

Analysis of the evolution of artificial intelligence as a key tool in digital education

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ABSTRACT

The Ukrainian educational system has experience of the digital quicker uptake by two significant crises in the country that occurred in the year 2019-2025 as compared to the rest of the world. The study examines how AI and Generative AI (GenAI) have been adopted and adapted within the Ukrainian educational context across multiple crisis phases between 2019 and 2025. A longitudinal mixed-methods was used for the study. A total of 200 university instructors in Ukrainian higher education was selected for survey while 20 participants was selected for interview using purposive sampling technique. Qualitative and quantitative data were collected using interviews and structured online questionnaires respectively. The result showed that AI tools in education increased steadily and significantly between 2019 and 2025. AI adoption factors changes from technical (4.32 ± 0.58) to contextual (4.32 ± 0.58) over time. There is a significant difference in AI/GenAI adoption and motivation across the crisis's phases ($p < 0.05$) with a partial η^2 value of 0.162 and 0.125 respectively. AI-LMS platforms, Adaptive Learning Systems and GenAI are the most adaptable to the Ukrainian context. The result showed that language barriers, infrastructure limitations, and resource availability were statistically significant challenges of AI adoption ($p < 0.0$). The study concluded that there is an exponential growth in AI adoption and turning points, however crises and technological breakthroughs jointly redefined digital education. Policies and ethical frameworks of AI-use should be introduced to universities to steer students in the ethical use of AI and academic honesty.

Keywords: Adaptability index, Digital transformation, Educational AI, Generative AI, Higher education, Longitudinal mixed-methods, Ukraine

1. Introduction

Artificial intelligence (AI), a main digital advancement has brought about global digital transformation of education between 2019 and 2025, redefining how knowledge is delivered and evaluated [1], [2]. The use of its tools, such as learning management systems (LMS), adaptive learning platforms, chatbots, grading and decision-making systems, and generative tools like Gemini, Claude, ChatGPT and Copilot has really reshaped teaching and learning environments [3]. UNESCO [4] reports that by 2023, over 40% of higher education institutions all over the world had adopted at least one AI-supported system. The AIs are now able to solve particular problems of the PSA related to problem-solving that demonstrate a significant change in educational capabilities [5]. It is mentioned by the World Bank [6] as well that AI-based analytics and adaptive tools are expected to touch over 60 percent of the digital learning processes around the world by 2025, which discloses the fast adoption of intelligent technologies in the education process. Although on the global scale, the evolution of AI can introduce a significant change in education, in Ukraine, it is taking a different path that is predetermined by health, economic, and geopolitical factors. The history of its digital

development indicates not only the correspondence with the global progress but also a specific conflict situation in which the continuity of education is maintained in the conditions of a crisis.

Between 2019 and 2020, Ukraine was in the initial phase of digitalization, during which the establishment of the primary infrastructure and the first LMS implementation in educational institutions and universities were being tested [7], [8]. During this period, digital competence frameworks and self-assessment systems started coming up as means for improving teachers' readiness for digital education [9]. The emergency event in 2020, like the COVID-19 pandemic, to the year 2022 fast-tracked technological change as institutions quickly embraced distance learning to ensure teaching continuity [10]. Studies across Ukrainian higher education reveal that this phase saw large-scale implementation of online platforms and blended learning formats, yet it also exposed gaps in digital equity and how prepared the teachers were [11], [12]. AI-enhanced systems were gradually introduced to assist teachers with workload management, automate assessments, and provide adaptive feedback for students who are learning remotely [13].

From 2022 onward, Ukraine's education system became more complex due to the war, including infrastructure destruction, blackouts, population displacement, and even unstable connectivity [14], [15]. The teachers and learners were compelled to use flexible hybrid models that are backed by cloud-based and AI-powered tools to make learning continue even in the face of constant disruptions [16]. The inequality of access and resources also increased during the war, posing different digital inclusion issues [17], [18]. Nevertheless, such numerous crisis shocks have also served as an innovation trigger, boosting the digitization of the localization of digital platforms, the creation of context-aware artificial intelligence solutions, and creative problem-solving in the Ukrainian education sector [6], [2]. The popularity of automated tools among educators reflects strength and flexibility despite the long-term unpredictability [19].

The 2019-2025 phase is a turning point in which not only are artificial intelligence instruments redefining the instructional approaches globally and nationally, but they are also redefining educational resilience. The Ukrainian case is a vivid example of the crisis being able to accelerate the digital maturity, making AI a technological solution and a strategic response to a vulnerability on a systemic level [8], [20], [21].

1.1. Theory and Contextualization of AI in Ukrainian Learning

To derive the significance of Artificial Intelligence (AI) as a revolutionary instrument in digital learning, it is necessary to be anchored in solid theoretical frameworks that describe how technology becomes accepted, and a change in the pedagogical approach is achieved. Models like TAM [22], UTAUT [23], and the SAMR framework [24] aid in the understanding of why individuals would go ahead to adopt, adapt or not adopt the new tools. They are also helpful when analyzed together to offer a significant perspective of understanding, supporting learning, changing teaching practice, and transforming institutions on a global and Ukrainian level.

1.1.1. Model for Technology Acceptance (TAM)

This framework was founded in 1989 [22]. TAM explains that the risks of using technology largely depend on two important determinants, they are; perceived usefulness (PU), which entails the degree by which a user believes that the use of technology will assist in their performance and perceived ease of use (PEOU), which entails the degree to which a user believes that the technology use will not demand any effort [21], [25]. The further developments of TAM involved further variables, attitude toward use, behavioral intention, and external factors and have become applicable to various learning settings [19], [15].

TAM has been extensively used globally to comprehend the involvement of teachers and students with artificial digital tools as a means of instruction and learning. It has been found that the perception of the usefulness of AI tools in mediating pedagogical outcomes and the perceived ease of integrating the tools in the classroom practices are key factors of teacher acceptance of AI tools [3, 26]. As an example of such a study, adaptive learning systems that are based on AI and automated assessment techniques have shown that positive PU and PEOU perceptions can correlate with higher adoption rates, whereas the lack of training and digital literacy may be a barrier to integration [15], [27]. The TAM has been useful in the Ukrainian society to examine the adoption of AI in the context of crisis-induced digital renovation. Experience of higher education has shown that the faculty members use AI-supported instructional platforms based on both their belief in the usefulness, particularly in distance and hybrid learning situations triggered by the current conflict [11], [12], [28]. TAM is therefore an excellent model of understanding global and localized trends of AI acceptance in

terms of the significance of cognitive impressions, technology design and context when determining the decision of adoption [29].

1.1.2. Unified Framework for Technology Use and Adoption (UTAUT)

This framework, formulated by Venkatesh et al. working on a single model to bring together eight previous models of technology adoption, offered a model that would help predict the acceptance and usage behaviour of users [23]. UTAUT hypothesizes that four fundamental constructs and how they moderately influence these effects [25], [30]. UTAUT has been extensively applied in the field of education to investigate the usage of new digital tools with the involvement of teachers and students, including AI and GenAI systems.

Recent studies related to AI and GenAI in education conducted between 2019 and 2025 indicate a rise in the usage of AI and GenAI. The systematic reviews suggest that AI applications based on automated grading, adaptive learning, and chatbots support personalized learning, but their importance, digital competence, and institutional provision affect the usage as well [16], [20], [21], [31]. Generative AI applications are transforming the pedagogical process by enabling the creation of content and learning analytics, but questions of trust, ethics and teacher preparedness continue to be [32-34]. Analysis based on UTAUTs always provides that facilitating conditions are where educators introduce AI in classrooms [35], [36]. The conflict-related disruptions have uniquely influenced the use of digital technologies in Ukraine, and scholars have reported that Ukrainian higher education is swiftly being digitally transformed and adapted to the crisis by creating distance learning and AI-assisted instructional resources and self-evaluation monitoring to ensure the continuity of education [6], [7], [23], [37]. Ukrainian studies show the importance of institutional support, resilience, and technological infrastructure as important facilitating conditions in agreement with UTAUT's predictions for technology acceptance under high-stress environments [15, 17]. These studies confirm UTAUT as a good framework for examining AI adoption in both stable and crisis-impacted educational contexts globally and within Ukraine.

1.1.3. SAMR Model

SAMR model introduced by Ruben Puentedura [19] offers the achievement of assessing the level of technology integration in education on the four levels [38]. The framework has been used worldwide to evaluate the role of developing digital tools, such as AI and GenAI, in supporting the teaching and learning practices by transforming tasks rather than just substituting such traditional ones [2], [17]. In research, it is found that adaptive learning, automatic grading and customized feedback can be supported using AI, which fits into the modification and redefinition levels of SAMR that promote greater cognitive engagement and pedagogical innovation [12, 39]. Chatbots and AI-assisted content creation platforms are further examples redefining learning experiences to allow creativity, critical thinking and collaboration in a number of learning settings [27], [40]. Studies indicate that SAMR assists systematic analysis of the application of technology among teachers that causes professional growth and curriculum design plans, which are consistent with the changing digital capabilities [17, 20]. Digital application in Ukraine was more prevalent during wartime, and this has prompted an urgency to take on AI-based distance education, which has offered SAMR an effective prism to analyze the pedagogical effects of such applications [8], [28]. The Ukrainian literature states that AI applications, which assist in self-assessment monitoring to virtual labs, etc, redefine the experiences in online and hybrid environments [9], [11]. In addition, SAMR assists teachers and government officials to find the discrepancies between technology availability and its purposeful application, especially in institutions of higher learning that have been adjusted to martial law [15], [37]. Consequently, the SAMR framework continues to be an internationally and nationally applicable instrument to assess AI-based educational innovation, informing the practices of teachers as well as the institutional digital change policy in Ukraine and other countries [28, 38].

1.2. Global Studies on AI/GenAI in Education (2019–2025)

The educational use of AI and GenAI has indeed grown between 2019 and 2025, and it has been accelerated by the steady technological advancements and the changing pedagogical methods [17]. According to recent systematic research, AI can be used in numerous applications in the field of education, such as adaptive learning, automated grading, chatbots and personalized platforms tailored to the requirements of multiple learners [2], [18], [39]. The result of these developments is higher instructional efficiency and less workload on teachers, as well as increased learner motivation and engagement in primary, secondary, and higher education institutions [10], [40].

Effective use of AI in learning requires acceptance and trust on the part of the educators, and their readiness to make use of AI relies heavily on the perceived usefulness, technological competence, and pedagogical confidence [20], [31], [35], [36]. AI-based assessment and feedback systems, e.g., automated grading and learning analytics, provide useful feedback in the classroom to understand the learner's progress and implement more data-driven instructional methods [39], [41]. These areas have been further extended using generative AI, which has been applied to design lessons automatically, tutor students online in an adaptive manner, and to create interactive simulations that can handle large cohorts of students [27, 30].

In addition to international studies, some studies about particular countries and fields of knowledge can have practical implications for AI. As an example, Sobolenko et al. explain that AI and virtual reality can be used to develop cognition and solve mathematical problems by future-proofing using dynamic modeling [32]. Similarly, the article by Vasylyuk-Zaitseva et al. addresses the implementation of AI in Ukrainian education and explains how the local implementation conforms to global trends and supports the alignment of teacher training, digital infrastructure, and innovation policy [28]. Comparing research has also increased awareness of the ethical and social aspects of the use of AI. The issues of concern to scholars are the fairness of algorithms, data security, and disparate access, inclusion, and transparency in determining AI policy [3], [42]. Reviews across the nations revealed that, although AI may positively influence the educational outcomes, as can be demonstrated in PISA testing, governance and equity need to stay central to prevent irresponsible use [5], [6].

Research publications dated 2019 to 2025 consistently establish AI and GenAI as redefining education by customizing learning, enhancing educators, and bringing new ethical and policy concerns to that debate [3], [12], [27]. Examples of sustainable, equitable and future-oriented AI use globally and in national settings such as Ukraine give hopeful evidence [28], [38].

1.3. Ukrainian Research on Digital Transformation and Crisis Adaptation

The Ukrainian education system has undergone a major digital transformation in recent years, especially in response to the full-scale Russian invasion and other disruptions related to the war [10], [29]. The scientists emphasized that the scale of the quickly adopted distance and hybrid learning went far beyond mere technological adjustment, which necessitated adaptability on the part of teachers and colleges [12, 13]. The digital transformation initiatives have been done to ensure that teachers are equipped with technology competencies, adoption of virtual learning environments, and integration of AI-driven pedagogical applications to ensure learning is sustained even in the conditions of crisis situations [7], [8], [43].

Empirical research done in Ukraine has indicated that self-assessment and monitoring instruments contribute to the digital competence of teachers, as they assist them in getting around the challenges posed by online learning and resource constraints [44]. On the same note, Kononova et al. [14] noted that academic staff and students found online education a need and a transformative opportunity, with adaptive teaching strategies and digital collaboration emerging as the main facilitators of engagement. Digital transformation has also contributed to institutional resilience, whereby higher education institutions have been able to sustain operations even when there is a relocation, destruction of infrastructure, and displacement of staff [37], [45].

In Ukraine, AI and combined digital technologies are currently used to maximize the learning outcomes. The use of AI that incorporates virtual reality and other digital technologies enhances the development of cognitive skills and involvement in complicated topics among students, e.g., STEM education [38]. The use of AI in Ukrainian education, with particular emphasis on the use of national policies to use AI to personalize instruction, support teachers, and introduce new policies, especially in times of war [28] [46].

Recent Ukrainian research demonstrates an improvement in the use of digital in education, but there remain problems, e.g., the unequal access to technology, lack of digital skills in educators, and continued psychosocial stress among learners and educators [8], [11]. The research also indicated that, as much as there is increased use of digital tools, their effectiveness depends on the ability to apply them with specific objectives of instruction as well as the necessity of teaching to accomplish long-term instruction [10], [14]. Ukraine scholarship indicates that the digital transformation and crisis adaptation are linked through integrating technological innovation, the capacity of teachers and systemic resilience. Combining AI, virtual learning and context-sensitive approaches, Ukraine provides a unique example of how educational systems can be continued, assist learners, and change the pedagogical practice in the most extreme circumstances [28], [38].

1.4. Research Gap

Even though AI and Generative AI (GenAI) are actively introduced into the education sector all over the globe, the lack of current studies that track this process throughout the years remains apparent [17], [19]. Reports by earlier studies are based on single methods of study, more often on one-time questionnaires or limited means, thus it becomes hard to determine the dynamics of teacher attitudes, institutional readiness and teaching practices during consistent technological and social stress [20].

The situation in Ukraine has worsened. War and emergency remote learning have combined to put schools and universities more rapidly into the digital tools than predicted, but little research has followed this change in any structured and longitudinal way [9], [10]. As it has been demonstrated, the level of confidence that teachers place in their own digital competence, as well as the type of institutional support they have in place, has a strong impact on the implementation of AI-based tools in the crisis scenario [7], [8]. Nevertheless, the majority of these studies are still descriptive, relying predominantly on self-report or short-term observations and are also missing the dynamics between educators, students and the dynamic digital infrastructure [14, 37].

The new opportunities introduced by the rapid emergence of GenAI as a teaching and learning tool since 2022 have also sparked new ethical and practical questions. These modifications still have to be researched in more detailed methods, involving the numbers with human experiences, such as relating adoption statistics with the teacher's thoughts on trust, usefulness, and classroom influence [22, 36]. Some Ukrainian research has begun to delve into these topics, especially e-learning in the war context and the initial application of AI in higher education. Their results suggest that further context-focused studies are necessary to provide further training, curriculum change, and policy choices in the future [13, 23].

All these gaps demonstrate why Ukraine and other pressure situations would be well served with a long-term and multi-method investigation that tracks the actual adoption of AI and GenAI in the real world. This evidence would assist in connecting the results of global research to local conditions and justify the fair and sustainable approach to digital transformation in education.

The study examines the historical development, current applications, and transformative impact of Artificial Intelligence (AI) in digital education. It specifically focuses on how AI and Generative AI (GenAI) have been adopted and adapted within the Ukrainian educational context across multiple crisis phases between 2019 and 2025. The study raised these key questions;

- RQ1: How have the frequency and diversity of AI tools evolved across 2019–2020, 2020–2022, and 2022–2025?
- RQ2: Which factors (technical, organizational, contextual) influenced adoption during each phase?
- RQ3: How did COVID-19 and the war alter AI/GenAI adoption trajectories and motivations?
- RQ4: Which AI tools exhibit the highest Adaptability Index to the Ukrainian context?
- RQ5: How have barriers (language, resources, ethics, institutional support) evolved over time?

2. Methodology

2.1. Research Design

A longitudinal mixed-methods design was used for the study. This approach was considered appropriate because it combines both survey (quantitative) and interview (qualitative) designs, and data are collected over an extended period (2019-2025), to track shifts in the acceptance and perception of AI, especially during significant turning points. The study employed the convergent parallel method, which allows for individual analysis of survey and interview data, but allows the combination and comparison of findings from these methods for a more comprehensive and validated interpretation of the results [47].

2.2. Participants

A total of 200 university instructors in Ukrainian higher education were selected and participated in the survey, selected using a purposive sampling technique based on their year of teaching experience at a recognised university in Ukraine since 2019 or earlier and their demonstrated digital instruction. This sample size is sufficient for carrying out basic descriptive and inferential statistics, and accounts for potential non-

response [48]. The sample includes different strata such as region, university type, and discipline (STEM, humanities, social sciences), with the stratified purposive sampling and snowball procedure employed.

10% representing 20 instructors were selected using certain criteria such as experience regarding generative AI (GenAI) exposure, discipline, and regional context. This sampling method was appropriate because it allowed the researcher to deliberately choose individuals who had direct engagement with or implemented AI tools [39]. Each semi-structured interview lasted for approximately 45 minutes, which was conducted online via Zoom or Google Meet to ensure accessibility and flexibility of participants

2.3. Instruments for Data Collection

The survey instrument was a self-developed online questionnaire with 35 items that participants could respond to within 8 minutes. The online questionnaire consists of five main blocks (1-5). Block 1 consists of the demographic characteristics of participants, which include age, gender, teaching experience, discipline, university type, region, and educational technology (EdTech) experience. Block 2 comprised items on the types and usage of AI tools such as AI-LMS, adaptive systems, chatbots, automated assessments, generative AI, and student analytics. Block 3 includes items on factors affecting the adoption of AI tools, such as institutional support, infrastructure, digital literacy, resources, peer influence, and external events. Block 4 includes items on perceived challenges or barriers such as training deficits, funding, ethics, resistance, or language barriers. Block 5 consists of items on self-assessment, like perceived teaching efficiency, student engagement, assessment quality, personalization, and workload. All the items in blocks 2-5 were measured on a 5-point Likert scale. The questionnaire was designed to have an integrated timeline, such as Pre-GenAI Phase (2019–2020), Transitional Phase (2020-2022), and Full GenAI Phase (2023-2025), characterized by blistering growth of generative AI products.

This consists of a semi-structured interview guide, which was held for 45 minutes, that explored participants' personal experiences on AI adoption and key milestones from 2019–2025, challenges in the Ukrainian higher education environment context (language, institutional, infrastructural), cases of success and failure, student reactions, future visions, and policy recommendations.

To validate the instruments, a pilot test was conducted with 20 university instructors who were not part of the study sample to test clarity and ease of use before the actual administration. The reliability test was conducted using responses obtained from the pilot study to determine the internal consistency of the items, to give an estimated Cronbach alpha coefficient of 0.91, indicating the appropriateness of the instrument to be fully used [40]. Additionally, the semi-structured interview guide will be reviewed by two professionals in technology to make the content valid and transparent. Their suggestions were applied in order to narrow down the wording, order and applicability to the study objectives.

2.4. Data Collection Procedure

To maximize the input, the survey questionnaire was distributed through Google Forms to gather information [51]. The interview was based on the English language, which was carried out in a period of 45 minutes per instructor to allow them to reflect on their adoption, implementations, and challenges of AI tools. All of the sessions were recorded and audio-taped with the consent of the participants and transcribed and verified by hand. The time frame for the collection of data was two weeks.

2.5. Data Analysis

Collected data differently, analysed, compared, but incorporated into each other for an overall picture and interpretation of the development of AI in education. This combination of findings provides a deeper understanding of results and enhances the validity and generalizability of results [52]. Quantitative data assessed at the three time points (2019-2021, 2021-2022, 2022-2025) were analysed using SPSS. Average, standard deviations and frequency, ANOVA and Chi-square were applied to the data. Factor structures associated with items on adoption and barriers were analysed by using principal component analysis (PCA), whereas Pearson correlation analysis was used to explore the relationships and patterns of their use. NVivo software was employed, applying thematic investigation following the six-phase method of Braun and Clarke [53]. After initial familiarisation with the transcripts, codes were inductively and deductively developed and grouped into themes. This process allowed a deeper understanding of instructors' lived experiences towards AI adoption, implementation and challenges.

2.6. Ethics

Participants consent to the study before participation begins and may withdraw at any time whenever they can no longer continue. The study ensured the confidentiality of the participants. All data was pseudonymized and stored in encrypted, password-protected formats; audio recordings were deleted post-transcription. Finally, in line with each university's research standards, the study ensured ethical clearance [54].

2.7. Limitations

The study acknowledges some limitations, which include the possibility of social bias or wrong assessment arising from participants' retrospective reporting of their experiences. Also, the use of purposive sampling for the selection of participants may introduce sampling bias, which may limit the extent of generalization of the findings. The study relies on the reconstruction of events; it does not establish the cause and effect of variables. Finally, the study does not take into account extraneous variables such as the ongoing war in Ukraine, which may also influence the findings of this study.

3. Results and discussion

Participants' demographic profiles, such as gender, age, year of experience, field, university type, and region, as shown in Table 1

Table 1. Demographic Profile of Participants (N= 200)

Demographic	Category	Frequency (f)	Percentage (%)
Gender	Female	88	44.0
	Male	112	56.0
Age Group (years)	25–34	36	18.0
	35–44	74	37.0
	45–54	60	30.0
	55 and above	30	15.0
Teaching Experience (years)	6-8	28	14.0
	9-11	54	27.0
	12–14	68	34.0
	15 and above	50	25.0
Field of Specialization	STEM	78	39.0
	Social Sciences	70	35.0
	Humanities	52	26.0
University Type	National/Public	136	68.0
	Private	64	32.0
Region	Western	50	25.0
	Central	64	32.0
	Eastern	42	21.0
	Southern	26	13.0
	Northern	18	9.0

From the participants of 200 instructors in Table 1, 112 (56%) were male, while 88 (44%) were female. The Age range is from 25 to above 55 years, with 14% having 6-8 years of teaching experience, 27% have 9-11 years of experience, 12-14 (34%), and 25% have above 15 years. According to their field of specialization, 39% are from STEM, 35% are from Social Sciences, while 26% are from Humanities. Also, 136 (68%) instructors are from public or national universities, while 64 (32%) are from private universities. 25% came from the western region, 32% from the central region, 21% from the eastern region, 13 % from the southern region, while 9% came from the northern region.

Research Question One: How have the frequency and diversity of AI tools evolved across 2019–2020, 2020–2022, and 2023–2025?

Quantitative Findings

The frequency and diversity of AI tool usage among university staff across the three observed periods (2019–2020, 2020–2022, and 2022–2025) were presented in Figure 1 and Table 2, respectively.

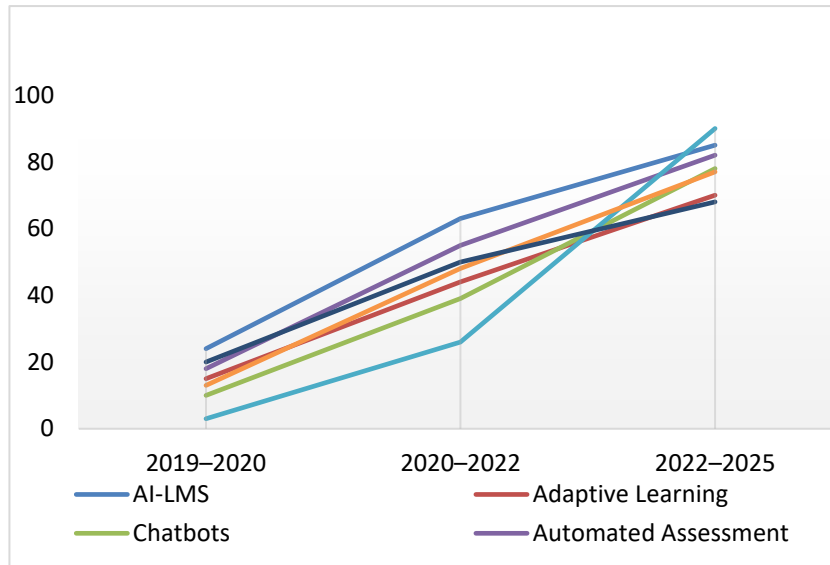


Figure 1. Profile Plot of the Trend of AI tool Usage (2019–2025)

The profile plot shows how university educators’ use of different AI tools has changed over three time periods (2019–2025). Figure 1 shows that all of the lines are going up, which means that tools steadily and significantly rise between 2019 and 2025. This shows how education is changing to digital technology and how much more it relies on AI for teaching, learning, and testing, as presented in Table 2.

Table 2. Percentage of AI Tools by Periods (2019–2025)

AI Tool Type	2019–2020 (%)	2020–2022 (%)	2022–2025 (%)
AI-based Learning Management Systems (AI-LMS)	22	68	84
Adaptive Learning Systems	15	46	73
Chatbots and Virtual Assistants	10	41	78
Automated Assessment Tools	18	57	81
Generative AI Tools (ChatGPT, Copilot, etc.)	4	22	89
Students Data Analytics	12	50	76
Other (e.g., plagiarism checkers, AI translation etc.)	25	55	70
Average Usage (%)	14.7	46.4	78.5

The distribution or comparison of different AI tools within each specific period is presented in Table 2. The result shows that during 2019-2020, the most adopted AI tools were other utilities, such as plagiarism checkers, etc. (25%) and AI-LMS (22%), while AI tools like chatbots (10%) and adoption of GenAI (4%) had the least adoption rate. Similarly, during the period 2020-2022, AI-LMS recorded a significant increase in its adoption rate from 22% to 68%. Finally, the 2022–2025 Generative AI tools (e.g., ChatGPT, Copilot) explosively increased from 22% to 89% dramatic increase, indicating it to be the most adopted AI tool during this period. This illustrates the increasing adoption of AI technologies in academic settings, initially spurred by the COVID-19 pandemic's need and subsequently by advancements in generative AI systems.

Qualitative Findings

The in-depth interview of the participants regarding the evolution of the AI tools use in (2019-2025) led to the identification of three principal themes. The key quotes made by the participant were chosen and used at random.

Theme 1: Foundational Integration of AI in Learning: The participants asserted that this period in the time frame, where institutions tried AI tools, was termed as foundational integration. Instead of contributing to the pedagogical innovation, these tools at the time were predominantly administrative and basic didactic tools. The views of one of the male participants at a state university were given.

“At that time, our use of AI was quite minimal; we saw it more as a convenience tool than a learning partner, especially using LMS for grading assessments” (P5).

Theme 2: Transition Period: Participants described this period as one of transition and trust-building, where educators begin to trust influence rather than merely assist with tasks. As one participant observed:

AI began to appear everywhere between 2020 and 2022; analytics enabled us to identify struggling students early on. We started to have greater faith in the technology” (P17)

Theme 3: Revolutionary Expansion: This period represents a shift where AI transitioned from a reactive, data-driven assistant to an active co-creator in educational processes (P2 and P7). Since tools like ChatGPT came into the picture, ideas can be generated, and content can be created even for assignments and feedback (P16).

Research Question Two: Which factors (technical, organizational, contextual) influenced adoption during each phase?

Items that measured AI tools during each phase. The mean and standard deviations of the three factors across the AI adoption phases are presented in Table 3.

Table 3. Mean Factor Ratings (M ± SD) Across AI Adoption Phases

Factor Type	Specific Factors	2019–2020	2020–2022	2022–2025
Technical Factors	Digital Infrastructure	3.21 ± 0.82	3.89 ± 0.74	4.46 ± 0.51
	Resource Availability (software/hardware)	3.02 ± 0.79	3.77 ± 0.72	4.31 ± 0.64
	Ease of Use	2.94 ± 0.81	3.64 ± 0.77	4.28 ± 0.59
	Integration with Existing Tools	2.88 ± 0.84	3.55 ± 0.75	4.22 ± 0.58
	(M ± SD)	3.01 ± 0.81	3.71 ± 0.74	4.32 ± 0.58
Organizational Factors	Institutional Support	3.38 ± 0.88	4.02 ± 0.68	4.15 ± 0.57
	Training Availability	3.06 ± 0.91	4.13 ± 0.63	4.29 ± 0.54
	Institutional Policy	2.87 ± 0.92	3.41 ± 0.81	4.05 ± 0.66
	(M ± SD)	3.1 ± 0.90	3.85 ± 0.70	4.16 ± 0.59
Contextual Factors	Digital Literacy	3.45 ± 0.77	3.88 ± 0.69	4.42 ± 0.55
	External Events (COVID-19, war disruptions)	2.76 ± 0.96	3.64 ± 0.82	4.33 ± 0.62
	Peer Influence & Collaboration	3.58 ± 0.81	4.12 ± 0.63	4.67 ± 0.48
	Perceived Usefulness	3.34 ± 0.79	4.01 ± 0.71	4.53 ± 0.52
	(M ± SD)	3.28 ± 0.83	3.91 ± 0.71	4.49 ± 0.54

Findings demonstrated that overall mean scores increased steadily in each stage, indicating an increase in institutional preparedness, digital maturity and AI users' acceptance. The largest gains were in Institutional Policy (+1.18) and Ease of Use (+1.34), which are the better system usability and codified policy frameworks of the GenAI age. The highest score was received in digital literacy (M = 4.42 ± 0.55) and peer influence and collaboration (M = 4.67 ± 0.48) in the period of GenAI integration, which emphasizes the significance of individual proficiency and group learning. The dramatic rise of 2.76 ± 0.96 to 4.33 ± 0.62 of external events (COVID-19, war disruptions) indicated that crises accelerated the use of digital technology. Moreover, Figure 2 demonstrates how the factors of AI adoption (technical, organizational, and contextual) change over time.

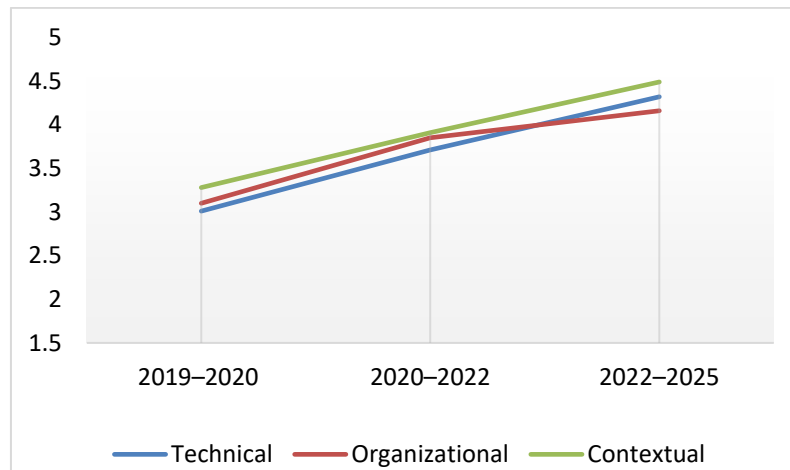


Figure 2. Changes in the Importance of AI Adoption Factors Over Time

Figure 2 shows that the three factor categories exhibit steady upward trends, and technical factors experience the biggest increases between 2022 and 2025 as a result of improved infrastructure and the quick integration of GenAI (Figure 2). The highest overall mean is maintained by contextual factors, which highlight environmental and human preparedness (Table 4). The institutional response to organizational factors is consistent, especially in the form of digital policy frameworks and more training. Furthermore, Principal Component Analysis (PCA) was conducted on the 11 items measuring potential factors influencing AI adoption as presented in Table 4.

Table 4. Factor Component Analysis of AI Adoption Influencing Factors

Component	Initial Eigenvalue (Total)	Initial % of Variance	Initial Cumulative %	Extraction Total	Extraction % of Variance	Extraction Cumulative %
1	4.672	26.012	26.012	4.672	26.012	26.012
2	2.918	16.594	42.606	2.918	16.594	42.606
3	2.436	13.534	56.140	2.436	13.534	56.140
4	1.983	11.019	67.159	1.983	11.019	67.159
5	1.336	7.422	74.581	1.336	7.422	74.581
6	1.111	6.172	80.753	1.111	6.172	80.753
7	0.872	4.679	85.432	–	–	–
8	0.691	3.839	89.271	–	–	–
9	0.523	2.905	92.176	–	–	–
10	0.367	2.039	94.215	–	–	–
11	0.243	1.350	95.565	–	–	–

The result in Table 4 showed that six components emerged from the data because they had eigenvalues greater than 1, indicating that six meaningful factors emerged from the data set. These six factors jointly explained 80.75% of the total variance, implying that the extracted factors capture most of the statements in the original 11 items. In addition, the first three components together explained more than 56% of total variance, indicating that technical, organizational, and contextual factors are the primary dimensions influencing AI adoption.

Qualitative Findings

The narratives of the participants were also examined to determine how various variables influenced AI uptake in the three phases to supplement the quantitative results. A few of the quotes that brought out the factors that contributed towards adoption out of the in-depth interviews are highlighted as follows:

“One of our participants noted that upon the digitalization of their university, it became simpler to implement AI into the lesson delivery process (Participant 6).”

“We had mandatory training sessions; that made us more confident using AI tools in assessments.” (Participant 18)

“When COVID hit, our usual teaching methods stopped working, and that’s when AI tools became essential for reaching our students. (Participant 11)

Other participants’ experiences highlight that institutional training and external disruptions were key drivers of AI adoption. Both the quantitative and qualitative results support the fact that different factors shaped AI adoption across the three phases.

3.4. Research Question Three: How did COVID-19 and the war alter AI/GenAI adoption trajectories and motivations?

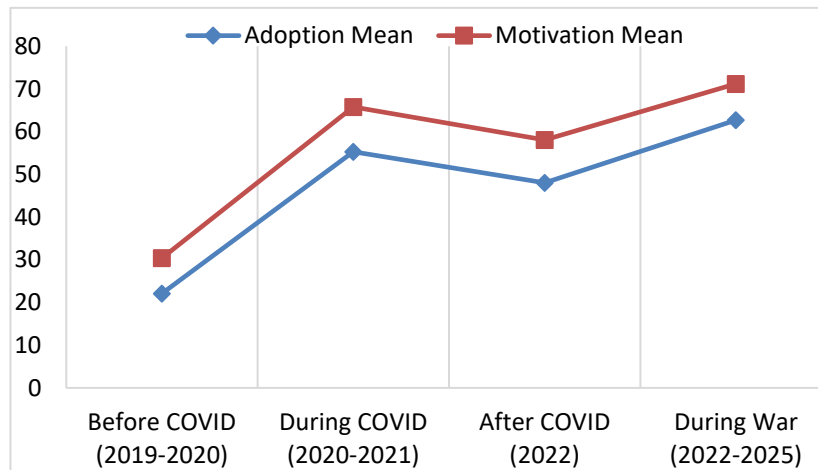


Figure 3. AI adoption and motivation scores Across Periods

The mean AI adoption and motivation scores are plotted in Figure 3 for four different time periods. Due to the importance of continuing remotely, with localized language tools, both scores exhibit a significant increase during COVID, a slight decline following the acute pandemic period as some practices normalized, and a strong renewed spike during the war period.

Table 5. ANOVA of AI/GenAI Adoption Trajectories and Motivations Across Crises

Phase (AI Adoption)	Mean	SD	F-value	p-value	Partial η^2
Before COVID (2019–2020)	2.41	0.68	18.72	0.000	0.162
During COVID (2020–2021)	3.78	0.74			
After COVID (2022)	3.35	0.71			
During War (2022–2025)	4.12	0.70			
Phase (AI Motivation)	Mean	SD	F-value	p-value	Partial η^2
Before COVID (2019–2020)	2.83	2.83	14.29	0.000	0.125
During COVID (2020–2021)	3.94	0.73			
After COVID (2022)	3.67	0.71			
During War (2022–2025)	4.45	0.70			

The results in Table 5 show there is a significant difference in AI/GenAI adoption and motivation across the crisis’s phases ($p < 0.05$) with a partial η^2 value of 0.162 and 0.125, respectively, indicating a moderate-to-large effect, suggesting that global and regional crises substantially reshaped the motivation behind AI/GenAI adoption.

Research Question Four: Which AI tools exhibit the highest Adaptability Index to the Ukrainian context?

Adaptability Index scores for each AI tool were calculated using technical compatibility, pedagogical relevance, language and cultural fit, ease of implementation, and institutional support readiness. Table 6 displays the results (index and confidence intervals) that show how consistently respondents rated the items.

Table 6. Adaptability Index of AI Tools to the Ukrainian Educational Context

AI Tool	Mean Adaptability Index	95% Confidence Interval	Rank	Interpretation
Learning Management Systems (Moodle)	0.86	0.83 – 0.89	1	Very High Adaptability
Adaptive Learning Systems (Smart Sparrow etc.)	0.83	0.80 – 0.86	2	Very High Adaptability
Generative AI (ChatGPT)	0.80	0.76 – 0.84	3	High Adaptability
Student Data Analytics Platforms (Power BI)	0.78	0.74 – 0.82	4	High Adaptability
AI Writing Assistant Tools (Grammarly).	0.76	0.72 – 0.80	5	High Adaptability
Automated Assessment Tools (Gradescope)	0.73	0.70 – 0.77	6	Moderate Adaptability
Generative AI for Content Creation (Jasper AI etc.)	0.71	0.67 – 0.75	7	Moderate Adaptability
AI Tutoring Systems (Duolingo Max etc.)	0.69	0.65 – 0.73	8	Moderate Adaptability
Speech and Translation AI Tools (Google Translate.)	0.66	0.62 – 0.70	9	Moderate Adaptability
AI Classroom Management Tools	0.62	0.58 – 0.66	10	Fair Adaptability

Table 6 shows that AI-LMS platforms and Adaptive Learning Systems are the most adaptable to the Ukrainian context, with strong institutional alignment, content integration, and infrastructure flexibility. From the result, there is a high degree of adaptability for GenAI, as it can be communicated in many languages, such as Ukrainian. In a similar vein, student data analytics also demonstrated great adaptability in student development and instruction. On the other hand, tools such as Generative AI for Content Creation and Automated Assessment Systems received a moderately adaptable rating, while AI Classroom Management Systems and Speech and Translation AI tools received a lower adaptability.

Research Question Five: How have barriers (language, resources, ethics, institutional support) evolved over time?

Barrier dynamics across different phases are illustrated in Figure 5. Furthermore, quantitative analysis using the Chi-square (χ^2) test (Table 7) and qualitative insights from participants' interviews were employed to understand how barriers influencing AI adoption in higher education have evolved across different phases.

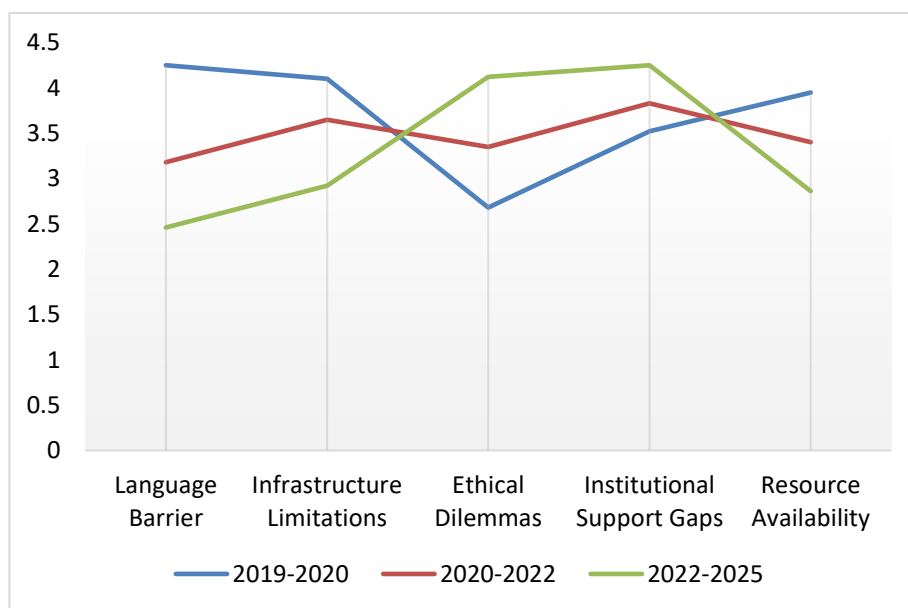


Figure 5. Barrier dynamics across different phases

Figure 5 showed that while language, infrastructure, and resource barriers declined dramatically over the course of the phases, institutional support gaps and ethical dilemmas increased as AI use increased, pointing to new issues with data privacy, academic integrity, and long-term institutional frameworks.

Table 7. Chi-square (χ^2) test of the Top 5 Barriers by Period

Barrier	AI Adoption Phases			Total	df	χ^2	P
	2019-2020	2020-2022	2022-2025				
Language Barrier	85	70	45	200	2	15.62	0.001
Infrastructure Limitations	80	75	45	200	2	11.47	0.004
Ethical Dilemmas	45	65	90	200	2	13.58	0.002
Institutional Support Gaps	55	65	80	200	2	9.84	0.009
Resource Availability	78	68	54	200	2	10.73	0.006

The Chi-square result showed that the frequency of reported barriers varied across the three AI adoption phases (2019-2025). The result showed that language barriers, infrastructure limitations, and resource availability are statistically significant ($p < 0.05$) and decreased over time from 85 to 45, 80-45, and 78 to 54, respectively. Conversely, the result showed that ethical concerns and the institutional support gap are both statistically significant and increased over time from 45 at the early age to 90, and 55 to 80, etc.

Qualitative Findings and Quotes

Theme 1: Language Barriers: There are challenges as a result of the dominance of English-based AI tools. One participant remarked:

“Most AI tools didn’t support Ukrainian translation, which made it difficult for both instructors and students at first.” (Participant 15)

Theme 2: Infrastructure Limitations: Respondents raised the issues of internet connectivity and facilities challenges. As one educator noted:

“Even though some tools are available, unstable internet is a major problem” (Participant 20)

Theme 3: Ethical Dilemmas: Some instructors expressed concern over students’ ethical use of AI, such as plagiarism:

“What I see is how to use AI responsibly without compromising assessment fairness.” (Participant 1)

3.1. Discussion of Findings

The findings of the study revealed an exponential adoption of AI and GenAI among university instructors in Ukraine due to three significant events, such as the COVID-19 Pandemic, the emergence of GenAI tools, and the ongoing war between 2019 and 2025. Evidence across the world also corroborates this finding that crises hasten the spread of technology because of the demands for flexible assessment, remote learning, and institutional resilience [4], [55].

The adoption of AI progressed from the state of experimentation in 2010–2020 to the full-scale utilization of AI. The pandemic marked the first significant turning point, which participants characterized as a time of "forced digitalization" during which teachers quickly shifted to AI-supported platforms like AI-LMS, automated assessment systems, and analytics tools for continuity and to preserve instructional continuity. This is in line with research by [25], [2] that AI tools can be used for emergency remote teaching across the globe. Furthermore, according to the study's findings, the progressive increase in the use of generative AI tools in 2023, such as ChatGPT and numerous others, is another significant turning point. As a result, AI's function from one of passive assistance to one of active cooperation. A study asserted that GenAI has transformed human-machine collaboration in educational settings, which is supported by educators' in-depth reflections that describe AI as a "co-creator of content and feedback"[56]. Finally, a new kind of institutional resilience

was demonstrated by the deliberate and ongoing integration of AI, which was incorporated into long-term academic policy, resource management, and instructional design as a result of the ongoing war period (2022-2025), as mirrored by literature [28].

Furthermore, there is a shift from technical and organizational factors to contextual factors as key influencers of AI integration. In the first stage, the use of AI will rely on digital infrastructure and LMS systems. Such results are in line with current research [26, 27], which highlights the role of teacher preparedness and policies in determining AI adoption. GenAI was also a game changer in this modern technology era, and its index of adaptability also made it the preferred AI tool among others that can be applied in the Ukrainian context in the aspect of flexibility and language capability. GenAI introduced creative, dialogic and contextual intelligence which facilitates educators to co-design learning materials, simulate tutoring and enhance the quality of feedback. This is consistent with the results that GenAI boosts academic productivity and creativity, but it is not without challenges that include the issue of originality and unethical utilization [57].

The external triggers of the war and COVID-19 led to a shift in motivation, being driven by technological curiosity to necessity innovation and eventually to implementation that is resilient and adaptive, which is supported by [28]. Besides, the COVID-19 pandemic and a full-scale war in Ukraine impacted the adoption of AI and conditioned the implementation of AI learning management systems, automated assessments, remote instructions and educational continuity. The war transformed the use of AI, which was just a need, into a mechanism that resists and supports remote work. Issues such as insufficient accessibility and translation of most English-based AI tools between 2019 and 2021, and grassroots efforts to localize interfaces and produce bilingual interfaces were all challenges. This dynamic enables universities to ensure their own policies and training on AI, which leads to flexible learning ecosystems able to be run even in a time of governance disruption [29], [46].

The result complements the current Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) by providing the example of how external crises, including COVID-19 and war, are triggers that transform the classic predictors of adoption. The study recommends an evolutionary process in adoption factors of technical to organizational and contextual aspects, where human and cultural variables are more relevant than technical preparedness in the case of sustainable AI integration as digital maturity rises [58].

4. Conclusions

This study examines the adoption of AI and Generative AI (GenAI) in Ukrainian higher education from 2019 to 2025, influenced by the COVID-19 pandemic, the 2022 war, and the GenAI revolution in 2023, using the combination of quantitative and qualitative approaches.

Findings indicate exponential growth in AI and GenAI adoption in the three periods, which was a major turning point, by 2019, adoption was small; however, crises and technological breakthroughs jointly redefined digital education by 2022 and 2025, respectively. Findings also showed that the most crucial among the factors that affect adoption are organizational factors like training, institutional support, and peer collaboration. More so, the strongest predictors are contextual factors of COVID-19 and war. The catalysts of COVID-19 and war resulted in three significant changes from traditional instruction to coerced digitalization, to digital adaptation, and finally to digital innovation and motivation, indicating that crisis conditions were shown to not only hasten technological adoption but also to transform motivations and behaviours. Findings showed that barriers encountered changed over time such as barriers of poor digital literacy and infrastructure was observed before 2019, during the year 2022, barriers include psychological issue, unreliable power and internet connection, while post 2023 barriers are ethical risks, academic dishonesty, bias, integrity in assessment. Qualitative insight reported increased efficiency, engagement and creativity using AI and GenAI, which reinvented teaching and assessment, but GenAI provided the best advantages. However, this does not come without concerns from the respondents, which include academic integrity, equal computerized grading of students, and over-reliance on AI in thought processes.

Study presents Crisis-Driven Adoption Model (CDAM) that integrates contextual stressors and traditional adoption constructs and shows how crises can increase the value of technical readiness, digital literacy and institutional adaptability. In Ukraine, such factors as resilience and local innovation proved to be the key adoption processes in the case of long-term disruptions. Thus, the teacher ought to utilize the readily available AI tools with a large pedagogical outcome (with regard to academic integrity and ethics of use). Universities

will need to invest in infrastructure, create AI competence centres to enhance best practices, and institutionalize AI adoption using policy and interventions. Policymakers should develop a National AI-in-Education Strategy to enhance the educational activities by covering AI resources specified for a particular language, ethical data management, and teacher training programs.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

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