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From challenges to opportunities: Using ICT and AI in Ukrainian education in times of pandemic and War

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ABSTRACT

Rapid advancement of information and communication technologies (ICT) and artificial intelligence (AI) has significantly influenced various sectors of society, including education. Global challenges such as climate change, pandemics, and military conflicts have further accelerated the adoption of these technologies, driving digital transformation in educational practices. This study examines the role of ICT and AI in shaping education in Ukraine during the COVID-19 pandemic and the ongoing war. Based on international research and insights from the Ukrainian university community, the study involving 458 Ukrainian educators addresses several questions about the use of ICT and AI tools in teaching and learning during these crises. The study also explores the impact of ICT and AI on the teaching and learning process, providing a comprehensive analysis of the' perceptions and practices of Ukrainian educators. In addition, the paper presents the results of the study on the use of digital tools by educators in the dynamics. That is, not only at different stages of the pandemic and the war but also at the stage of using traditional methods and tools during face-to-face (F2F) education (before the pandemic) and in the expected postwar period. This shows changes in educators' attitudes and perceptions of using technology. Despite technological barriers, educators acknowledge the potential of ICT and AI to sustain and enhance educational outcomes. The study offers insights into the effective integration of these tools in education, highlighting the importance of adaptability, professional development, and innovative teaching models in times of uncertainty.

1. Introduction

In recent years, the world has been experiencing global changes due to human activity, including climate change, pandemics, military conflicts, and intensive development of information and communication technologies (ICT), digital technologies, and artificial intelligence (AI) (Kuzior, 2024; Bugdol et al., 2023). The report data from the International Telecommunication Union (ITU) on measuring the digital development of countries in 2023 (ICT Development Index - IDI) show an average global IDI score of 72.8 out of 100, which represents the significant role of technology in the current stage of human development (ITU, 2023) and digital transformation developments in many sectors of society.

Such transformations change the approaches to activities in various sectors of humanity, including education, causing constant transformation in the educational landscape, with students increasingly interacting with educators and technologically advanced learning environments (Komar et al., 2024). This shift requires a reevaluation of traditional pedagogical models and encourages educational stakeholders to adopt more flexible, technology-driven approaches. As a result, many scholars and practitioners are analysing the impact of ICT and digital technologies on education and transformation and are looking for new practical approaches in the teaching and/or learning process (Murwaningsih, 2025; Svalina and Ristivojević, 2025; Thankalayam et al., 2025; Kuzior et al., 2023; Weryński and Dolińska-Weryńska, 2024). As noted by Pylypenko et al. (2023), social capital plays a

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key role in supporting such innovations.

In recent years, the use of AI in education has become another essential new topic to define the future of learning due to the constant development of these technologies. Numerous national and international efforts and studies demonstrate the importance of AI in education research and practice (Fengchun et al., 2021). However, much of the discourse remains broad and lacks empirical insight into how these technologies are adopted, especially in crisis contexts. Thus, the question of how education is transforming under the influence of ICT, AI, the pandemic, and the need to conduct the educational process online and remotely for a sufficiently long time remains relevant in current settings.

Although existing research extensively explores the transformative role of ICT and AI in education, there is a significant gap in understanding their deployment during overlapping crises, such as pandemics and wartime, particularly in regions such as Ukraine, which face unique geopolitical and infrastructural challenges. This study addresses this gap, focusing on the' experiences and strategies of Ukrainian educators in leveraging digital tools to sustain educational practices during the COVID-19 pandemic and the ongoing war.

Consequently, the following research questions were formulated:

- RQ1 - How do the types and frequency of use of ICT and AI tools in the teaching and learning process vary across each stage concerning the COVID-19 war and pandemic?
- RQ2 - How do the opinions of professionals in the Ukrainian university community regarding the necessity and impact of using ICT and AI tools in the teaching and learning process depend on the stage of the war and the COVID-19 pandemic to which they refer?
- RQ3 - Do professionals' experiences in the Ukrainian university environment using ICT and AI tools during the teaching and/or learning process differ at different stages compared to the war and the COVID-19 pandemic?

Hypothesis: Ukrainian educators' skills and tools in using ICT and AI have changed quantitatively and qualitatively due to the pandemic and war.

Auxiliary hypothesis: the ICT tools and AI tools of Ukrainian educators depended on the stage at which they were used (before the pandemic, during COVID-19, and during wartime).

The research seeks to illuminate the patterns, challenges, and opportunities in this context by examining how these tools are used in different stages of crisis. Specifically, it investigates the evolution, effectiveness and institutional support for ICT and AI tools in education, offering information on their potential for resilience and innovation in adversity. The study's findings aim to contribute to the global discourse on digital transformation in education, emphasising context-specific strategies and future preparedness.

At the beginning of the pandemic, in March 2020, F2F was replaced by technology-based learning, which also continued during the 2020–2021 academic year. At the beginning of the 2021–2022 academic year, F2F learning was partially resumed (mainly in the first semester), but then the training continued in a blended learning environment.

In the first months of the war and during the 2022–2023 academic year, the Ministry of Education and Science of Ukraine decided to focus on distance learning (online and asynchronous). From the 2023–2024 academic year, the Ministry recommended that educational institutions, including universities, choose the form of education depending on the military situation, namely, online and asynchronous learning in the occupied and dangerous territories; and mixed learning in the areas close to the front line. In all other regions, preference is given to F2F training, provided that the educational institution can ensure the safety of all participants in the educational process in the event of mass attacks by the aggressor. This distribution continues to this day.

In the next section of the manuscript, we provide a brief review of the literature and present related scientific works. In the third part, we describe the methods, materials, and tools used, as well as the research sample. In the next section, we present the results obtained and build a model for the use of ICT and AI tools in teaching and/or learning using PROFIT analysis. In the fifth section, we discuss and compare the results obtained with similar studies. In the last section, we present conclusions, recommendations for policy makers and educational leaders, and possibilities for future research in this area.

2. Related works

ICT profoundly impacts education, teaching-learning, business, transportation, and all forms of production, including procedures, methods, techniques, tools, and relationships. The COVID-19 lockdown has affected every facet of life, and education is no exception. During the pandemic, when educational institutions were shut down globally and stakeholders were unsure how to handle the issue, distance learning gained popularity and particular attention (Rahimi et al., 2024). According to UNESCO (2023), more than 1.5 billion learners worldwide were affected at the peak of school closures, necessitating rapid digital adaptation. Online education and distance learning have become the new norm since the pandemic in 2019 (Strutynska and Umryk, 2020; Ansari and Waheed, 2024; Pirzado et al., 2024; Faisal and Dharmaraj, 2024). Ansari and Waheed (2024), examining the implications of its impact on educational spaces and learning, note that educational institutions (including higher education) face numerous obstacles to sustainable growth in the form of lack of ICT infrastructure, support, expertise, and limitations in mobility and access to services and resources. At the same time, Faisal and Dharmaraj (2024) note that the effectiveness of online and distance learning is influenced by learning management systems, which is why some researchers emphasise that to navigate the technological learning environment effectively, teachers need to be adequately trained, increase their digital literacy, and allocate ICT resources more effectively (Holik et al., 2023; Alghamdi and Alzahrani, 2024; Munyanyo and Simuja, 2024; Ovcharuk et al., 2023; Ovcharuk, 2024; Antón-Sancho et al., 2024). This is also facilitated by the development of cognitive skills necessary for scientific, critical and systematic thinking in order to respond to contextual challenges in the field of education (Ramírez-Montoya et al., 2022; Mezinska et al., 2024).

In the context of Ukraine, the need for resilient and adaptive education systems has become even more urgent. Although the world is gradually returning to face-to-face learning, there is an urgent need in Ukraine for experience, organization, and implementation of wartime training, as the educational process and the opportunity to receive education for the new generation should not be stopped (Vishkaie, 2020; Matviichuk et al., 2022). In Ukraine, teachers face the challenge of teaching online, as many schools cannot organise classroom learning, and part of the school infrastructure is destroyed. Ukrainian education must use blended learning technologies and ICT tools in such circumstances. The continuity of the educational process during the war in Ukraine is mainly supported by learning management systems, digital learning platforms, video communication platforms, and social media networking platforms (Martynets et al., 2024). Kuzheliev et al. (2023) investigate the role of distance learning tools in addressing wartime challenges. The researchers note that distance learning tools are a valuable resource for universities to mitigate the negative impact of war on educational quality within academic governance processes. However, the effectiveness of innovative distance learning tools in maintaining educational quality during the large-scale war in Ukraine has decreased (Kuzheliev et al., 2023). More research is also needed on the practical organisation of the educational process in wartime (Strutynska and Romero, 2023).

In an era of rapid technological change, the rise of artificial intelligence has added a new dimension to the digital transformation of education. The fast advancement of AI has emerged as a new challenge for many industries (Jonek-Kowalska and Rupacz, 2023; Tutak and Brodny, 2024) and has led to the development of a wide array of tools that are transforming the education industry (Gupta, 2024). Educators are

currently exploring various AI tools and their impact on the effectiveness of the teaching-learning process. The importance of AI in education research and practice (AIED) is reflected in multiple national and international initiatives and reports (Chiu et al., 2023).

These rapid developments have highlighted the need for educators to develop AI-related skills and competencies to integrate the technologies meaningfully into their professional practice (Fitria, 2021). AI literacy has become a global educational strategic objective (Yim and Su, 2023). Aubá (2024) believes that improving teacher training on AI and updating teaching and assessment methods is necessary. Tenberga and Daniela (2024) suppose that although teachers' AI literacy aligns with other digital skills and competencies, focused attention is required to develop AI-specific competencies professionally. A similar opinion is shared by Sperling et al. (2024). Train teachers and students of all educational levels in the fundamentals of AIED is key to developing AI literacies so they can understand how tools based on AI work and build practical skills for applying AI affordances (Chounta et al., 2022; Al-Abdullatif, 2024; Bellas et al., 2024). At the same time, an essential factor is building trust in teachers' adoption of AI technologies, as there are fears among educators regarding the use of AI, e.g., mass unemployment, privacy violations (Nazaretsky et al., 2022), concerns over academic honesty, and the possible negative impact on student's writing and thinking skills (Khlaif et al., 2024). These concerns highlight the need for teacher training programs to focus on providing comprehensive conceptual knowledge and skills, as well as an understanding of the application of these tools in teaching and learning (Kong et al., 2024; Santos et al., 2024).

3. Materials and methods

3.1. Research tool

The study material consisted of the results of an anonymous questionnaire developed specifically for this study. The survey questionnaire contained 16 closed questions, including four on anonymous sociodemographic information. Respondents answered the remaining 12 questions on a 5-point Likert scale, referring to each of the four stages, such as:

- Stage 1: during F2F (face-to-face) learning,
- Stage 2: during the COVID-19 pandemic,
- Stage 3: during the war,
- Stage 4: after the war is over (as you think it will be, as you plan).

The respondents were asked in the content part of the questionnaire about the frequency of their use of various ICT and AI tools during the teaching and/or learning process, their opinions on the necessity of using AI tools during the teaching and/or learning process, the truthfulness of statements describing their experiences in using ICT and AI tools during the teaching and/or learning process, and their opinions on the impact of ICT and AI tools on the teaching and/or learning process. The reliability of the questionnaire was tested with Cronbach's alpha internal consistency coefficient, the results of which indicated a high level of reliability (alpha = 0.92).

The questionnaires were collected electronically through the Google Forms online platform from 10.10.2023 to 24.01.2024. Individuals with professional ties to the Ukrainian university community who agreed to participate in the study were eligible. All participants in the study were informed of its scientific purpose and the anonymous and voluntary nature of their participation.

To ensure a broad institutional representation, the survey was distributed through several professional networks and academic communication channels. Specifically, we contacted university administrators (rectors and deans) with requests to circulate the questionnaire among faculty. Additionally, we disseminated the survey through professional networks in the Ukrainian segment of social networks (e.g., Facebook, LinkedIn) and relevant educator communities on messaging platforms (such as WhatsApp, Telegram, and Viber).

3.2. Subject matter and methodology of the analysis

The focus of this analysis was the use of ICT and artificial intelligence (AI) tools in teaching and/or learning by the professionals surveyed in the Ukrainian university environment, considering the different stages of the war and the COVID-19 pandemic. Consequently, the main area of this research was a comparative analysis of the various stages in terms of the frequency with which the study participants used different ICT and AI tools during the teaching and/or learning process, such as:

- Distance learning platforms,
- Video conferencing tools,
- Tools for creating surveys and/or tests,
- Social media tools (social networks, video tools, etc.),
- Communicators (WhatsApp, Viber, Telegram, etc.) for communication,
- MOOCs (Massive Open Online Courses),
- Platforms for designing digital learning resources (e.g., Padlet, LearningApps, etc.),
- Cloud technology (storage, online office, shared documents, etc.),
- AI tools.

In this study, the term 'online learning' refers to learning using video conferencing tools, where teachers and students can communicate in real-time. Whereas the term 'distance learning' is used to refer to 'asynchronous learning', in which some classes are held online, and some material is mastered by students independently outside of class time). At the same time, teachers used pre-designed e-courses/materials (designed distance learning courses) located on distance learning platforms. During the survey, teachers were informed about this interpretation of the terms.

A model was also built to use ICT and AI tools in teaching and/or learning at different stages.

The research material collected was subjected to quantitative and descriptive analysis. Descriptive statistics were compiled for quantitative (measurable) variables, while categorised (non-measurable) variables were presented by count (n) and percentage (%) of people characterised by a given characteristic. The conformity of the quantitative variables considered to a normal distribution was tested using the Shapiro-Wilk test.

The Kruskal-Wallis test was used to compare the different stages (due to their independent nature, i.e., the study was not repeated in the same group of respondents at different stages in time, and one of the stages concerned predictions of the postwar situation) in terms of variables of quantitative nature.

In addition, PROFIT Analysis was used for statistical analysis to assess the similarity of the studied objects in terms of selected characteristics and to develop a graphical presentation of the results of grouping objects and their relations to the studied characteristics in the form of a perception map. The first stage of the PROFIT analysis for the set of objects $A = (A_1,\ldots, A_n)$ and the dissimilarities δ_{ij} between A_i and A_j (i, j = 1, …, n) consisted of creating a perceptual map of objects in the r-dimensional space using multidimensional scaling methods.

3.3. Characteristics of the research sample

A total of 458 people participated in the survey, of whom the predominant group was female (91.92 %). The detailed distribution of the respondents is shown in Table 1.

4. Results

To address Research Question 1, we examined the frequency (4.1)

Table 1
Sociodemographic characteristics of the respondents.

		n	%
Gender	Female	421	91.92 %
	Male	37	8.08 %
Age(in years)	17–25	61	13.32 %
	26–30	50	10.92 %
	31–40	118	25.76 %
	41–50	121	26.42 %
	51–60	83	18.12 %
	> 60	25	5.46 %
Teaching experience (years)	1	26	5.68 %
	2–4	115	25.11 %
	5–10	87	19.00 %
	11–20	83	18.12 %
	21–30	146	31.88 %
	> 30	1	0.22 %
Work discipline	Life sciences	38	8.30 %
	Social Sciences	26	5.68 %
	Informatics	98	21.40 %
	Mathematics	58	12.66 %
	Philology	82	17.90 %
	Primary school	194	42.36 %
	Humanities	50	10.92 %
	Technology	17	3.71 %
	Sport	9	1.97 %
	Other	8	1.75 %

and types (4.2) of ICT and AI tools used across four educational stages: before the pandemic (F2F), during the COVID-19 pandemic, during the war, and in the anticipated postwar period. To address Research Question 2, we analysed respondents' views on the necessity (4.3) and impact (4.4) of ICT and AI tools in the teaching and learning process across the abovementioned four educational stages. The results present their perceptions of how these tools affect the quality of student learning outcomes, workload, and instructional organization. To address Research Question 3, we assessed the self-reported experiences of educators in using ICT and AI tools during the teaching and/or learning process across the different stages (4.5).

4.1. Comparative analysis of the different stages in terms of frequency of use of different ICT and AI tools during the teaching and/or learning process

The frequency with which the respondents used ICT and AI tools during the teaching and/or learning process differed between stages. As the analysis with the Kruskal-Wallis test showed, the different stages were statistically significantly different in terms of the frequency with which the study participants used tools such as both distance learning platforms: $H(3, N = 1832) = 128.94$; $p < 0.001$; $\varepsilon^2 = 0.07$; video conferencing tools: $H(3, N = 1832) = 109.72$; $p < 0.001$; $\varepsilon^2 = 0.06$; tools for creating surveys and/or tests: $H(3, N = 1832) = 66.45$; $p < 0.001$; $\varepsilon^2 = 0.04$; social media tools: $H(3, N = 1832) = 33.48$; $p < 0.001$; $\varepsilon^2 = 0.02$; instant messaging for communication: $H(3, N = 1832) = 16.16$; $p < 0.01$; $\varepsilon^2 = 0.01$; MOOCs: $H(3, N = 1832) = 64.71$; $p < 0.001$; $\varepsilon^2 = 0.04$; digital learning resource design platforms: $H(3, N = 1832) = 92.69$; $p < 0.001$; $\varepsilon^2 = 0.05$; cloud technology: $H(3, N = 1832) = 61.15$; $p < 0.001$; $\varepsilon^2 = 0.03$; as well as AI tools: $H(3, N = 1832) = 198.31$; $p < 0.001$; $\varepsilon^2 = 0.11$ (Table 2).

In cases where the sum of the mean and standard deviation exceeds the maximum value of the data range, the cause is an asymmetrical distribution and the presence of outliers. This effect is particularly noticeable when the first quartile value is 4 (on a scale of 1–5), indicating a strong tendency towards high ratings with a few lower values. For complete transparency, both mean values and SD are presented in accordance with the rules for reporting statistical data.

4.2. Model the use of ICT and artificial intelligence (AI) tools in teaching and/or learning at different stages

In the next step, a model of using ICT and AI (artificial intelligence) tools in teaching and/or learning at different stages was built using PROFIT (PROperty FITting) analysis. The aim was to identify the ICT and AI tools used by the subjects at different stages. In this model, the subjects analysed were the following groups:

- Stage 1: during F2F learning,
- Stage 2: during the COVID-19 pandemic,
- Stage 3: during the war,
- Stage 4: after the war.

In contrast, the variables (features) of this model were the individual ICT and AI tools used in teaching and/or learning.

To develop this model, average frequency scores on a point scale (on a scale of 1–5) were used for the use of the above ICT and AI tools in teaching and/or learning. During the construction of this model, multidimensional scaling was performed to develop a graphical representation of the structure of similarity (or dissimilarity) between the analysed objects with respect to a selected set of variables (characteristics). The identical nature of the characteristics analysed (5-point Likert scale) as variables precluded the need to standardize them. The classical Euclidean distance was used for multidimensional scaling, and consequently, the nine features describing the four objects were reduced to two dimensions. The STRESS coefficient for multidimensional scaling, including all features, was 0.00, demonstrating the high reliability of the results of the multidimensional scaling procedure.

The fit of the individual items was then verified. For this purpose, a regression analysis was performed in which the explanatory variable was the frequency of use of each ICT and AI tool in teaching and/or learning. In contrast, the explanatory variables were the values of the two dimensions for each individual obtained by multidimensional scaling. Dim.1 and Dim.2. As a criterion for considering a tool as the key, it was assumed that it had a fit of R^2 0.70. The following table (Table 3) shows the results of this analysis. As can be read from them, all the frequency dimensions investigated were characterised by a very high impact on the differentiation of the units investigated (R-values^2 of 1.00 or 0.99). Consequently, the number of features studied was not limited in the model.

At the end of this part of the research, a model was developed to use ICT and AI tools in teaching and/or learning at different stages using PROFIT analysis (Fig. 1). This model indicates that in stage 2 (during the COVID pandemic), respondents used mainly instant messaging for communication (T5), while in stage 3 (during the war), they used distance learning platforms (T1) and video conferencing tools (T2), respectively. The latter two tools were also used relatively frequently in stage 2 (compared to stages 1 and 4). Additionally, social media tools (T4) were used slightly less frequently in stage 3. Survey and/or test development tools (T3) and cloud technology (T8) were used similarly frequently in stages 3 and 4 (i.e., during the war and postwar anticipation). Survey and/or test development tools (T3) and cloud technology (T8) were used similarly frequently in stages 3 and 4 (i.e., during the war and postwar anticipation). Stage 4 itself diverged from the others in terms of greater frequency of use of MOOCs (T6), digital learning resource design platforms (T7), and AI tools (T9). In contrast, stage 1 (during F2F learning) diverged from all other stages and did not stand out in terms of using any of the above ICT and AI tools in teaching and/or learning (it is placed on the opposite side for all characteristics).

4.3. Comparative analysis of the different stages in terms of opinions on the necessity of using AI tools during the teaching and/or learning process

The respondents' opinion on the necessity of using AI tools during the teaching and/or learning process changed statistically significantly

Table 2
Comparison between stages in terms of the frequency with which respondents used different ICT and AI tools during the teaching and/or learning process.

	Stages	Descriptive statistics - Frequency of use of different ICT and AI tools during the teaching and/or learning process						Kruskal-Wallis test	ε^2	Post hoc
		Mean ± Standard deviation	Median [Q25 - Q75]	Min. - Max.	Confidence interval		Stand error.			
					-95.00 %	+ 95.00 %				
Distance learning platforms	Stage 1: during F2F learning (n = 458)	3.52 ± 1.45	4 [2–5]	1–5	3.39	3.65	0.07	H(3, N = 1832) = 128.94; p < 0.001	0.07	Stage 1 < Stage 2 (p < 0.001) / Stage 1 < Stage 3 (p < 0.001) / Stage 2 > Stage 4 (p < 0.001) / Stage 3 > Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	4.3 ± 1.1	5 [4–5]	1–5	4.20	4.40	0.05			
	Stage 3: during the war (n = 458)	4.33 ± 1.07	5 [4–5]	1–5	4.23	4.43	0.05			
	Stage 4: after the war (n = 458)	3.88 ± 1.14	4 [3–5]	1–5	3.78	3.99	0.05			
Video conferencing tools	Stage 1: during F2F learning (n = 458)	3.48 ± 1.58	4 [2–5]	1–5	3.33	3.62	0.07	H(3, N = 1832) = 109.72; p < 0.001	0.06	Stage 1 < Stage 2 (p < 0.001) / Stage 1 < Stage 3 (p < 0.001) / Stage 2 > Stage 4 (p < 0.001) / Stage 3 > Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	4.26 ± 1.11	5 [4–5]	1–5	4.16	4.37	0.05			
	Stage 3: during the war (n = 458)	4.24 ± 1.16	5 [4–5]	1–5	4.13	4.34	0.05			
	Stage 4: after the war (n = 458)	3.79 ± 1.12	4 [3–5]	1–5	3.69	3.89	0.05			
Tools for creating surveys and/or tests	Stage 1: during F2F learning (n = 458)	3.33 ± 1.36	3 [2–4]	1–5	3.20	3.45	0.06	H(3, N = 1832) = 66.45; p < 0.001	0.04	Stage 1 < Stage 2 (p < 0.001) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	3.75 ± 1.28	4 [3–5]	1–5	3.63	3.87	0.06			
	Stage 3: during the war (n = 458)	3.84 ± 1.29	4 [3–5]	1–5	3.72	3.96	0.06			
	Stage 4: after the war (n = 458)	4.01 ± 1.05	4 [3–5]	1–5	3.92	4.11	0.05			
Social media tools (social networks, video tools, etc.)	Stage 1: during F2F learning (n = 458)	3.77 ± 1.2	4 [3–5]	1–5	3.66	3.88	0.06	H(3, N = 1832) = 33.48; p < 0.001	0.02	Stage 1 < Stage 2 (p < 0.001) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	4.09 ± 1.09	4 [3–5]	1–5	3.99	4.19	0.05			
	Stage 3: during the war (n = 458)	4.16 ± 1.06	5 [4–5]	1–5	4.06	4.25	0.05			
	Stage 4: after the war (n = 458)	4.14 ± 0.96	4 [4–5]	1–5	4.06	4.23	0.05			
Communicators (WhatsApp, Viber, Telegram, etc.) for communication	Stage 1: during F2F learning (n = 458)	4.19 ± 1.14	5 [3–5]	1–5	4.08	4.29	0.05	H(3, N = 1832) = 16.16; p < 0.01	0.01	Stage 2 > Stage 4 (p < 0.05) / Stage 3 > Stage 4 (p < 0.05)
	Stage 2: during the COVID−19 pandemic (n = 458)	4.37 ± 1.01	5 [4–5]	1–5	4.27	4.46	0.05			
	Stage 3: during the war (n = 458)	4.37 ± 0.99	5 [4–5]	1–5	4.28	4.46	0.05			
	Stage 4: after the war (n = 458)	4.17 ± 1.06	5 [4–5]	1–5	4.08	4.27	0.05			
MOOCs (massive open online courses)	Stage 1: during F2F learning (n = 458)	2.71 ± 1.32	3 [2–4]	1–5	2.59	2.83	0.06	H(3, N = 1832) = 64.71; p < 0.001	0.04	Stage 1 < Stage 2 (p < 0.01) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001) / Stage
	Stage 2: during the COVID−19	2.99 ± 1.36	3 [2–4]	1–5	2.87	3.12	0.06			

(*continued on next page*)

Table 2 (*continued*)

	Stages	Descriptive statistics - Frequency of use of different ICT and AI tools during the teaching and/or learning process						Kruskal-Wallis test	ε^2	Post hoc
		Mean ± Standard deviation	Median [Q25 - Q75]	Min. - Max.	Confidence interval		Stand error.			
					-95.00 %	+ 95.00 %				
	pandemic (n = 458)									2 < Stage 4 (p < 0.001) / Stage 3 < Stage 4 (p < 0.01)
	Stage 3: during the war (n = 458)	3.07 ± 1.36	3 [2−4]	1–5	2.95	3.20	0.06			
	Stage 4: after the war (n = 458)	3.43 ± 1.21	3 [3−4]	1–5	3.32	3.54	0.06			
Platforms for designing digital learning resources (e.g., Padlet, LearningApps, etc.)	Stage 1: during F2F learning (n = 458)	2.72 ± 1.46	3 [1−4]	1–5	2.59	2.85	0.07	H(3, N = 1832) = 92.69; p < 0.001	0.05	Stage 1 < Stage 2 (p < 0.01) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001) / Stage 2 < Stage 4 (p < 0.001) / Stage 3 < Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	3.07 ± 1.44	3 [2−4]	1–5	2.93	3.20	0.07			
	Stage 3: during the war (n = 458)	3.22 ± 1.46	3 [2−5]	1–5	3.09	3.35	0.07			
	Stage 4: after the war (n = 458)	3.64 ± 1.19	4 [3−5]	1–5	3.53	3.75	0.06			
Cloud technology (storage, online office, shared documents, etc.)	Stage 1: during F2F learning (n = 458)	3.17 ± 1.38	3 [2−4]	1–5	3.05	3.30	0.06	H(3, N = 1832) = 61.15; p < 0.001	0.03	Stage 1 < Stage 2 (p < 0.01) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001) / Stage 2 < Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	3.48 ± 1.36	4 [3−5]	1–5	3.36	3.61	0.06			
	Stage 3: during the war (n = 458)	3.66 ± 1.36	4 [3−5]	1–5	3.53	3.78	0.06			
	Stage 4: after the war (n = 458)	3.86 ± 1.16	4 [3−5]	1–5	3.75	3.97	0.05			
AI tools	Stage 1: during F2F learning (n = 458)	2.12 ± 1.26	2 [1−3]	1–5	2.01	2.24	0.06	H(3, N = 1832) = 198.31; p < 0.001	0.11	Stage 1 < Stage 2 (p < 0.05) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.001) / Stage 2 < Stage 3 (p < 0.01) / Stage 2 < Stage 4 (p < 0.001) / Stage 3 < Stage 4 (p < 0.001)
	Stage 2: during the COVID−19 pandemic (n = 458)	2.37 ± 1.33	2 [1−3]	1–5	2.25	2.50	0.06			
	Stage 3: during the war (n = 458)	2.69 ± 1.39	3 [1−4]	1–5	2.56	2.82	0.06			
	Stage 4: after the war (n = 458)	3.31 ± 1.21	3 [2−4]	1–5	3.20	3.42	0.06			

Table 3
Results of the regression analysis between individual ICT and AI tools used in teaching and/or learning and the resulting dimensions of the individuals studied (applicable to groups distinguished by stage).

	Free expression		Dim. 1		Dim. 2		R^2
	b0	p	b	p	b	p	
Distance learning platforms (T1)	4.008	p < 0.001	0.256	p < 0.01	0.420	p < 0.01	1.00
Tools for videoconferencing (T2)	3.941	p < 0.01	0.230	p < 0.056	0.432	p < 0.05	1.00
Tools for creating surveys and/or tests (T3)	3.733	p < 0.01	0.329	p < 0.05	0.008	p = 0.762	1.00
Social media tools (social networks, video tools, etc.) (T4)	4.040	p < 0.001	0.194	p < 0.01	0.074	p < 0.05	1.00
Communicators (WhatsApp, Viber, Telegram, etc.) for communication (T5)	4.274	p < 0.001	0.024	p = 0.208	0.144	p < 0.05	1.00
MOOCs (massive open online courses) (T6)	3.051	p < 0.01	0.316	p < 0.059	−0.122	p = 0.179	0.99
Platforms for the design of digital learning resources (e.g., Padlet, LearningApps, etc.) (T7)	3.163	p < 0.01	0.413	p < 0.05	−0.151	p < 0.073	1.00
Cloud technology (storage, on-line office, shared documents, etc.) (T8)	3.544	p < 0.01	0.324	p < 0.05	−0.053	p = 0.247	1.00
AI tools (T9)	2.624	p < 0.01	0.520	p < 0.05	−0.303	p < 0.074	1.00

depending on the stage for which they expressed this opinion, as found by the results of the analysis with the Kruskal-Wallis test: H(3, N = 1832) = 41.22; p < 0.001; $\varepsilon^2 = 0.02$. On the other hand, the post hoc test showed that in stage 1 (during F2F learning), respondents considered the use of AI tools during the teaching and/or learning process less necessary ($M_{Stage\ 1} = 2.93$; $SD_{Stage\ 1} = 1.15$) compared to stages 3 (during the war) and 4 (postwar anticipation) ($M_{Stage\ 3} = 3.32$; $SD_{Stage\ 3} = 1.17$ and $M_{Stage\ 4} = 3.39$; $SD_{Stage\ 4} = 1.18$). Additionally, the

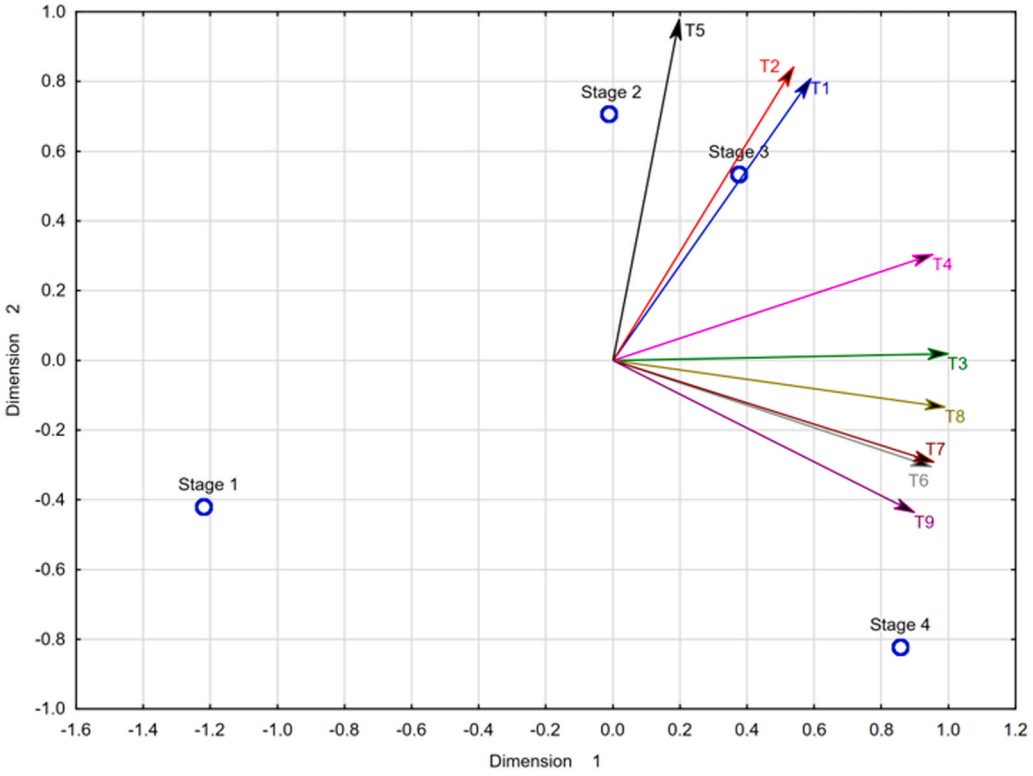


Fig. 1. Biplot considering the result of multidimensional scaling for individual objects (groups distinguished by stage) based on individual ICT and AI tools used in teaching and/or learning. *Explanation of abbreviations: T1 - Distance learning platforms, T2 - Video conferencing tools, T3 - Survey and/or test creation tools, T4 - Social media tools (social networks, video tools, etc.), T5 - Instant messaging (WhatsApp, Viber, Telegram, etc.) for communication, T6 - MOOCs (massive open online courses), T7 - Platforms for designing digital learning resources (e.g. Padlet, LearningApps, etc.), T8 - Cloud technology (storage, online office, shared documents, etc.), T9 - AI tools.*

results of the *post hoc* test indicate that at stage 2 (during the COVID-19 pandemic), the use of AI tools was considered less necessary than at stage 4 ($M_{Stage\ 2} = 3.11$; $SD_{Stage\ 2} = 1.19$ and $M_{Stage\ 4} = 3.39$; $SD_{Stage\ 4} = 1.18$) (Table 4).

4.4. Comparative analysis of the different stages in terms of individual opinions on the impact of ICT and AI tools on the teaching and/or learning process

The respondents' opinions on the impact of ICT and AI tools on the teaching and/or learning process did not differ significantly according to the stage at which they expressed their opinions. With the statement with content "The quality of student learning outcomes deteriorates during online and/or distance learning", the respondents agreed at each stage to an estimated degree between $M_{Stage\ 1} = 3.15$; $SD_{Stage\ 1} = 1.2$, and $M_{Stage\ 3} = 3.34$; $SD_{Stage\ 3} = 1.27$; "Teacher workload becomes more difficult when teaching online and/or at a distance" is estimated to be between $M_{Stage\ 1} = 3.9$; $SD_{Stage\ 1} = 1.22$ and $M_{Stage\ 2} = 3.95$; $SD_{Stage\ 2} = 1.22$ respectively; and "The use of digital technologies and ICT facilitates forms of organising the teaching/learning process" is estimated to be between $M_{Stage\ 3} = 4.15$; $SD_{Stage\ 3} = 1.09$ and $M_{Stage\ 4} = 4.22$; $SD_{Stage\ 4} = 1.01$. Based on the results of the analysis with the Kruskal-Wallis test, it was found that there were no statistically significant differences between the stages mentioned above in terms of the degree of agreement between the participants. Stages in terms of the degree of agreement of the respondents with statements such as "The quality of student learning outcomes deteriorates during online and/or distance learning" $H(3, N = 1832) = 6.74$; $p < 0.081$; $\varepsilon^2 = 0$; "Teacher workload becomes more difficult during online and/or distance learning": $H(3, N = 1832) = 0.56$; $p = 0.905$; $\varepsilon^2 = 0$; and "The use of digital technologies and ICT facilitates forms of organisation of the teaching/learning process": $H(3, N = 1832) = 0.54$; $p = 0.91$; $\varepsilon^2 = 0$ (Table 5).

Table 4
Comparison of the different stages regarding respondents' opinions on the necessity of using AI tools during the teaching and/or learning process.

Stages	Descriptive statistics - Opinion on the necessity of using AI tools during the teaching and/or learning process (on a scale of 1–5)						Kruskal-Wallis test	ε^2	Post hoc
	Mean ± Standard deviation	Median [Q25 - Q75]	Min. - Max.	Confidence interval		Stand error.			
				-95.00 %	+ 95.00 %				
Stage 1: during F2F learning(n = 458)	2.93 ± 1.15	3 [2–4]	1–5	2.83	3.04	0.05	H(3, N = 1832) = 41.22; p < 0.001	0.02	Stage 1 < Stage 3(p < 0.001) / Stage 1 < Stage 4(p < 0.001) / Stage 2 < Stage 4(p < 0.01)
Stage 2: during the COVID−19 pandemic (n = 458)	3.11 ± 1.19	3 [2–4]	1–5	3.00	3.22	0.06			
Stage 3: During the war(n = 458)	3.32 ± 1.17	3 [3–4]	1–5	3.22	3.43	0.05			
Stage 4: after the war (n = 458)	3.39 ± 1.18	3 [3–4]	1–5	3.28	3.50	0.06			

Table 5
Comparison of the different stages regarding respondents' opinions on the impact of ICT and AI tools on the teaching and/or learning process.

	Stages	Descriptive statistics - opinions on the impact of ICT and AI tools on the teaching and/or learning process						Kruskal-Wallis test	ε^2
		Mean ± Standard deviation	Median [Q25 - Q75]	Min. - Max.	Confidence interval		Stand error.		
					-95.00 %	+ 95.00 %			
The quality of student learning outcomes deteriorates during online and/or distance learning	Stage 1: during F2F learning (n = 458)	3.15 ± 1.2	3 [2–4]	1–5	3.04	3.26	0.06	H(3, N = 1832) = 6.74; p < 0.081	0.00
	Stage 2: during the COVID−19 pandemic (n = 458)	3.26 ± 1.22	3 [2–4]	1–5	3.14	3.37	0.06		
	Stage 3: During the war(n = 458)	3.34 ± 1.27	3 [3–4]	1–5	3.23	3.46	0.06		
	Stage 4: after the war (n = 458)	3.29 ± 1.25	3 [3–4]	1–5	3.18	3.41	0.06		
Teachers' workload becomes more difficult when teaching online and/or at a distance	Stage 1: during F2F learning(n = 458)	3.9 ± 1.22	4 [3–5]	1–5	3.79	4.02	0.06	H(3, N = 1832) = 0.56; p = 0.905	0.00
	Stage 2: during the COVID−19 pandemic (n = 458)	3.95 ± 1.22	4 [3–5]	1–5	3.84	4.06	0.06		
	Stage 3: During the war(n = 458)	3.95 ± 1.22	4 [3–5]	1–5	3.84	4.06	0.06		
	Stage 4: after the war (n = 458)	3.93 ± 1.21	4 [3–5]	1–5	3.82	4.04	0.06		
The use of digital technologies and ICT facilitates forms of organising the teaching/learning process	Stage 1: during learning of F2F (n = 458)	4.2 ± 0.99	5 [3–5]	1–5	4.11	4.29	0.05	H(3, N = 1832) = 0.54;p = 0.91	0.00
	Stage 2: during the COVID−19 pandemic (n = 458)	4.19 ± 1.03	5 [3–5]	1–5	4.10	4.29	0.05		
	Stage 3: During the war(n = 458)	4.15 ± 1.09	5 [3–5]	1–5	4.05	4.25	0.05		
	Stage 4: after the war (n = 458)	4.22 ± 1.01	5 [3–5]	1–5	4.12	4.31	0.05		

4.5. Comparative analysis of the different stages in terms of the degree of agreement with each statement about their experience in using ICT and AI tools during the teaching and/or learning process

Most of the respondents' experiences using ICT and AI tools during the teaching and/or learning process differed statistically significantly between stages, as shown by analysis with the Kruskal-Wallis test. This was true for online teaching using designed distance courses (and/or digital learning resources): H(3, N = 1832) = 21.22; $p < 0.001$; $\varepsilon^2 = 0.01$; partial online teaching and use of designed distance courses (and/or digital learning resources): H(3, N = 1832) = 16.14; $p < 0.01$; $\varepsilon^2 = 0.01$; not teaching online but using designed distance courses (and/or digital learning resources): H(3, N = 1832) = 16.52; $p < 0.001$; $\varepsilon^2 = 0.01$ and not teaching and/or learning online and/or at distance: H(3, N = 1832) = 35.31; $p < 0.001$; $\varepsilon^2 = 0.02$. The results of the post hoc test indicate that online teaching using designed distance courses (and/or digital learning resources) occurred at stage 1 (during F2F learning) less frequently ($M_{Stage\ 1} = 3.37$; $SD_{Stage\ 1} = 1.46$) than at the other stages (from $M_{Stage\ 2} = 3.72$; $SD_{Stage\ 2} = 1.32$ in $M_{Stage\ 3} = 3.77$; $SD_{Stage\ 3} = 1.32$); while partial online teaching and use of designed distance courses (and/or digital learning resources) were predicted at stage 4 (post-F2F learning) more frequently ($M_{Stage\ 4} = 2.87$; $SD_{Stage\ 4} = 1.28$) compared to earlier stages (from $M_{Stage\ 3} = 2.59$; $SD_{Stage\ 3} = 1.34$ to $M_{Stage\ 2} = 2.6$; $SD_{Stage\ 2} = 1.31$). In contrast, not teaching online but using designed distance learning courses (and/or digital learning resources) was predicted at stage 4 more often ($M_{Stage\ 4} = 2.53$; $SD_{Stage\ 4} = 1.38$) than at stages 2 and 3 ($M_{Stage\ 2} = 2.23$; $SD_{Stage\ 2} = 1.35$ and $M_{Stage\ 3} = 2.26$; $SD_{Stage\ 3} = 1.39$); similarly, not teaching and/or learning online and/or at distance ($M_{Stage\ 4} = 2.03$; $SD_{Stage\ 4} = 1.31$; stages 2 and 3: $M_{Stage\ 2} = 1.64$; $SD_{Stage\ 2} = 1.23$ and $M_{Stage\ 3} = 1.76$; $SD_{Stage\ 3} = 1.32$).

On the other hand, teaching online without using designed distance courses (and/or digital learning resources) was not stage dependent. At each stage, the respondents used ICT and AI tools in the above-mentioned manner to a degree rated between $M_{Stage\ 4} = 2.16$; $SD_{Stage\ 4} = 1.33$ and $M_{Stage\ 2} = 2.29$; $SD_{Stage\ 2} = 1.37$. Analysis with the Kruskal-Wallis test did not show statistically significant differences in this respect between the above-mentioned stages: H(3, N = 1832) = 3.25; $p = 0.355$; $\varepsilon^2 = 0$ (Table 6).

In cases where the sum of the mean and standard deviation exceeds the maximum value of the data range, the cause is an asymmetrical distribution and the presence of outliers. This effect is particularly noticeable when the first quartile value is 4 (on a scale of 1–5), indicating a strong tendency towards high ratings with a few lower values. For complete transparency, both mean values and SD are presented in accordance with the rules for reporting statistical data.

5. Discussion

This research aligns with previous studies that emphasize the importance and effectiveness of distance learning during crises and wartime (Rajab, 2018; Matviichuk et al., 2022; Stecuła and Wolniak, 2022a). The data revealed statistically significant variations in the frequency of ICT and AI tool usage across different stages. These findings align with earlier studies that emphasise the surge in digital technology use during crises. For instance, during the COVID-19 pandemic, there was a global increase in the development and implementation of digital education platforms (Korkmaz and Toraman, 2020; Stecuła and Wolniak, 2022b). Similarly, our results showed higher utilisation rates of video conferencing tools and distance learning platforms during crisis periods (the COVID-19 pandemic and wartime) compared to face-to-face (F2F) learning periods. Tejedor et al. (2021) emphasise that the transition from F2F to virtual learning has affected the entire educational process, favouring innovation in higher education institutions also considering the challenges in the global workplace associated with the rapid development of generative AI (Wong, 2024). Charina et al. (2022) also note the importance of sustainable education, which influences knowledge and experience in developing economic, social, and environmental innovations. Improving teachers' digital competence will

Table 6
Stage-by-stage comparison in terms of respondents' experiences in using ICT and AI tools during the teaching and/or learning process.

	Stages	Descriptive statistics - Experience of using ICT and AI tools during the teaching and/or learning process						Kruskal-Wallis test	ε^2	Post hoc
		Mean ± Standard deviation	Median [Q25 - Q75]	Min. - Max.	Confidence interval -95.00 %	Confidence interval + 95.00 %	Stand error.			
Teaching online without using designed distance learning courses (and/or digital learning resources)	Stage 1: during F2F learning (n = 458)	2.16 ± 1.32	2 [1−3]	1–5	2.04	2.28	0.06	H(3, N = 1832) = 3.25; p = 0.355	0.00	-
	Stage 2: during the COVID−19 pandemic (n = 458)	2.29 ± 1.37	2 [1−3]	1–5	2.16	2.42	0.06			
	Stage 3: during the war (n = 458)	2.19 ± 1.39	2 [1−3]	1–5	2.07	2.32	0.06			
	Stage 4: after the war (n = 458)	2.16 ± 1.33	2 [1−3]	1–5	2.03	2.28	0.06			
Delivering online classes using designed distance learning courses (and/or digital learning resources)	Stage 1: during F2F learning (n = 458)	3.37 ± 1.46	4 [2−5]	1–5	3.24	3.51	0.07	H(3, N = 1832) = 21.22; p < 0.001	0.01	Stage 1 < Stage 2 (p < 0.01) / Stage 1 < Stage 3 (p < 0.001) / Stage 1 < Stage 4 (p < 0.01)
	Stage 2: during the COVID−19 pandemic (n = 458)	3.72 ± 1.32	4 [3−5]	1–5	3.60	3.85	0.06			
	Stage 3: during the war (n = 458)	3.77 ± 1.32	4 [3−5]	1–5	3.65	3.89	0.06			
	Stage 4: after the war (n = 458)	3.73 ± 1.27	4 [3−5]	1–5	3.61	3.84	0.06			
Not teaching online but using designed distance learning courses (and/or digital learning resources)	Stage 1: during F2F learning (n = 458)	2.45 ± 1.44	2 [1−4]	1–5	2.32	2.58	0.07	H(3, N = 1832) = 16.52; p < 0.001	0.01	Stage 2 < Stage 4 (p < 0.01) / Stage 3 < Stage 4 (p < 0.05)
	Stage 2: during the COVID−19 pandemic (n = 458)	2.23 ± 1.35	2 [1−3]	1–5	2.10	2.35	0.06			
	Stage 3: during the war (n = 458)	2.26 ± 1.39	2 [1−3]	1–5	2.13	2.39	0.07			
	Stage 4: after the war (n = 458)	2.53 ± 1.38	2 [1−3]	1–5	2.40	2.66	0.06			
Partial online teaching and use of designed distance learning courses (and/or digital learning resources)	Stage 1: during F2F learning (n = 458)	2.6 ± 1.37	3 [1−4]	1–5	2.47	2.72	0.06	H(3, N = 1832) = 16.14; p < 0.01	0.01	Stage 1 < Stage 4 (p < 0.01) / Stage 2 < Stage 4 (p < 0.05) / Stage 3 < Stage 4 (p < 0.01)
	Stage 2: during the COVID−19 pandemic (n = 458)	2.6 ± 1.31	3 [1−4]	1–5	2.48	2.73	0.06			
	Stage 3: during the war (n = 458)	2.59 ± 1.34	3 [1−4]	1–5	2.46	2.71	0.06			
	Stage 4: after the war (n = 458)	2.87 ± 1.28	3 [2−4]	1–5	2.76	2.99	0.06			
Failure to conduct the teaching and/or learning process online and/or at a distance	Stage 1: during F2F learning (n = 458)	1.95 ± 1.49	1 [1−3]	1–5	1.81	2.09	0.07	H(3, N = 1832) = 35.31; p < 0.001	0.02	Stage 2 < Stage 4 (p < 0.001) / Stage 3 < Stage 4 (p < 0.01)
	Stage 2: during the COVID−19 pandemic (n = 458)	1.64 ± 1.23	1 [1−2]	1–5	1.53	1.75	0.06			
	Stage 3: during the war (n = 458)	1.76 ± 1.32	1 [1−2]	1–5	1.64	1.89	0.06			
	Stage 4: after the war (n = 458)	2.03 ± 1.31	1 [1−3]	1–5	1.91	2.15	0.06			

help accelerate these processes (Jekabsone and Anohina-Naumeca, 2024).

Although our study does not cover a post-war context empirically (as this is impossible so far during the ongoing war), the predicted postwar stage relies more on MOOCs, AI tools, and digital learning resource design platforms. These postwar references reflect educators' expectations and projections and should be interpreted as anticipatory insights. Nevertheless, the convergence between our participants' anticipations and the current wartime practices described by Banyoi et al. (2023) suggests that innovations adopted during crises may influence future educational strategies.

The findings regarding user experiences with ICT and AI tools highlighted a shift in teaching practices. For example, during the COVID-19 pandemic and wartime, online teaching with designed digital

resources became more prevalent, reflecting the findings of Punjani and Mahadevan, who noted that such tools are critical in transitioning to online learning during emergencies (Punjani and Mahadevan, 2022). However, our study also identified a divergence in the postwar stage, where hybrid and resource-intensive teaching methods were anticipated to gain prominence. This shift reflects the trend toward blending synchronous and asynchronous modalities for improved educational outcomes, as noted by Hrastinski (2019).

Notably, respondents' opinions on the impact of ICT and AI tools on learning outcomes, workload, and organisational processes were consistent across stages. Respondents consistently agreed that digital tools facilitated the organisation of teaching and learning processes but expressed concerns about the potential decline in student learning outcomes and increased teacher workload. These findings echo those of Hodges et al. (2020), who underscored the dual-edged nature of digital technologies in education, offering convenience and scalability while introducing new challenges.

6. Conclusions

The frequency of ICT and AI tools used during the teaching and/or learning process varies at different stages relative to the war and the COVID-19 pandemic. During the COVID-19 pandemic and the war, distance learning platforms and video conferencing tools are used more frequently (in contrast to F2F learning and postwar predictions), as well as instant messaging for communication (in contrast to postwar predictions). At the F2F learning stage, survey and/or test development and social media tools are noticeably less frequently used, as well as - in contrast to postwar predictions - MOOCs, digital learning resource design platforms, and cloud technology.

According to the model developed for the use of ICT and AI tools in teaching and/or learning at different stages, during the COVID-19 pandemic, professionals in the Ukrainian university community mainly used instant messaging for communication; during the war, distance learning platforms and video conferencing tools, respectively; and postwar predictions are mainly directed towards MOOCs, digital learning resource design platforms, and AI tools. Survey and/or test development tools and cloud technology are used similarly frequently during the war and in postwar predictions. On the contrary, F2F learning does not involve using any ICT and AI tools.

According to Ukrainian university experts, using AI tools during the teaching and/or learning process is less necessary during F2F learning and during the COVID-19 pandemic.

The opinions of professionals in the Ukrainian university community on the impact of ICT and AI tools on the teaching and/or learning process are not dependent on the stage relative to the war and the COVID-19 pandemic to which they refer.

This study contributes to the growing literature on crisis-driven digital transformation in education by offering a nuanced understanding of ICT and AI tool usage in a uniquely challenging context - wartime Ukraine. While prior studies have predominantly focused on the COVID-19 pandemic, this research provides insights into how multiple overlapping crises shape educators' adoption and perceptions of digital technologies. Incorporating anticipated postwar scenarios add a forward-looking dimension, emphasising the need for strategic planning in educational technology adoption.

According to the study's findings, an educational ecosystem that is resilient and adaptable must be fostered to effectively and efficiently withstand future crisis outbreaks. This calls for the holistic investment into digital tools and the creation of strategic frameworks that incorporate AI and ICT into curricula in a pedagogically sound and sustainable way. To close the gap between technological innovations and their real-world implementation in education, a collaboration between policymakers, educators, and technology developers should be significantly strengthened.

The findings underscore the importance of context-specific strategies in implementing ICT and AI tools. Policymakers and educational leaders should prioritize training and resources tailored to the unique demands of crisis periods. Future research should explore the longitudinal impacts of these adoption patterns, examining how they influence long-term educational outcomes and resilience. Additionally, comparative studies across different geopolitical contexts could offer valuable insights into the universality or specificity of these findings.

CRediT authorship contribution statement

Józef Ober: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Oksana Strutynska:** Resources, Investigation, Formal analysis, Conceptualization. **Tetiana Matusevych:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation, Formal analysis, Conceptualization.

Institutional review board statement

The survey research was conducted in accordance with the ethical principles of conducting research with human participants based on the guidelines of the Helsinki Declaration.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

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