicators of digital transformation of secondary education in Ukraine;
- to highlight the quality of science and mathematics secondary education and take into account the peculiarities of training, educational losses in the conditions of martial law;
- to investigate the opinion of teachers regarding the impact of digital transformation on the quality of general secondary education, to investigate the attitude of teachers to the digital transformation of education and its positive impact on the quality of the science and mathematics field;
- to determine how the level of digital competence of teachers affects the attitude towards digital transformation and the readiness to implement it.

2. Literature review

In recent decades, many strategies have been used in education for its digital transformation, including persuasion, motivation of teachers to integrate e-learning, adoption of digital transformation and successful implementation in public schools [10]; the creation of a planning

policy and strategy for e-learning of the school, professional development of teachers and the formation of their digital competence, pay great attention to the digital transformation of higher education to prepare young people for the labour market under modern conditions. The most significant driving forces for the implementation of digital transformation in higher education in the era of Industry 4.0 are the development, updating and adaptation of the curriculum, and the integration of digital technologies for general education and cloud computing [7].

N. Razak, S. Rasli and N. Subhan have conducted a systematic literature review of studies published with a focus on digital transformation in school and have found that the majority of published articles during the last 2010-2022 indexed in Scopus are related to the digital transformation of secondary education 64.3% (n=27), not the initial one. The authors have noted the barriers to the digital transformation of primary and secondary education: the availability of technological resources and their support, the readiness of teachers. The focus of the theories used to conduct digital transformation research are models of people's perception and behaviour regarding the use of technology (CHAT, TPACK, TAM, UTAUT) [13].

Ukrainian scientists also determine the relevance of the topic of digital transformation in education and the prospects for its implementation, and note that the terms digital transformation and digitalization are synonymous: "Digital transformation of society (digitalization of society) is an imperative for the formation of future (next, future) generations (levels, generations) social self-organization of human civilization, can be considered in different aspects, each of which has corresponding objects and relationships (relations) and the possible (accessible) depth of their presentation"[3]. Digitalization of secondary education, primarily as a basic link in the system of continuous education, should be implemented in the following directions: student access to technology (Student Accessibility), teacher access to technology (Teacher Accessibility), administrator access to technology (Administration Accessibility), educational Internet (models Fiber to the Building and Wi-Fi), digital multimedia content, digital competences and literacy of teachers and students [3].

In another approach to the interpretation of the terms: "digital transformation means the integration of digital technologies into all areas of life and business. This integration leads to fundamental changes in the way citizens, enterprises, and organizations act, how they provide value for themselves, their employees, customers, and partners, achieving their own and common economic and social goals faster, cheaper, and with new quality. And digitization is the saturation of the physical world with electronic and digital devices, means, systems and the establishment of electronic communication interaction between them". The basis of digital transformation is digital trends, in particular new 4.0 technologies: IIOT platforms, Digital Twins, Cobots, 3D, AI, Cybersecurity, VR/AR, Blockchain, Wearable, and drones, which complement classic 3.0 technologies: cloud computing, industrial networks, mobile technologies, data warehouses, accounting/dispatching, automation, SCADA/HMI, MES/APS/APC, EPR, robots [14].

The Ministry of Digital Transformation of Ukraine joined the formation and development of digital literacy of the population, including those seeking education, and developed the "Action. Digital education" project, concept of development of digital competences until 2025.

The main regulatory frameworks for the implementation of the digital transformation of education in Ukraine are Decrees of the President of Ukraine "On the Sustainable Development Goals of Ukraine for the period until 2030", "On the Strategy of Human Development", National Economic Strategy for the period until 2030, Regulations on the National Educational Electronic

Platform (2018), Regulations on electronic textbooks 2018), Regulations on electronic educational resources (2019), Concept of development of science and mathematics education (STEM education) (2020), Description of the framework of digital competences of citizens of Ukraine (2021 r.), Concept of implementation of state policy in the field of general secondary education reform “New Ukrainian School” for the period until 2029; Concept of development of digital economy and society of Ukraine [15], National strategy of Industry 4.0; Laws of Ukraine “On Telecommunications”, “On Cyber Security”.

2.1. Indicators of digital transformation of secondary education in Ukraine

The Digital Education Action Plan (2021-2027) is a renewed European Union (EU) policy initiative that sets out a common vision of high-quality, inclusive, accessible digital education in Europe and aims to support the adaptation of the education and training systems of Member States to the digital age. The Joint Research Centre of the European Commission (JRC) in close cooperation with experts – representatives of educational institutions, ministries of education and research institutes of EU countries created the SELFIE tool for self-assessment by educational institutions of the effectiveness of the implementation of innovative digital technologies in the educational process, the stage of digital development of the educational institution [16].

The concept of the development of the digital economy and society of Ukraine emphasizes the development of digital infrastructure, in particular the introduction of broadband Internet and its coverage, stimulation of digital transformations in the education system [15]. To ensure the digital transformation of secondary education, we will consider the possibilities of students' and teachers' access to computers and the Internet and the availability of a single support system for digital education in wartime conditions. At the end of 2022, there were 22.1 million people in Ukraine (by 24.02.2022 – 28.7 million), of which 19 million were Internet users (by 24.02.2022 – 24.5 million), which indicates that the share of Internet users among the population of Ukraine is at the level of other Eastern European countries – 86% [17]. Even in the conditions of war, the indicators of the possibilities of using the Internet are better than in 2017, when Ukraine had a great mobile potential and the development of the fixed broadband market and availability of a computer at home – 62% (the indicator in the world is 47.1%, in Europe – 78.6%); availability of access to the Internet at home – 58.8% (the indicator in the world is 54.7%, in Europe – 80.6%) [17].

According to the study of the State Service of the Quality of Education of Ukraine in 2023: in the conditions of martial law, students in different regions have different opportunities to choose the form of education. In the east and south of the country, the distance form of education prevails, 90% and 70% correspondingly, in the west face-to-face education dominates (62%), in the centre and in the north all the forms of education are in approximately equal proportions.

The majority of elementary and high school students indicate that they have a smartphone (74% in 2023, 68% in 2022), but only 51% have their own computer/laptop, or tablet [18], which indicates that when choosing a distance learning support system, it is necessary to take into account its cross-platform and mobile learning capabilities. About 2% of students do not have their own gadget (computer, laptop, tablet, smartphone) for studying, but can use the one that their family has. Under the conditions of the change in the working mode of the educational institution, 25% of teachers are not provided with a work computer, and 20% have no access

to the Internet, but this need is compensated by the presence of a personal computer (at least 9% of teachers have it) and the ability to work remotely (at home at least 91% of teachers are provided with the Internet). At the same time, a third of teachers use a home computer together with other family members, which can cause difficulties when working remotely.

The largest number of teachers who do not have access to the Internet in an educational institution is in the East of the country which is 28%, and the least is in the West (15%). In other regions, the situation is more uniform which is 18–20%. According to the heads of schools: 61% of institutions use a single educational platform, and in 34% of institutions each teacher independently chooses which platform to work with. Despite the fact that 75% of teachers have noted that they are provided with working computers and access to the Internet, the same number (74%) need technical support for more productive work in war conditions: provision of equipment, stable Internet, and electricity supply. About half of the teachers see such support in the increase of wages, one-third needs psychological support, 15–20% of the teachers require methodical support [18].

The Ministry of Digital Transformation has developed an index of the digital transformation of regions, the components of which are: digital education (coverage of the population with digital education, registration of teaching staff on the All-Ukrainian online school portal, e-journals in educational institutions), Internet development (connecting shelters to the Internet, promoting access to infrastructure), “paperless” mode (e-document circulation), industry digital transformation (information protection, cybersecurity policy, e-food safety). Since 2019, the country has introduced and implemented electronic platforms that promote the development of digital literacy among the population, already in 2021 the share of people with “basic” and “higher” levels has become 52.2% [19].

The indicators of digital transformation include the level of use of hardware and software, the digital competence of participants in the educational process. According to the Ukrainian Institute for the Future, an indicator of the development and penetration of digital skills and competencies in Ukraine in 2030 will be that 99% of citizens aged 5–15 years will fully master a package of digital skills [14].

Based on the analysis of the scientific and methodological literature, the indicators of the digital transformation of secondary education can be attributed [4, 8, 9, 10, 14]: the level of access to computers and high-speed Internet, the availability of platforms, e-learning support systems, the level of digital adaptation in the organization, which can be measured by assessing the level of digital competence of participants in the educational process and the level of digital culture in the organization, the level of use of digital technologies in the educational process, which can be measured by analysing the number and level of use of digital tools and processes, the effectiveness of digital transformation in education, which can be measured by analysing indicators such as reducing costs and improving the quality of education, the level of satisfaction of participants in the educational process with the digital experience provided by the organization, which can be measure by analysing reviews, ratings.

2.2. The quality of science and mathematics education in crisis conditions

Science and mathematics education, including STEM (science, technology, engineering, and mathematics), is important in wartime Ukraine for the reasons of technology development,

cybersecurity, engineering and technical equipment, and scientific research work:

- Digital skills, such as understanding computer systems, programming, robotics, and other modern technologies, help in the implementation of scientific research, the development of new military technologies and their application in practice.
- Education in the field of cybersecurity allows to protect against cyberattacks, preserve confidential information and ensure the security of critical infrastructures.
- Engineering solutions and technical equipment play an important role in the construction of defense structures, reconnaissance, transportation, treatment of the wounded people and many other aspects. Knowledge of engineering and mathematics is essential to the development and application of effective technological solutions on the battlefield.
- Scientific research becomes the basis for the development of new strategies, technologies and weapons.

The adoption of the Concept of the Development of Science and Mathematics Education (STEM Education) in 2020, the introduction of mandatory external independent testing in mathematics from 2021 confirms the importance of the development of these fields for the education and development of students in Ukraine. The results of Ukrainian students in PISA 2018 showed that on average, 15-year-old students score 453 points in mathematics compared to an average of 489 points in OECD countries, where students perform better, with a non-statistically significant difference of 7 points (OECD average: 5 points higher for boys). In Ukraine, the average performance in science of 15-year-old students is 469 points, compared to an average of 489 points in OECD countries, where students perform better with a non-statistically significant difference of 2 points (OECD average: 2 points higher for girls) [16].

In the conditions of martial law, the provision of high-quality science and mathematics education is the main component of the educational process. The opinions of teachers regarding the success of students in the fields of science and mathematics differ, in particular, rural teachers indicate an improvement in the level of knowledge acquisition of students in the 2022-2023 academic year, while urban teachers note a deterioration of knowledge compared to 2021-2022 [18].

No difference was found in the assessment of their achievements by students in cities and villages. 38-39% of elementary and high school students believe that their academic results have not changed, a third believes that the results have improved, and 27% have worsened. Teachers' and students' answers regarding educational achievements differ, which indicates the need to develop students' critical thinking and self-assessment skills. Under the conditions of remote synchronous learning, no more than a third of teachers use types of educational activities that involve the interaction of students with each other, active participation in the educational process: group work, work in pairs, practical and laboratory work. At the same time, under the conditions of remote synchronous and asynchronous learning, the vast majority of teachers suggest that students watch presentations, videos, do exercises, and independently process educational materials, despite the fact that 39% of teachers consider the fact that students are not able to learn independently to be a challenge for the educational process in wartime conditions. Teachers gave the highest scores to more than half of the students' self-assessment skills, problem-solving and cooperation with others and indicated that with asynchronous

distance learning mode they used not only auxiliary educational videos, presentations (79%) but also project, research and research tasks (36%), and with synchronous learning: modelling experiments using simulation on electronic resources (16%), practical and laboratory work (20%) [18].

From the results of the research of the quality of the organization of the educational process in the conditions of war in the 2022/2023 academic year [18], it is possible to draw conclusions about the need in today's conditions to use distance learning, digital tools and create safe digital educational environments.

The analysis of scientific literature has revealed the need to determine how the level of digital competence of teachers affects their attitude to digital transformation and their readiness to implement it. It requires research and the opinion of teachers regarding the impact of digital transformation on the quality of general secondary education, the attitude of teachers to the digital transformation of education and its positive impact on the quality of the science and mathematics field.

3. Methodology Description of research plan and methods

For this study, theoretical methods have been used: the literature analysis for building hypotheses and developing the theoretical basis of the study, defining the problem to be solved, and empirical methods: the qualitative approach using interviews and focus groups as data collection methods and statistical methods for processing the results. The statistical analysis uses descriptive statistics, in particular, a two-dimensional distribution – “cross-tabulation” to determine the relationship between the teacher's digital competence and their understanding of the impact of digital transformation on the quality of education. The study has been conducted on the basis of a sample of teachers of science and mathematics disciplines, informatics, and technologies from schools located in war conflict zones. The sample consists of 64 teachers who have experience in teaching using digital technologies.

3.1. Data collection process

Interviews, focus groups, and online surveys of teachers were conducted to collect data. Interviews were conducted individually with each teacher, which made it possible to obtain detailed information about their experience of teaching with the use of digital technologies and their vision of the impact of digital transformation on the quality of teaching natural and mathematical sciences under martial law.

Focus groups were conducted in order to obtain additional information and verify the results of the interviews. The research was conducted in compliance with ethical principles, in particular, permission was obtained from the research participants and the confidentiality of the obtained data was ensured. 95.6% of teachers, 1.6% of heads of educational institutions took part in the study. 2.8% of respondents were methodologists and teachers of postgraduate education, in particular, teachers of natural sciences (33.53%), teachers of mathematics (26.36%), informatics (18.64%), and elementary school teachers (21.50%). 40.63% of respondents had the senior teacher titles, 26.47% of teachers were of the highest category, which indicates the ability of teachers to teach at a high level not only to students but also to other teachers and to influence the

development of quality education in Ukraine. 70.31% of teachers with more than 20 years of teaching experience took part in the study, 14.06% of teachers had experience from 10 to 20 years, 4.69% – from 5 to 10 years, 10.94% – up to 5 years, which is a representative sample of teachers working in Ukrainian education. The data analysis was carried out using thematic analysis. The obtained data were transcribed and analysed in order to identify key themes and sub-themes that reflect the impact of digital transformation on the quality of teaching natural and mathematical sciences under martial law.

4. Result

Let us consider the results of the survey on the possibility of the influence of the digital competence of teachers on the digital transformation of secondary education and the quality of natural and mathematical sciences in the conditions of martial law. To determine the teachers' understanding of the term digital transformation, they were offered several statements. The results of the focus group survey showed that the majority of teachers (82.8%) understand digital transformation as complex work in the field of education, which involves creating a safe electronic educational environment, providing the necessary digital infrastructure of educational institutions, increasing the level of digital competence and qualitative changes in educational services. More than half of the teachers (51.6%) understand digital transformation as “the use of digital technologies to change educational processes with the aim of their simplification, automation and convenience for all participants of the educational process”, while the minority (15.6%) believe that “digital transformation will lead to a complete change in educational services that take place in educational institutions based on the effective use of digital technologies”.

Teachers noted that IT is necessary for the use of augmented, virtual, and mixed reality, cloud technologies, mobile and Internet technologies, distance education, mass open online courses, gamification of the educational process, and development of digital libraries (40.6%); creation of digital educational content, use of digital technologies at all stages of the lesson, automation of management processes and facilitation of the teacher's work (37.5%); organizational changes in educational institutions and institutions caused by digital technologies (26.6%). Only 1.6% of teachers noted that they did not have any problems with the use of digital technologies in the conditions of war. They organize webinars using Zoom, Google Meet, etc. – 84.6% of teachers work using the distance learning support system Google Class, Teams, Moodle, teachers use messengers (Viber, WhatsApp, etc.) (68.2%), Telegram channels (61.3%), use online boards, posters (47.7%), use resource libraries for general education, My Class, etc.(43.1%), use lessons from the All-Ukrainian School online (21.5%), lessons from YouTube channels (75.4%), create their own interactive exercises, notebooks, interactive presentations (52.3%) and video lessons (26.2%), organize online projects (33.8%), and post materials on the website of the school and (or) class (26.2%).

The three main factors that prevent the introduction of digital technologies according to teachers are lack of gadgets among students (48.4%), lack of electricity (62.5%), availability and speed of the Internet (68.8%), different settings on different gadgets (25%), studying at different times of students living abroad (43.8%), academic dishonesty of students (48.4%), lack of social communication (25%), negative impact on health (26.6%), an organisation in online experiments,

experiments, laboratory works (23.4%) and low level of digital competence of students (21.9%), limitations of digital tools (price, time of use, number of users, etc.) (17.2%), and low level of own digital competence (14.1%). According to teachers, the factor that least hinders the use of digital technologies is their own digital competence. In particular, the majority of teachers evaluating their own digital competence on a 10-point scale noted it above the average value (6-8 points (59.4%), 15.6 % of teachers indicated it below 6 points, and 25% of teachers indicated a high level (9 -10 points) (figure 1)

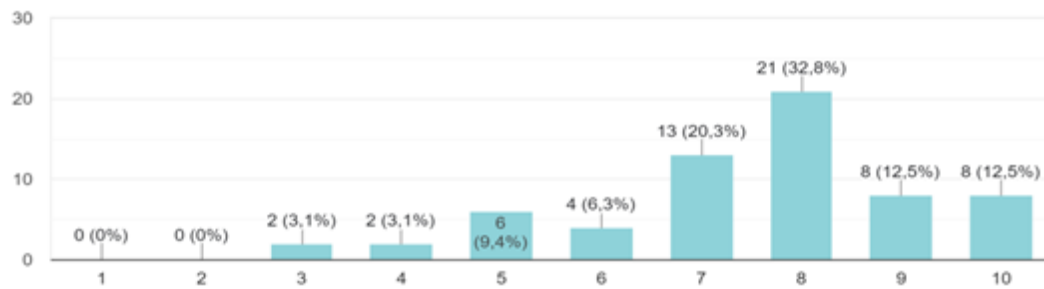


Figure 1: Self-assessment of teachers on a 10-point scale of the level of their own digital competence.

Teachers answered that they can confirm their level of digital competence: with certificates of completion of courses on the use of ICT (64.1%) and certificates on the Diia portal (14.3 %), and with their own electronic educational resources (presentations, tests, quizzes, etc.) (60.9%), having their own YouTube channel (17.2%), educational blog or website (14.1%), creating an online community for learning and (or) professional development (10.9%). Only 1.6% of teachers noted that students have a low level of digital competence, 68.8% consider it average, and 9.4% high, while 20.3% of teachers noted that it is difficult to determine the level of students in general. Educators assessed the readiness to use digital technologies in the educational process in war conditions in the majority at an average level (5-8 points) – 70.4%, a high level (9-10 points) – 20.4% and a low level (9.4 %) (figure 2).

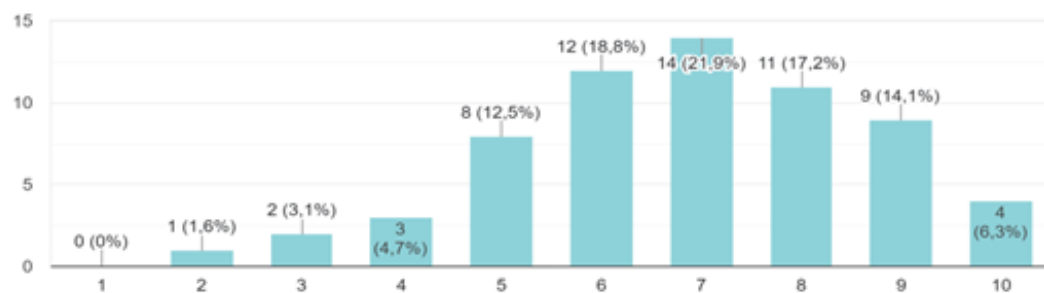


Figure 2: Level of training of teachers for the use of digital technologies in war conditions

89.07% of teachers believe that the components of a teacher’s digital competence are “Professional development (use of digital technologies for communication, joint activity) and “infor-

mation literacy and culture of data use, including content management, communication and collaboration, social activism, creation of digital content taking into account ethical principles, security, taking into account digital well-being, cybersecurity”. The analysis of the results of the survey shows that other components of the teacher’s digital competence have a significant impact on the quality of education: the creation and joint use of digital resources in educational activities – 87.5%, the formation of students’ digital competence – 79.69%, the management and organization of the student assessment process with the use of digital technologies – 70.31%.

The factor “Strategic planning of digital transformation and change management” for teachers turned out to be the least important among others (87.5% of teachers). From (figure 3), it is possible to draw conclusions about the significance of the impact of each indicator on the level of digital transformation of education.

The level of digital competence	Digitization of all components of the educational process	Creating a modern digital educational environment	Effective use of modern digital technologies and data	Formation of competences	Strategic planning of digital transformation and change management	Providing participants of the educational process with gadgets	Creating a safe educational digital environment	Increasing the level of digital competence	Ensuring equity, integration and access to education
3	2	2	2	2	2	2	2	2	2
4	1	1	1	1	1	0	1	0	0
5	5	6	5	6	5	6	6	6	6
6	3	3	3	3	2	3	3	3	3
7	13	13	12	13	12	13	13	13	13
8	20	20	20	20	20	19	18	20	20
9	8	8	8	8	7	7	7	7	7
10	7	7	7	7	7	8	8	8	8
In total? Number of the teachers	59	60	58	60	56	58	58	59	59

Figure 3: Cross-table comparing the level of digital competence of teachers and their opinion about the influence of the components of digital transformation on the quality of education.

The survey participants specified the level of positive impact of the components of digital transformation on the quality of education. More than half of the teachers noted the influence of the use of advanced analytics and artificial intelligence for making management decisions (it does not affect – 10.34%, it has little effect – 43.10%).

In focus groups, we clarified the opinions of teachers regarding the use of AI in education. According to the results of the survey: they believe that the use of AI is a threat in all spheres of life (6.2%) and that the use of AI will negatively affect the quality of education (4.6%). They do not know how to use AI in education, and understand how to implement AI in professional activities, but 7.7% of teachers do not do this. It should be noted that the use of AI is a promising direction for ensuring the quality of education (29.2%) and improving the qualifications for its use (16.9%). The majority of teachers intend to improve their qualifications on the use of AI (63.1%) and believe that they fill in that AI in education has its advantages and disadvantages (60.0%), and already use AI applications to prepare classes (24.6 %).

Teachers identified the positive impact of digital transformation on the quality of education (figure 4).

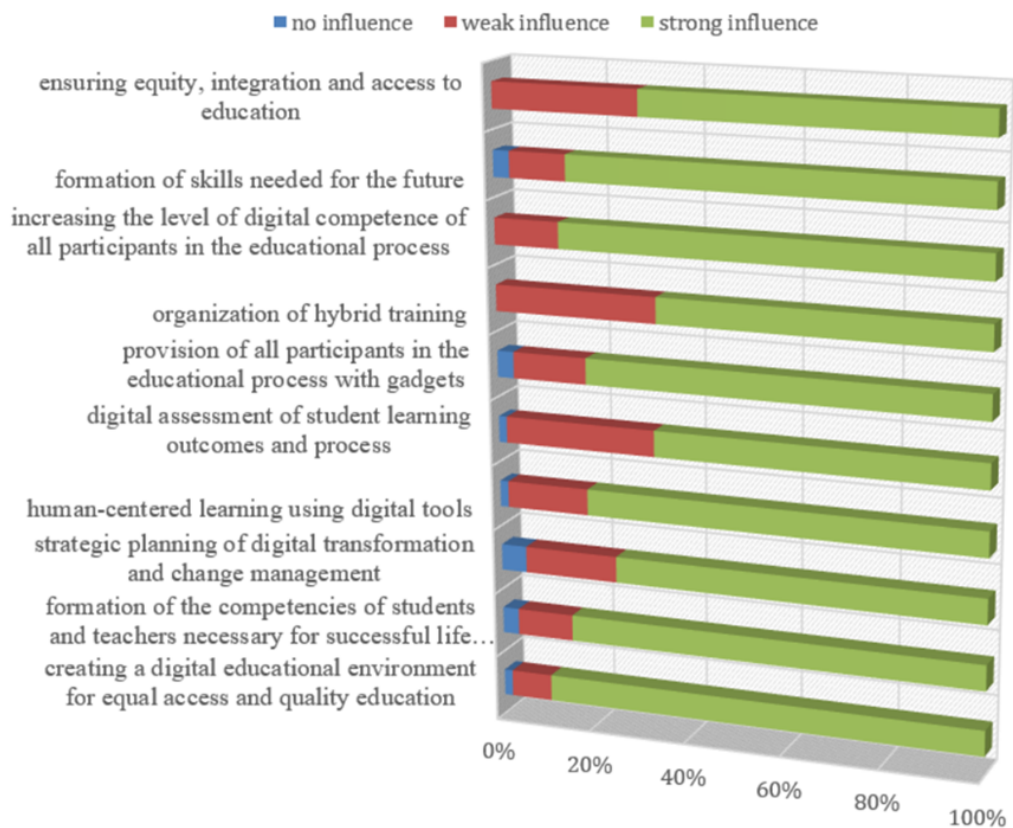


Figure 4: The level of positive impact of the components of digital transformation on the quality of education.

Digital technologies have changed lives and prompted education systems around the world to adopt strategies and policies to integrate ICT. The latter has given rise to problems regarding the quality of teaching and learning with the help of ICT, especially regarding the understanding, adaptation and design of education systems in accordance with modern technological trends. Teachers noted the need to take into account the needs and characteristics of modern students: they quickly search for and forget information, like using gadgets, depend on technology, prefer the visual form of presentation of educational material, communicate more on social networks, are fond of online games, focus on learning skills, have a deficit of life skills, and can be multitaskers.

In addition to digital competence, teachers also took into account the characteristics of children of the alpha generation to increase their positive motivation to study in order to reduce educational losses (figure 5)

In general, the majority of teachers rated the impact of digital transformation on the quality of science and mathematics education under martial law higher than 7 points out of 10 (figure 6.

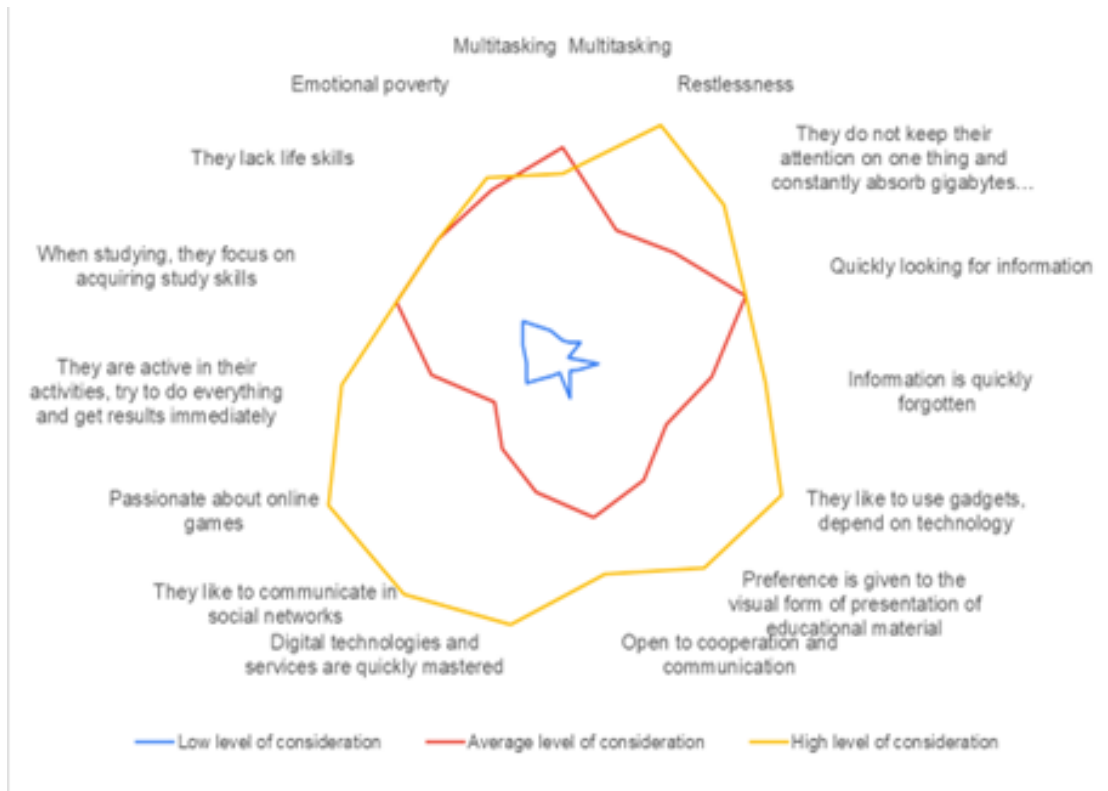


Figure 5: Teachers’ opinion regarding the level of consideration of alpha generation children’s characteristics during their training

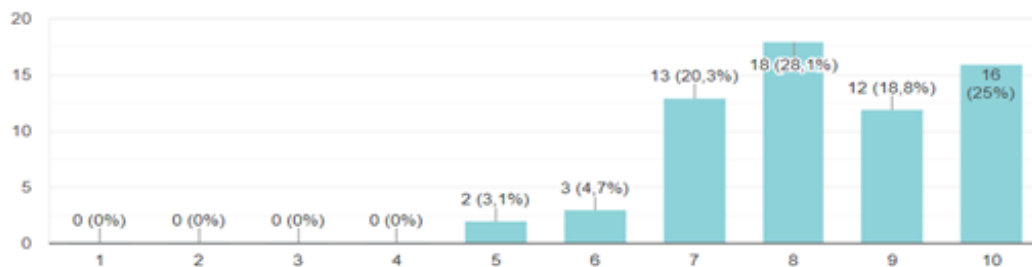


Figure 6: Assessment on a 10-point scale of the impact of digital transformation on the quality of science and mathematics education under martial law

5. Conclusions, discussion and interpretation of results

Digital technologies have changed lives and prompted education systems around the world to adopt strategies and policies to integrate ICT. The latter has given rise to problems regarding the quality of teaching and learning with the help of ICT, especially regarding the understanding, adaptation and design of education systems in accordance with modern technological

trends. The survey of teachers confirmed the hypotheses that the digital transformation of general secondary education contributes to the quality of teaching natural and mathematical sciences, and increasing the level of digital competence of teachers, attitudes towards digital transformation have a positive effect on the quality of science and mathematics education in the conditions of war. Each institution of general secondary education can carry out self-assessment and monitoring of activities regarding the processes of digital transformation using the tool of the European community, the digital competence of teachers and the effectiveness of using modern digital technologies, the selection and application of information collection methods for the study of educational and management processes in the educational institution, the use of various types and forms of control according to the level of digitization and effective response to changes and their management [19]. According to the teachers of the city, in the conditions of the war, the results of studying science and mathematics have worsened, while for the villages, the situation has remained at the level of the previous school year. More than half of the surveyed teachers correctly understand what the digital transformation of education is and consider it to be a necessary condition for quality science and mathematics education.

Digital transformation of secondary education is effective if the indicators of digital transformation are determined, strategies are developed in which it is necessary to describe all processes that need to be changed, the nature of changes, possible risks and problems, ways to solve problems; implementation should be carried out gradually, evaluating the results and effectiveness of methods, taking into account the unreadiness of the existing system for changes, introducing teachers and students to new digital tools and teaching them how to use them; determine the period of digital transformation in the educational institution and evaluate its effectiveness. We agree with the opinion of American researchers [20] that digital transformation covers the organization's ability to adapt, react and position itself to achieve success in the conditions of rapid technological development and who emphasize the existence of four important levers that ensure it: a diverse and purposeful team composition, iterative goal setting, continuous learning and talent management.

Educators identified directions for the development of the digital transformation of education: students must master new digital tools to increase the effectiveness of their educational activities, while their digital competence must develop (64.0%), educational institutions must master new digital tools that increase the effectiveness of the organization of the educational process (61.3%); transformation of goals, content and corresponding methods and forms of an educational activity (48.0%), teachers must master: new digital tools to increase the efficiency of their professional activities; the content, methods and forms of educational activity, which are transformed in connection with the impact of new digital tools on various spheres of human activity (10.7%); education leaders must master: new digital tools that increase the efficiency of their professional activities (5.3%). In the interview, teachers confirmed the importance of digital transformation to ensure the quality of science and mathematics education, 52.4% of teachers argued their readiness for such changes, 51.3% of teachers noted that digital transformation should be in Ukrainian secondary education in the conditions of martial law, but taking into account socialization and child-centeredness. According to the majority of respondents (89.07%), the quality of education is influenced by such a component of digital competence as the professional development of teachers, the use of digital technologies for communication, and joint activities. 82.8% of teachers have a sufficient level of digital competence and understand digital transformation as complex

work in the field of education, which involves creating a safe electronic educational environment, providing the necessary digital infrastructure of educational institutions, increasing the level of digital competence and qualitative changes in educational services. Only 1.6% of teachers reported that “They do not understand the trends of digital transformation and do not see its possibilities”. In addition to digital competence, teachers pointed out the importance of taking into account the characteristics of children to increase their positive motivation to study in order to reduce educational losses. Based on the analysis of scientific and methodical literature and the survey of teachers, the indicators of the digital transformation of secondary education can be determined: access to computers and high-speed Internet, availability of platforms, e-learning support systems; digital adaptation in the organization, the level of digital competence of participants in the educational process of digital culture in the organization, the use of digital technologies in the educational process, the effectiveness of digital transformation in education in the form of improving the quality of education, the satisfaction of participants in the educational process with digital experience.

6. Limitations and direction of the future research

In the conditions of war, it is difficult to foresee challenges for the organization of the educational process. In 2022, teachers singled out the main ones: power outages (87%), lack of permanent high-speed Internet (55%), absence or lack of technical means of learning for students (35%), use of various communication channels by teachers (8%), lack of a single electronic educational platform (7%), teachers’ lack of skills in working with remote technologies (3%) [20]. The analysis of approaches to the factors of digital transformation of institutions of general secondary education allows us to draw conclusions that the main indicators are the level of access to computers and high-speed Internet, the availability of platforms, support systems for e-learning, the level of digital adaptation in the organization, the level of digital competence of participants in the educational process, the level digital culture in the organization, the level of use of digital technologies in the educational process, the number and level of use of digital tools and processes, the effectiveness of reducing costs and improving the quality of education, the level of satisfaction of the participants of the educational process with the digital experience. The state educational policy of Ukraine, in particular the Adoption of the Concept of the Development of Science and Mathematics Education (STEM-education) and the introduction of mandatory external independent assessment in mathematics, and participation in the Pisa studies, testify to the importance of the development and quality of science and mathematics secondary education in the conditions of martial law and taking into account the peculiarities and motivation of students to study. The analysis of educational losses based on the survey of the participants of the educational process shows the difference in the answers of teachers (the results of students have worsened or not changed) and students (the results have improved or not changed) regarding educational achievements in the conditions of war, testify to the need for the formation of critical thinking and self-assessment skills in students. The study of teachers’ opinions regarding the impact of the digital transformation of general secondary education institutions on the quality of education confirmed the hypothesis that increasing the level of digital competence of teachers will positively affect the quality of teaching natural and

mathematical sciences in the conditions of martial law.

Educators assessed their own readiness to use digital technologies in the educational process in the conditions of war at a high and average level of 90.8% and the level of digital competence, confirmed by certificates of professional development and the practice of introducing digital tools, in particular, conducting synchronous distance lessons by more than 84% of teachers and use of distance learning support systems by 68% of teachers. 92.2% of teachers evaluate on a 10-point scale the impact of digital transformation on the quality of science and mathematics education in the conditions of martial law. One of the results of digital transformation is access to electronic educational resources of students of different ages and taking into account their needs, which allows removing barriers to access to quality education in wartime conditions. Institutions of general secondary education can use a set of the best foreign practices of digital education transformation to overcome educational gaps and losses, compete in the expansion of the landscape of distance learning, and the introduction of innovative learning technologies. The directions of further research are the analysis of modernization and adaptation of current systems in the conditions of their digital transformation for the processing of learning results based on big data analytics and AI, the introduction of personalized approaches to learning using cloud solutions for effective data storage and management, the implementation of high-quality science and mathematics education at different levels of digital transformation of secondary education.

References

- [1] MON, Digital transformation of education and science (2023). URL: <https://mon.gov.ua/ua/tag/cifrova-transformaciya-osviti-ta-nauki>.
- [2] Verkhovna Rada of Ukraine, Law of Ukraine "on education" [(2145-viii dated 05.09.2017)] (2017). URL: <https://zakon.rada.gov.ua/laws/show/2145-19#Text>.
- [3] V. Kremen, V. Bykov, O. Liashenko, S. Lytvynova, V. Lugovyi, Y. Malovanyi, O. Pinchuk, O. Topuzov, Scientific and methodological provision of digitalisation of education in Ukraine: Status, problems, prospects: Scientific report to the general meeting of the national academy of educational sciences of Ukraine "scientific and methodological support for the digitalisation of education in Ukraine: State, problems, prospects", November 18-19, 2022, Herald of the National Academy of Educational Sciences of Ukraine 4 (2022) 1–49. URL: <https://visnyk.naps.gov.ua/index.php/journal/article/view/320>. doi:10.37472/v.naes.2022.4223.
- [4] B. Bogdandy, J. Tamas, Z. Toth, Digital Transformation in Education during COVID-19: a Case Study, in: 2020 11th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), 2020, pp. 000173–000178. doi:10.1109/CogInfoCom50765.2020.9237840.
- [5] M. Bond, V. Marín, C. Dolch, S. Bedenlier, O. Zawacki-Richter, Digital transformation in German higher education: student and teacher perceptions and usage of digital media, International Journal of Educational Technology in Higher Education 15 (2018). doi:10.1186/s41239-018-0130-1.
- [6] L. M. C. Benavides, J. A. Tamayo Arias, M. D. Arango Serna, J. W. Branch Bedoya,

- D. Burgos, Digital Transformation in Higher Education Institutions: A Systematic Literature Review, *Sensors* 20 (2020). URL: <https://www.mdpi.com/1424-8220/20/11/3291>. doi:10.3390/s20113291.
- [7] K. Wang, B. Li, T. Tian, N. Zakuan, P. Rani, Evaluate the drivers for digital transformation in higher education institutions in the era of industry 4.0 based on decision-making method, *Journal of Innovation & Knowledge* 8 (2023) 100364. URL: <https://www.sciencedirect.com/science/article/pii/S2444569X23000604>. doi:10.1016/j.jik.2023.100364.
- [8] V. Díaz-García, A. Montero-Navarro, J.-L. Rodríguez-Sánchez, R. Gallego-Losada, Managing Digital Transformation: A Case Study in a Higher Education Institution, *Electronics* 12 (2023). URL: <https://www.mdpi.com/2079-9292/12/11/2522>. doi:10.3390/electronics12112522.
- [9] S. Timotheou, O. Miliou, Y. Dimitriadis, S. Sobrino, N. Giannoutsou, R. Cachia, A. Monés, A. Ioannou, Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review, *Education and Information Technologies* 28 (2023) 6695–6726. doi:10.1007/s10639-022-11431-8.
- [10] E. Epaminonda, L. Efthymiou, E. Doukanari, Linking Digital Transformation to Learning Strategies and Pedagogy, in: 2022 IEEE Global Engineering Education Conference (EDUCON), 2022, pp. 2088–2092. doi:10.1109/EDUCON52537.2022.9766614.
- [11] L. Milord, V. Regina, A. Aiello, A. Waterman, DreamCoder 2.0: An Example of Digital Transformation for Education, volume E1, International Astronautical Federation, IAF, 2021. URL: <https://iafastro.directory/iac/paper/id/65118/abstract-pdf/IAC-21,E1,2,6,x65118.brief.pdf?2021-03-29.16:21:02>.
- [12] Cabinet of Ministers of Ukraine, Decree of the CMU of No. 960 Concept for the development of science and mathematics education (STEM education) (2020). URL: <https://zakon.rada.gov.ua/laws/show/960-2020-%D1%80#Text>.
- [13] N. Razak, R. Rasli, S. Subhan, N. Ahmad, S. Malik, Systematic review on digital transformation among teachers in public schools, *International Journal of Evaluation and Research in Education* 12 (2023) 1059–1078. URL: <https://ijere.iaescore.com/index.php/IJERE/article/view/24498>. doi:10.11591/ijere.v12i2.24498.
- [14] Ukrainian Institute of the Future, Ukraine 2030e — a country with a developed digital economy (2018). URL: <https://strategy.uifuture.org/kraina-z-rozvinutoyu-cifrovoyu-ekonomikoyu.html>.
- [15] Cabinet of Ministers of Ukraine, Cabinet of Ministers of Ukraine: Concept of development of the digital economy and society of Ukraine for 2018-2020 (2018). URL: <https://zakon.rada.gov.ua/laws/show/67-2018-%D1%80#Text>.
- [16] European Commission, European Education Area, Quality education and training for all (2023). URL: <https://education.ec.europa.eu/selfie>.
- [17] International Telecommunication Union, Measuring the Information Society Report, volume 2, 2018. URL: <https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-2-E.pdf>.
- [18] State Quality Service of Ukraine, The State Service of Education of the Quality of Education of Ukraine, Research of the quality of the organization of the educational process in the conditions of war in the 2022/2023 academic year, 2023. URL: <https://sqe.gov.ua/wp-content/uploads/2023/04/yakist-osvity-v-umovah-viyny-web-3.pdf>.

- [19] Ministry of Digital Transformation of Ukraine, Digital transformation index of Ukraine. Results of 2022, 2023. URL: https://oda.zht.gov.ua/wp-content/uploads/2023/04/Indeks_tsyfrovoyi_transformatsiyi_regioniv_Ukrayiny.pdf.
- [20] P. J. Guinan, S. Parise, N. Langowitz, Creating an innovative digital project team: Levers to enable digital transformation, *Business Horizons* 62 (2019) 717–727. URL: <https://www.sciencedirect.com/science/article/pii/S0007681319300965>. doi:10.1016/j.bushor.2019.07.005, digital Transformation & Disruption.