

The use of ICT by teachers for the development of students' critical thinking in the context of sustainable development in Ukraine

Oksana V. Ovcharuk, Maiia V. Marienko, Olena O. Hrytsenchyk, Oksana Ye. Kravchyna and Iryna D. Malytska

Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine

Abstract

The globalised world and modern society require teachers to use new digital technologies and at the same time set the task of developing critical thinking of their students. Critical thinking is one of the conditions and components of education for the sustainable development of society. The purpose of this article is to examine how teachers in Ukraine use ICT to foster students' critical thinking in the context of sustainable development. The analysis and interpretation of quantitative data were carried out using the methods of descriptive and mathematical statistics, following general scientific approaches. The most effective forms of education today are distance and mixed learning. One of the important aims and at the same time teaching method is the development of students' critical thinking. Results and practical significance. This article discusses the selection of ICT resources and tools for developing critical thinking skills. It also examines how teachers view the use of digital tools in their professional development and provides information on how Ukrainian teachers use these tools in wartime conditions. However, further research is needed to monitor how teachers use ICT tools to promote critical thinking.

Keywords

critical thinking, sustainable development, digital tools in education, distance learning, blended learning, teacher professional development, wartime education, 21st-century skills

1. Introduction

The development of critical thinking is an important task for Ukrainian teachers today. Circumstances related to military actions on the territory of Ukraine actualized the need to responsibly and critically use digital tools and ICT for education because a large part of educational activities is carried out remotely. According to the Ministry of Education and Science of Ukraine, 12,926 schools operate in Ukraine, 955 school children study face-to-face, 4,363 – remotely, and 4,608 – in a mixed form. More than 510,000 schoolchildren and more than 12,000 teachers continue to stay abroad [1]. This made it necessary for teachers to select and use digital resources that will contribute to the formation of students' responsible and critical behaviour and will form citizenship and democratic values in the framework of learning school disciplines. Also, the European vector of development and restoration of educational losses, both after the COVID-19 quarantine [2, 3] and in wartime, directs teachers to the formation of European and world values of humanity, in particular those related to the preservation of life and observance of human rights, preservation of the environment, sustainable development of society. The formation of critical thinking is carried out by teachers both within the framework of compulsory educational disciplines and within the framework of extracurricular activities and other activities. The educational practices of using online resources and various approaches to their use considered in this work allow forming the logical and critical thinking of students. The identification of several tools and teachers' attitudes to the use of digital tools forms a modern picture of teachers' perception of the educational process with the help of ICT.

AREdu 2024: 7th International Workshop on Augmented Reality in Education, May 14, 2024, Kryvyi Rih, Ukraine

✉ oks.ovch@hotmail.com (O. V. Ovcharuk); popel@iitlt.gov.ua (M. V. Marienko); helenakyiv2017@ukr.net

(O. O. Hrytsenchyk); oxi-krav@ukr.net (O. Ye. Kravchyna); irina_malitskaya@ukr.net (I. D. Malytska)

🆔 0000-0001-7634-7922 (O. V. Ovcharuk); 0000-0002-8087-962X (M. V. Marienko); 0000-0003-3173-7649 (O. O. Hrytsenchyk); 0000-0002-3903-0835 (O. Ye. Kravchyna); 0000-0003-1598-0120 (I. D. Malytska)



© 2025 Copyright for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

2. Research methods

The purpose of this article is to examine how teachers in Ukraine use ICT to foster students' critical thinking in the context of sustainable development.

The research tasks:

1. Identifying the public opinion of teachers and other school professionals regarding the problems and readiness of teachers to use digital technologies during the war period.
2. To single out recommendations for the teacher training system regarding the use of digital tools and means for the development of critical thinking.

In the research process, the results of the monitoring conducted by the Institute of Digitalization of Education of the National Academy of Sciences of Ukraine were used, which was aimed at identifying the public opinion of teachers and other school professionals regarding the problems and readiness of teachers to use digital technologies during the war period. The results of the teachers' survey presented in the article are based on the questions formulated according to the "European DigComp for Citizens" approach proposed by Clifford et al. [4]. The analysis and interpretation of quantitative data were carried out using the methods of descriptive and mathematical statistics, following general scientific approaches. The authors used the methods of descriptive analysis of the approaches of different authors to the use of ICT for the formation of students' critical thinking, and description of the experience of using ICT in other countries (Czech Republic, USA, Germany, etc.). The conducted analysis made it possible to single out recommendations for the teacher training system regarding the use of digital tools and means for the development of critical thinking.

3. Literature review

Critical thinking is defined as the process and practice of examining evidence to arrive at informed decisions and beliefs. This process involves examining the evidence and examining the problem from different perspectives. This approach is common in the Western tradition, dating back to famous figures from Socrates to R. Descartes and J. Dewey [5]. The theory of critical thinking was developed in modern cognitive psychology, which is based on a wide experimental and research base. The most famous representatives of cognitive psychology are G. Miller, J. Bruner, U. Neisser, A. Bandura, N. Chomsky, S. Carey, R. Gelman and others who have made significant contributions to the field of cognitive psychology [6].

Since the development of critical thinking is a subject of cognitive psychology, which is projected onto the pedagogical sphere, it is worth paying attention to the positions expressed by modern educators. Educators pay attention to the ways and means by which students' critical thinking can be developed. Castells et al. consider education and the development of critical thinking that can contribute to social and political changes in the context of ecology, media, and individual liberty in their pursuit of new ideas that can inform the fundamental practice of education and promote a more humane civil society [7]. Rashid proposes ways in which critical thinking can be developed in education: encourage students to ask questions; teach students to evaluate information; teach students to analyse information; encourage students to think creatively; provide opportunities for reflection; and teach students to communicate effectively [8]. Terno, the Ukrainian researcher, claims that critical thinking is thinking that is conscious, independent, reflective, purposeful, grounded, controlled, and self-organized and offers his vision of the formation of students' critical thinking in the process of studying history [9]. The technology proposed by him is based on programmed and developmental learning, which, in his opinion, ensures students' assimilation of historical concepts in the system at the theoretical level of generalization, as well as increases the systematicity, strength and depth of knowledge. Cole, DeLecce and Pisano believe that there are a variety of ways to parse the skills involved in critical thinking. One way to formulate the skills involved includes the following seven: emotional skills, inference, observation, questioning, imagination, consulting, and judging [5]. Semerikov et al. authors state the importance of developing design methods for immersive e-learning resources, educational, scientific, informational, reference

materials and tools used in an immersive environment, reproduced by immersive technical tools, and necessary for effective organization of the educational process [10]. At the same time, investigations in different countries show, that that even teachers with sufficient technology skills are not comfortable or prepared to integrate technology into the classroom. Mynaříková and Novotný state that even frequent ICT users are often not sure about how to implement digital instruments into their specific subjects. The authors point out that the missing link might be the absence of structured, continuous training in the use of ICT in teaching [11].

Based on the above-mentioned provisions, it is necessary to focus on important positions regarding the impact of the use of ICT by teachers on the development of students' critical thinking. At the same time, it is worth identifying those aspects related to the transformation of educational activities in the context of sustainable development. The role and impact of the use of ICT and digital tools by teachers in the process of the development of student's critical thinking in the context of sustainable development is closely related to the quality of education, in particular:

- ICTs have become indispensable tools to deal with different societal needs through a transformation of educational practices;
- ICTs contribute to inclusive education and the creation of learning opportunities;
- digital tools help reduce social and economic inequalities that may exist in society, as well as favour the inclusion of people in education, provided that there is equality of opportunity [12].

However, Plaza-de la Hoz states that ICT should not be used merely as a support resource or as something exceptional, but rather, should be carried out during pedagogical practices aimed at creating a more sustainable model [13]. In ICT-mediated classroom students, when they search the World Wide Web, their analytical thinking skills can be developed because students get the opportunity to gain access to information which provides them with many different perspectives, but these must be used with other tools [14].

Digitisation provides access to an integrated big data network with potential benefits for society. The development of digital technologies can create unique opportunities for strategic solutions to problems related to the UN Sustainable Development Goals [15]. The study by ElMassah and Mohieldin [16] examines how digital transformation can impact localisation and the achievement of the Sustainable Development Goals (SDGs). Despite the positive effects and variety of applications of digital technologies [17], issues such as data scarcity, high power consumption of computing resources, ethical concerns, privacy, ownership, and security issues stand in the way of achieving the 17 SDGs. Hoosain, Paul and Ramakrishna [18] explores, through implementation case studies, how digital technologies are being used across sectors to enable understanding and addressing the framework agreed upon in 2015 by 193 countries, i.e., the 17 UN Sustainable Development Goals.

4. Research results

Based on the work by Sachs et al. [19] six transformations of the Sustainable Development Goals can be presented as modular building blocks for achieving them: education, gender and inequality; health, welfare and demography; decarbonization of energy and sustainable industry; sustainable food, land, water and oceans; sustainable cities and communities; and the digital revolution for sustainable development.

The first block includes three sets of interventions to promote education and gender equality and reduce inequality. First, countries must expand and transform education systems. Early childhood development accelerates children's cognitive and emotional development with lasting effects into adulthood but is underinvested in many countries, including high-income countries. General quality primary and secondary education is the basis of education systems. This requires improved teacher training, curriculum development, and ongoing assessment of learning outcomes. Vocational training, school-to-work programs and higher education are underdeveloped in most countries, even though they improve school-to-work transitions, increase lifetime earnings and reduce inequality. Finally,

to promote economic growth, most countries need to stimulate innovation and ensure the spread of research and development. The introduction of new technologies can be accelerated through higher education; national science funding mechanisms and scientific advisory bodies; innovation hubs [19].

Artificial intelligence [20] and other digital technologies require a comprehensive set of regulatory standards, physical infrastructure and digital systems to take advantage of the digital revolution to achieve the Sustainable Development Goals.

The implementation of this block consists of several sets of interventions. First, universal access to high-quality, low-cost mobile broadband. Second, measures to promote digital inclusion, skills, privacy and universal identity. Also, it is necessary to strengthen state institutions to manage and shape digital innovations in the direction of sustainable development. Therefore, it can be argued that the development of students' critical thinking is directly related to the implementation of the following sustainable development goals (presented in the form of blocks): education, gender and inequality; digital revolution for sustainable development.

Based on the studied sources and scientific investigations, the main stages of the formation of critical thinking were clarified in the research process. The stages of formation of students' critical thinking include the following sequence of actions: asking questions, perceiving new information, self-analysis, and communication.

The most successful techniques for the formation of critical thinking are: brainstorming, clusters, working in pairs, associations, etc. Using ICT capabilities, the teacher can involve students in creating blogs, web applications, presentations, playcasts, exhibitions, electronic libraries, etc. These forms of organizing work with the class can be used in the process of mastering any educational subject. For their successful use, it is necessary to rethink the content of the educational material. The teacher should approach thematic planning from a different point of view. New and interesting forms of working with students are the use of virtual and augmented reality (VR, AR) [21], and artificial intelligence (AI) [22]. It is difficult for teachers to do this when the mixed form of education or distance learning prevails [23].

Considering these factors, it will be more appropriate to form critical thinking with the use of digital technologies, as they are an integral part of conducting distance or blended learning. Digital technologies in the educational process contribute to the development of student independence, adaptation, increased student motivation, individualization, and comfort.

In the context of the specified stages of the formation of students' critical thinking with the use of digital tools, it is worth paying attention to the relationships and interactions between the teacher and students (figure 1).

Figure 1 highlights the following main positions:

1. The sequence of the teacher's actions for the development of students' critical thinking (stages).
2. Forms, methods and techniques of using ICT to work with students.
3. Digital means and tools allow the teacher to apply new forms of learning for the development of critical thinking.

All the mentioned positions are interconnected and allow us to follow the relationships and interactions of the teacher and students in the learning process. According to Rashid, it should be agreed that among the teacher's tasks are the following: encourage students to ask questions; teach students to evaluate information; teach students to analyse information; encourage students to think creatively; provide opportunities for reflection; teach students to communicate effectively [8].

It was found that critical thinking develops in the process of creating new content by students. Thanks to the creation of cartoons, web applications, blogs, animated videos, scrapbooks, presentations, libraries, exhibitions, and participation in competitions, students acquire new information and master digital technologies. Working on a joint educational project encourages participation in creative competitions. Learning material becomes more interesting because it is studied in more detail by a group of students with common interests. In this way, students can develop critical thinking.

For example, a teacher in a computer science class may not just teach material on the subject of information security, which is the subject of study in the 9th grade (Basics of Information Security).

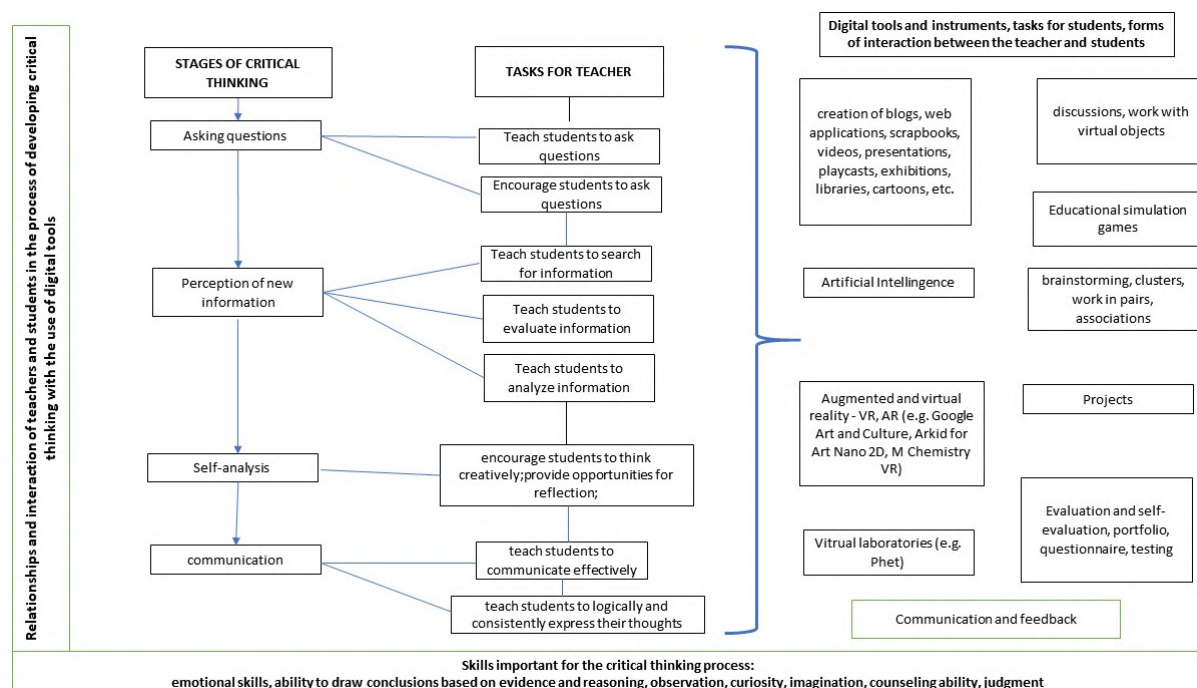


Figure 1: Relationships and interaction of teachers and students in the process of developing critical thinking with the use of digital tools.

Such a lesson can be built in such a way that it is an active activity of students, that it is an active discussion. It is important to stimulate discussion and teach students to express their point of view, to try to listen to others and to correctly treat the opposite point of view that does not coincide with their own. Together, in groups or micro-groups into which the class is divided, you should come to a common conclusion, or refute false theses, and false narratives, arguing it with concrete facts. Today, teachers are offered developed online materials that can be used to form critical thinking in an informatics lesson: the lesson is the game “Information Security” for the 9th grade [24]; online tests “Basics of information security” [25]; lesson notes and visual materials [26].

Artificial intelligence is a unique tool for the formation and development of critical thinking. How can a teacher use this in teaching? There are certain patterns of requests for AI services that students should be taught how to use correctly. It should be explained that from the way the request is formulated, it is possible to receive both completely reliable information and distorted or false information. AI does not always give a hundred per cent guarantee of the correct answer. Therefore, the teacher should explain to the students that they should be critical of the generation of answers by artificial intelligence. Among the practical tasks that stimulate students’ critical thinking, one can include, for example, questions related to how to recognize fake information. At the same time, the teacher encourages students to use digital resources. So, a computer science teacher can give examples of some services that store an archive of sites (for example, the Wayback Machine). If a page on a specific site has been deleted, this service helps to find the deleted page. This is useful if a particular news story has been published and then deleted. In this way, you can track the process of creating fake information. Google Images can be used to find the source of an image. This is useful to investigate, for example, when manipulating fake images. Students should be taught to be critical of anything they read on the Internet. It can be argued that the Google Image service is a kind of artificial intelligence service.

Critical thinking encourages students to respond to issues related to their position in society and community, in particular, democratic citizenship and human rights, sometimes in opposition to expectations of support and answers from teachers. This is important, because critical thinking helps learners to independently reflect on what are the signs of democratic citizenship, and also contributes to personal achievements and the ability to take responsibility for their actions and joint decisions

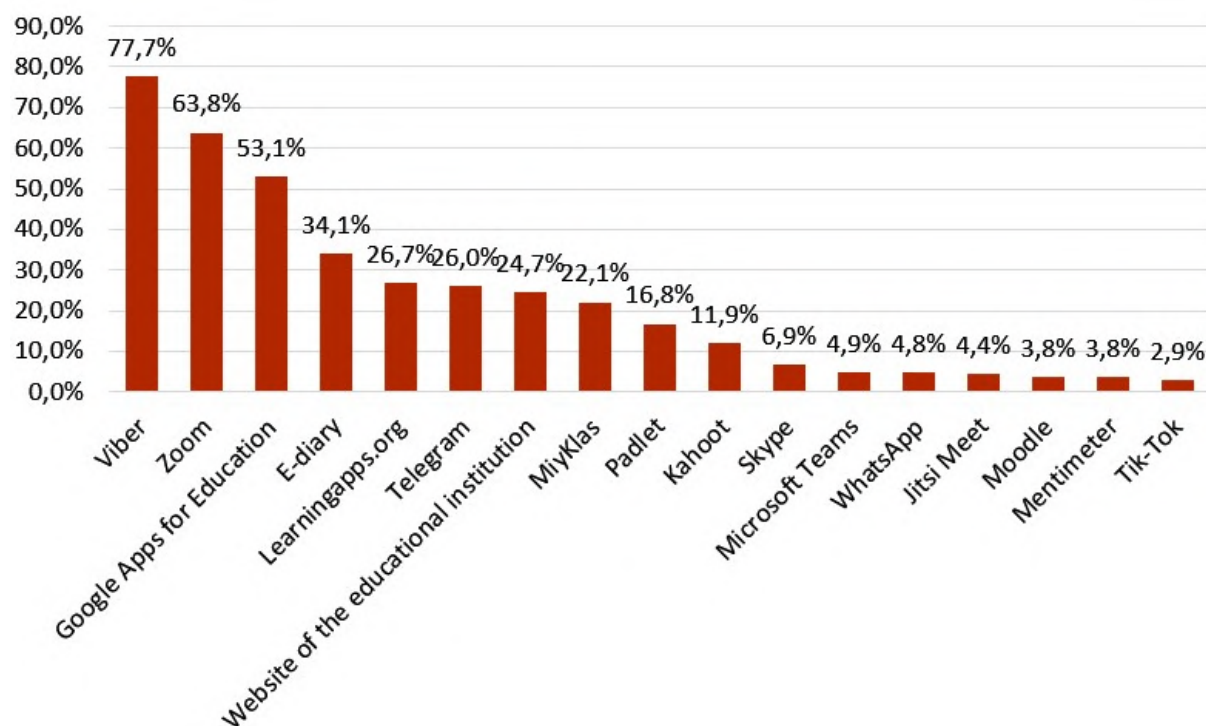


Figure 2: Digital instruments used by teachers for conducting online classes in 2023 [31].

[27]. This is important for students' understanding of social values, personal role in preserving the environment, development of impartial judgment skills and logical thinking in general.

Discussions, working in pairs, and brainstorming are unique incentives for forming the skills to draw conclusions and conduct their research, express opinions and defend students' positions, as well as generate ideas alone or in a group. Cowling states that these methods can be applied to teaching Mathematics, Science, Reading/Language Arts, and Social studies [28].

To find out the state of ICT use by teachers today, it is necessary to turn to current research that shows which tools and tools are most popular among teachers. In 2023, the Institute for Digitalization of Education of the National Academy of Educational Sciences of Ukraine conducted an all-Ukrainian survey "Readiness and needs of teachers regarding the use of digital tools and ICT in conditions of war: 2023". Regarding the type of Information and Communication Technology (ICT) used by teachers it was found that only a third of schools in Ukraine work full-time, at other institutions and, accordingly, teachers organize distance and mixed learning for their students [29]. The situation is further complicated by the fact that some of the institutions are located in the occupied territories, some of the educational infrastructure has been lost, and a certain number of teachers and children have left their places of permanent residence, that is, they are internally displaced persons (IDPs) or refugees. In the course of an all-Ukrainian survey conducted in 2023, it was found out that the following digital tools are mostly used by teachers to organize distance learning, as can be seen in figure 2: Viber – 78.4%; Zoom – 65.4%; Google Apps for Education – 53.1% (only 20.2% of respondents used this tool last year). Respondents use an electronic diary twice as much – 34.1% in 2023 compared to 15.4% in 2022. The percentage of Telegram users also doubled – 26% compared to 13.3% in 2022. Among other tools, respondents indicated the following: Learningapps.org – 26.7%; the website of the educational institution – 24.7%; MiiKlas – 22.1%; Padlet – 16.8%; Kahoot – 11.9%; Skype – 6.9%; Microsoft Teams – 4.9%; WhatsApp – 4.8%; JitsiMeet – 4.4%; Moodle – 3.8%; Mentimer – 3.8%. Less than 1% scored tools such as Twitter, Cisco Webex, Wordwall, Liveworksheets, Discord etc. [30].

Special attention during the survey of teachers was paid to their professional development. After all, teachers are changing traditional education in a variety of ways by taking advantage of technology, including increasing attention to distance education and its many uses in their classrooms and using it

as a way to address the inequality of participation and the digital divide in society. Therefore, during the survey, teachers were asked about the ways that they receive information about training on the use of digital tools and instruments in the classroom. Teachers were also asked which organisations primarily provide professional development for them (figure 3).

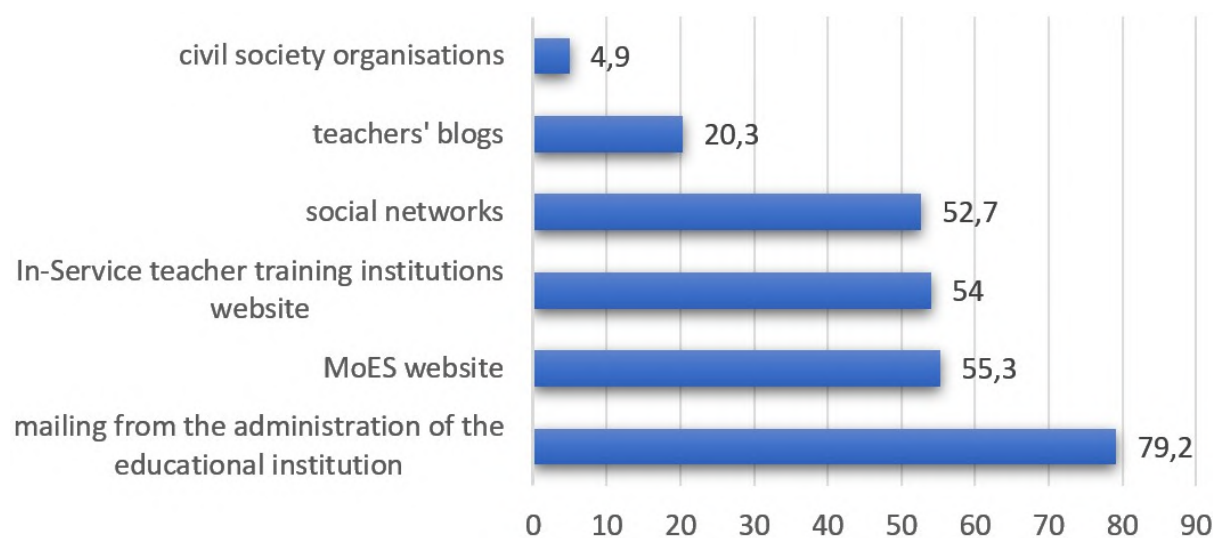


Figure 3: Teachers' answers on where they search for information about training on the ICT use for distance teaching (in %) [31].

First of all, Ukrainian teachers receive the main information from e-mails sent by the administration of their educational institutions (79.2%). 55.3% of teachers receive such information from the website of the Ministry of Education and Science of Ukraine, and only 54% receive information from professional development institutions (figure 3). This indicates the need to introduce more programs to study the possibilities of using ICT during lessons in such institutions and the existence of certain gaps today. A positive trend is that social networks have become a certain factor for sharing experiences regarding the use of digital tools by teachers, and this is evidenced by the results of the survey, which showed that 52.7% of teachers actively communicate on these topics.

5. Discussion

To compare the results we obtained during the teacher survey, we can refer to the study described by Lorente, Arrabal and Pulido-Montes [32]. The authors, based on the results of the Global Education Monitoring Report 2023, conduct a comparative study of the infrastructure, resources and real competencies of the teaching staff for the development of distance learning. Thus, the percentage of teachers with effective professional resources to learn to use digital devices was 75–95% in most countries in Central and East Asia, as well as in the United States, Canada, Norway, Denmark, Estonia, Lithuania, Austria, the Czech Republic, Slovakia, Bulgaria and the United Arab Emirates. The rest of the European countries, along with Chile, Panama, French Guiana and the Dominican Republic, achieved figures in the range of 55–75%. Countries below this range included Germany, Portugal, Ireland and the rest of the Latin American and Caribbean region, showing values between 35–55%.

As noted in the “Global Education Monitoring Report 2023: Technology in Education: a Tool on Whose Terms?” technology influences teacher training and is used to create flexible learning environments, engage teachers in collaborative learning, facilitate coaching and mentoring, develop reflective practice, and improve thematic or pedagogical knowledge. Distance education programs contribute to the improvement of the level of teacher training: virtual communities appear, mainly based on social networks, for the exchange of information and resources. About 80% of Caribbean teachers surveyed were in professional WhatsApp groups and 44% used instant messaging to collaborate at least once a week [33].

The results of the teachers' survey conducted in Ukraine also revealed several problems that arose during the war, including power outages and the lack of Internet access, students' unstable access to computers and the lack of necessary tools, psychological problems and other issues that need to be solved. The difficult conditions in which schools and teachers find themselves affect the full-fledged educational process. It is these conditions that encourage society and teachers to develop the critical thinking of their students, to develop the ability to independently study and research processes, defend their own opinions and develop civic qualities. It became obvious that the state and educational authorities should provide comprehensive support to teachers and students, implement policies aimed at sustainable development of education, and provide quality educational services.

6. Conclusions

The Sustainable Development Goals require profound transformations in every country, which will require additional actions by governments, civil society, science and business. For convenience, all the Sustainable Development Goals have been grouped into six blocks for achieving them: education, gender and inequality; health, welfare and demography; decarbonization of energy and sustainable industry; sustainable food, land, water and oceans; sustainable cities and communities; and the digital revolution for sustainable development. This study partially solves the problems of blocks: education, gender and inequality; and the digital revolution for sustainable development. The use of digital tools by teachers and the development of critical thinking in students is related to these two blocks.

The issue of supporting teachers in the use of digital means and tools for conducting lessons is extremely relevant. This is evidenced by the research results shown. Having analyzed the problem of the use of ICT by teachers to ensure the sustainability of quality education and the development of critical thinking, it is necessary to single out certain considerations and suggestions that may be useful at the current stage. The Ukrainian school entered the second phase of the implementation of the "New Ukrainian School" reform. This means that today the content of school programs is being updated and the transition to new textbooks, new online learning resources and new, active learning methods is taking place. Among the priorities of the reform is the development of soft skills, including critical thinking, as the main component of such skills. The national report on the results of the international study PISA-2022 showed disappointing results. For example, there are differences between schools observed in Ukraine, reflecting the gap between educational institutions located in large cities and towns and rural areas, as well as between different types of educational institutions; in many regions, educational opportunities remain unevenly distributed and depend on where students live. The educational environment and resources of educational institutions in urban and rural areas differ, which affects the success of students who live in different types of settlements and study in educational institutions with different educational programs [34].

Based on the mentioned above, attention should be paid to the opportunities of digital tools for learning. All teachers should receive appropriate training in the use of appropriate ICT. Professional development programs should include courses on training teachers of various subjects to use digital tools, teachers should be consulted at their request, individually, according to the needs of the school. Some work should be done with parents of students so that parents provide support for their children to access distance learning, and motivate them in the difficult conditions of war in Ukraine. Psychological support for teachers and students should be provided continuously, remotely and informally by various educational institutions, regardless of the level and location of the school. For this, tutors should be trained to work on the specified issues at the school level.

Critical thinking as a component of soft skills should be included in all teacher professional development programs, taking into account mandatory training in the forms and methods of using digital means and tools for the formation of students' critical thinking. The issue of monitoring the practice of teachers to form critical thinking using ICT tools, the creation of online networks for sharing positive experiences, the development of special professional development programs on these issues and the involvement of teachers require further research.

Declaration on Generative AI: The authors have not employed any Generative AI tools.

References

- [1] O. Barsukova, The Ministry of Education and Science told how many schools and kindergartens work full-time or remotely, 2023. URL: <https://life.pravda.com.ua/society/2023/02/16/252883/>.
- [2] V. Tkachuk, Y. Yechkalo, S. Semerikov, M. Kislova, Y. Hladyr, Using Mobile ICT for Online Learning During COVID-19 Lockdown, in: A. Bollin, V. Ermolayev, H. C. Mayr, M. Nikitchenko, A. Spivakovsky, M. Tkachuk, V. Yakovyna, G. Zholtkevych (Eds.), *Information and Communication Technologies in Education, Research, and Industrial Applications. ICTERI 2020*, volume 1308 of *Communications in Computer and Information Science*, Springer International Publishing, Cham, 2021, pp. 46–67. doi:10.1007/978-3-030-77592-6_3.
- [3] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, V. N. Soloviev, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, V. R. Ruban, Mask and Emotion: Computer Vision in the Age of COVID-19, in: *Digital Humanities Workshop, DHW 2021*, Association for Computing Machinery, New York, NY, USA, 2022, p. 103–124. doi:10.1145/3526242.3526263.
- [4] I. Clifford, S. Kluzer, S. Troia, M. Jakobson, U. Zandbergs, *DigCompSat: A Self-reflection Tool for the European Digital Competence Framework for Citizens*, Publications Office of the European Union, Luxembourg, 2020. doi:10.2760/77437.
- [5] D. Cole, T. DeLecce, G. Pisano, *Critical Thinking | Definition, Origins & Examples*, 2023. URL: <https://study.com/academy/lesson/what-is-critical-thinking-definition-skills-meaning.html>.
- [6] J. Koebele, *The 30 Most Influential Cognitive Psychologists Alive Today*, 2014. URL: <https://web.archive.org/web/20141110164845/https://www.onlinepsychologydegree.info/30-most-influential-cognitive-psychologists-alive-today/>.
- [7] M. Castells, R. Flecha, P. Freire, H. A. Giroux, D. Macedo, P. McLaren, P. Willis, *Critical Education in the New Information Age*, Rowman & Littlefield Publishers, 1999.
- [8] H. A. Rashid, *Role of Critical Thinking in Education*, 2023. URL: <https://limbd.org/role-of-critical-thinking-in-education/>.
- [9] S. Terno, *Critical thinking and innovative strategies in history education: a guide for higher education master's degree holders of the educational and professional program Secondary Education (History)*, ZNU, Zaporizhzhia, 2023. URL: <https://dspace.znu.edu.ua/jspui/handle/12345/13540>.
- [10] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, V. N. Soloviev, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, D. S. Shepiliev, *Immersive E-Learning Resources: Design Methods*, in: *Digital Humanities Workshop, DHW 2021*, Association for Computing Machinery, New York, NY, USA, 2022, p. 37–47. URL: <https://doi.org/10.1145/3526242.3526264>. doi:10.1145/3526242.3526264.
- [11] L. Mynaříková, L. Novotný, *The Current Challenges of Further Education in ICT with the Example of the Czech Republic*, *Sustainability* 13 (2021) 4106. doi:10.3390/su13084106.
- [12] M. Castells, *Information Technology, Globalization and Social Development*, Discussion Paper 114, UNRISD, Geneva, 1999. URL: <https://cdn.unrisd.org/assets/library/papers/pdf-files/dp114.pdf>.
- [13] J. Plaza-de la Hoz, *Cómo mejorar el papel de las TIC para promover una educación empoderadora en el desarrollo sostenible*, *Aloma: revista de psicología, ciencias de l'educació i de l'esport Blanquerna* 36 (1) 43–55. doi:10.51698/aloma.2018.36.2.43-55.
- [14] D. K. Chan, *The Role of ICT in a Constructivist Approach To the Teaching of Thinking Skills*, 2002. URL: <http://static1.1.sqspcdn.com/static/f/1751776/20693267/1350729059353/ICT-in-Constructivist-Teaching-of-Thinking-Skills.pdf?token=N5LzkUb5th/85%2BPaCEGYNhwEVX0%3D>.
- [15] M. E. Mondejar, R. Avtar, H. L. B. Diaz, R. K. Dubey, J. Esteban, A. Gómez-Morales, B. Hallam, N. T. Mbungu, C. C. Okolo, K. A. Prasad, Q. She, S. Garcia-Segura, *Digitalization to achieve sustainable development goals: Steps towards a Smart Green Planet*, *Science of The Total Environment* 794 (2021) 148539. doi:10.1016/j.scitotenv.2021.148539.

- [16] S. ElMassah, M. Mohieldin, Digital transformation and localizing the Sustainable Development Goals (SDGs), *Ecological Economics* 169 (2020) 106490. doi:10.1016/j.ecolecon.2019.106490.
- [17] N. Bachmann, S. Tripathi, M. Brunner, H. Jodlbauer, The Contribution of Data-Driven Technologies in Achieving the Sustainable Development Goals, *Sustainability* 14 (2022) 2497. doi:10.3390/su14052497.
- [18] M. S. Hoosain, B. S. Paul, S. Ramakrishna, The Impact of 4IR Digital Technologies and Circular Thinking on the United Nations Sustainable Development Goals, *Sustainability* 12 (2020) 10143. doi:10.3390/su122310143.
- [19] J. Sachs, G. Schmidt-Traub, M. Mazzucato, D. Messner, N. Nakicenovic, J. Rockström, Six Transformations to achieve the Sustainable Development Goals, *Nature Sustainability* 2 (2019) 805–814. doi:10.1038/s41893-019-0352-9.
- [20] M. V. Marienko, S. O. Semerikov, O. M. Markova, Artificial intelligence literacy in secondary education: methodological approaches and challenges, *CEUR Workshop Proceedings* 3679 (2024) 87–97.
- [21] S. O. Semerikov, M. M. Mintii, I. S. Mintii, Review of the course “Development of Virtual and Augmented Reality Software” for STEM teachers: Implementation results and improvement potentials, *CEUR Workshop Proceedings* 2898 (2021) 159–177.
- [22] I. Mintii, S. Semerikov, Optimizing Teacher Training and Retraining for the Age of AI-Powered Personalized Learning: A Bibliometric Analysis, in: E. Faure, Y. Tryus, T. Vartiainen, O. Danchenko, M. Bondarenko, C. Bazilo, G. Zaspá (Eds.), *Information Technology for Education, Science, and Technics*, volume 222 of *Lecture Notes on Data Engineering and Communications Technologies*, Springer Nature Switzerland, Cham, 2024, pp. 339–357. doi:10.1007/978-3-031-71804-5_23.
- [23] I. S. Mintii, T. A. Vakaliuk, S. M. Ivanova, O. A. Chernysh, S. M. Hryshchenko, S. O. Semerikov, Current state and prospects of distance learning development in Ukraine, *CEUR Workshop Proceedings* 2898 (2021) 41–55.
- [24] N. S. Levytska, Lesson-game “Information safety” for 9th Grade, 2022. URL: <https://vseosvita.ua/library/urok-gra-informacijna-bezpeka-512980.html>.
- [25] O. O. Nepotachova, Basics of information security, 2020. URL: <https://naurok.com.ua/test/osnovi-informaciyno-bezpeki-210265.html>.
- [26] M. Naumov, Urok informatyky - informatsiina bezpeka, 2024. URL: <http://surl.li/ofncd>.
- [27] O. V. Ovcharuk, Theory and practice of education for democratic citizenship in the member states of the Council of Europe, Phoenix Publishing House, Kyiv, 2021. URL: <https://lib.iitta.gov.ua/id/eprint/727361/>.
- [28] T. K. Cowling, How to Use the Think-Pair-Share Activity in Your Classroom, 2017. URL: <https://tinyurl.com/4cxcpf5x>.
- [29] Ministry of Education and Science of Ukraine, Secondary education, 2024. URL: <https://mon.gov.ua/ua/tag/zagalna-serednya-osvita>.
- [30] O. V. Ovcharuk, Monitoring the readiness of teachers to use digital tools during the war in Ukraine, *Information Technologies and Learning Tools* 98 (2023) 52–65. doi:10.33407/itlt.v98i6.5478.
- [31] O. V. Ovcharuk, I. V. Ivaniuk, O. O. Hrytsenchuk, I. D. Malyska, O. Y. Kravchyna, Results of the online survey “Readiness and needs of teachers for the use of digital tools and ICT in the context of war: 2023”, Analytical report, Institute for Digitalisation of Education of the NAES of Ukraine, Kyiv, Ukraine, 2023. URL: <https://lib.iitta.gov.ua/id/eprint/736435/>.
- [32] L. M. L. Lorente, A. A. Arrabal, C. Pulido-Montes, The Right to Education and ICT during COVID-19: An International Perspective, *Sustainability* 12 (2020) 9091. doi:10.3390/su12219091.
- [33] Global Education Monitoring Report Team, Global education monitoring report, 2023: technology in education: a tool on whose terms?, UNESCO, Paris, 2023. doi:10.54676/UZQV8501.
- [34] National report on the results of the international study of the quality of education PISA-2022, Technical Report, Ukrainian Center for Evaluation of the Quality of Education, Kyiv, 2023. URL: https://pisa.testportal.gov.ua/wp-content/uploads/2023/12/PISA-2022_Naczionalnyj-zvit_povnyj.pdf.