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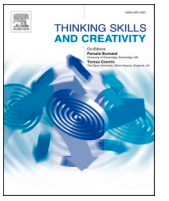

Digital education tools for critical thinking development

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ABSTRACT

The proliferation of digital technologies sometimes referred to as the 'industrial or technological (digital) revolution' primarily affects the education sphere. The introduction of online learning technologies and the focus on independent and critical thinking actualizes the problem of developing these skills in future teachers and lawyers with the help of digital tools. The study looked at the critical thinking development in education while focusing on the use of digital tools in rational thinking formation in education. The research involved a random sample of undergraduate pedagogy students from [BLINDED] Institute of [BLINDED] University and graduate law students from [BLINDED] Institute. The digital tools were used to develop test tasks and logic problems, present information in graphical form, brainstorm, and collaborate in real-time to solve the created problems. The level of critical thinking development was assessed in dynamics using the method designed by Mishina based on the research Diane Halpern, Igor Zageshev, and Sergei Zair-Beck. The outcomes confirm the original hypothesis about the positive impact of digital tools on the formation of critical thinking in students.

1. Introduction

The primary human activity in the modern post-industrial society is working with information. It is becoming the main resource of world community development and has a significant influence on the progress in all sectors and spheres of life, primarily social communication, culture, science, and education (Pegov & Pyanikh, 2010). The key competencies that determine the level of societal development include independent thinking and the ability to critically access information. These abilities are important objectives of education, as they allow one to find reasoned solutions to specific professional problems (Pegov & Pyanikh, 2010).

Qualitative changes in the production sphere and global markets associated with the development and spread of digital technologies (the new industrial or technological (digital) revolution) are primarily reflected in education, which is becoming increasingly individualized and focused on the quality of knowledge and holistic development of each person (Uvarov & Frumin, 2019) Multimedia and communication technologies are the means of implementing modern active teaching methods aimed at the development of independence and critical thinking (Pegov & Pyanikh, 2010). The importance of these abilities has become even more relevant because of the forced and sudden mass transition to distance forms of education due to quarantine restrictions imposed during the COVID-19 pandemic. If previously the process of introducing digital tools into education was gradual and uneven, the pandemic became a catalyst for truly revolutionary changes and the formation of a new educational paradigm with the priority of information and

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communication technologies. However, in order to develop key competencies in schoolchildren and students, teachers themselves must master them. That is why the problem of developing critical thinking in future teachers and lawyers with digital tools is relevant. The purpose of the study was to explore the possibilities and effectiveness of digital tools for the development of critical thinking in education. The research objectives were to (1) review the scientific literature on critical thinking as a key competence and the use of digital tools in the education process; (2) conduct a formative experiment aimed at developing critical thinking of future teachers and lawyers using digital tools and evaluate its effectiveness. The research hypothesis suggests that the use of digital tools contributes to the formation of students' critical thinking skills.

1.1. Literature review

Informatization of society is a social and historical process in which the dominant activity is the collection, accumulation, production, processing, transmission, and the use of information. The spread of electronic communication technologies highlights the importance of competence, the ability to think independently, acquire knowledge and more importantly apply it to solve specific problems (Pegov & Pyanikh, 2010). Education is seen as a consumer and producer of information. The ability of students to understand, apply, analyze, synthesize, evaluate information defines the concept of critical thinking (Pegov & Pyanikh, 2010). The priority of informatization of education involves the use of digital tools for the development of critical thinking through active learning methods, such as discussions, brainstorming, project-based learning, trainings, business games and case studies (Pegov & Pyanikh, 2010).

Russia's strategies for socioeconomic development until 2024 and a corresponding vision to 2035 set a course towards digital economy, where digital education plays a crucial role. (Uvarov & Frumin, 2019). The task of digital transformation is entrusted to all participants in the educational process, but the agents of its progressive change are mainly teachers and lawyers, the formation of critical thinking and other key competencies for which is the primary task of scientific and methodological support (Uvarov & Frumin, 2019).

Various digital tools and services can be used in the modern education process. These are designed to prepare teaching and learning materials, create tests, record audio, video, and animation clips, create graphics, maintain web portfolios, organize collaborative online work on projects or web quests, and more (Panyukova, 2020). But integrating digital technology into education is not an easy task. One significant problem is the lack of digital tools knowledge among educators, who are unable to provide the necessary technical assistance to their students (Viberg, Grönlund & Andersson, 2020). Therefore, the question of how to equip teachers with the necessary knowledge and skills in the digital age is becoming more and more relevant. One promising direction is to integrate a learning management system with a personal learning environment to train teachers and lawyers (Xu, Chan & Yilin, 2020).

Another significant problem is students' inability to analyze or summarize the information provided online, and that requires critical thinking (Jou, Lin & Wu, 2016). Given the importance of knowledge management, in recent years, the development of web-based applications that can serve as an effective teaching and critical thinking tools has been actively pursued (Jou et al., 2016). Critical thinking skills and motivation to learn are known to be improved with the help of a digital role-playing game developed with RPG Maker. The game includes storylines that focus on critical thinking issues (Chen & Wu, 2021). Digital tools are also increasingly used in online communication to bring students from different countries together to learn a new language or new skills through a virtual exchange (Rets, Rienties & Lewis, 2020). Efforts are underway to improve the design of online courses (Hrastinski, 2021). A progressive approach to teaching involving flowcharts has been used to develop students' computational and critical thinking skills, foster independent problem-solving abilities, and improve students' self-efficacy and performance (Zhang, Meng, Zou, Zhu & Hwang, 2021). Critical thinking, digital literacy, and technical skills are the most sought-after learning outcomes today. Researchers also emphasize the importance of practical training focused on critical thinking and navigation of the digital media environment (Vetter, Sarraf & Woods, 2020) Pacholek et al. (2021). positively assessed WhatsApp as an effective platform to support critical thinking and apply it in professional practice. However, one of the main goals of diverse education systems is to develop key competencies and enhance one's capacity for lifelong learning (Garcia-Esteban, Villarreal & Bueno-Alastuey, 2021). To address the challenge of creative and critical thinking development, a mobile approach with progressive peer feedback is proposed, which promotes students' creative thinking, metacognitive awareness, and cognition (Lee, Lin, Hwang, Fu & Tseng, 2021).

The development of information and communication technology has led to truly revolutionary changes, new realities of the global digital world, and new education technologies based on innovative ideas, critical thinking, effective communication, and productive collaboration (Feng & Wang, 2021; Makhambetova, Zhiyenbayeva & Ergesheva, 2021). The use of digital tools helps students develop their abilities of realistic goal-setting, self-control, self-reflection, self-awareness, and collaboration (Saadati, Zeki & Vatankhah Barenji, 2021). Therefore, there is a need to develop effective online courses or programs that foster critical thinking as a key competence in higher education (Varenina, Vecherinina, Shchedrina, Valiev & Islamov, 2021). It is necessary to either restructure subject curricula or create extracurricular spaces in which critical thinking can be intentionally encouraged (Piedade, Malafaia, Neves, Loff & Menezes, 2020). The importance of building competence in critical thinking, reflection, and self-reflection is growing due to the constant increase in complexity of knowledge the amount of which also grows, raising higher demands on teacher training. The method of reflective dialog is proposed to create a highly effective collaborative learning space for future teachers and those who educate them through digital tools (Kazhikenova, Zhumataeva, Kozhamzharova & Aubakirova, 2021). Creativity workshops are dedicated to make teachers more creative (Zhou, 2021). Some authors study the potential of social networks and other digital tools to improve innovative, creative, and critical thinking of students in class. It is argued that learning on Facebook has a tremendous impact on the development of communication and collaboration skills, creativity, critical thinking, digital literacy, and independence, while at the same time contributing to the intellectual foundation for developing innovative solutions and creative improvisations within

certain topics (Berestova, Ermakov, Aitbayeva, Gromov & Vanina, 2021).

2. Materials and methods

2.1. Research design

The research design relies on a stepwise approach. At the first stage, researchers defined the object, subject, goals, and objectives of the study and formulated a hypothesis. The authors reviewed the body of literature on critical thinking development and the use of modern digital technologies in this process. The analysis showed the important role of digital literacy, critical thinking, and other key competencies of future teachers and lawyers in ensuring the effectiveness of the education process, meeting the educational needs of modern students, and providing quality knowledge and skills for its practical application. The second stage involved identifying digital tools and ways to use them when instilling critical thinking in future teachers. For this, a random sample of respondents was selected from the population of undergraduate students in the [BLINDED] Institute of [BLINDED] University and graduate law students in the [BLINDED] Institute. The third stage was a formative experiment on critical thinking development in students with the aid of digital tools. The results were statistically processed, analyzed, and discussed. The final stage of the study involved summarizing the conclusions and determining the prospects for further work. The research was conducted between February and May 2021.

2.2. Sample

The random sample of respondents involves 82 undergraduate students (45 female and 37 male; average age: 19) in the [BLINDED] Institute of [BLINDED] University (group A) and 74 graduate students (38 female and 36 male; average age: 22) in the [BLINDED] University (group B). The students were enrolled in pedagogical and law programs.

The study used two digital tools:

- Online Test Pad (2021), a free, versatile, and simple constructor that allows creating various tests, tasks, logic games, dialogues, crosswords, collecting, and systematizing information (Panyukova, 2020).
- Mindmeister (2021), a website that allows for real-time collaboration in the form of brainstorming, presenting information graphically, sharing mental maps with other team members, visualizing ideas to see the big picture of the issue.

2.3. Methodology for critical thinking development

Methodology for critical thinking development relies on a project-based approach, which combines theory and practice. The project-based method facilitates the development of student's cognitive skills, critical thinking, and their ability to independently construct knowledge and navigate the information space (Pegov & Pyanikh, 2010). Mindmeister and Online Test Pad tools help understand the problem in question and search for the optimal solution algorithm by brainstorming and working with mental maps. Critical thinking exercises revolved around the independent construction of test problems and logical tasks by students. Critical thinking lessons were held online, outside of class, using the same digital tools and problem tasks. Both groups were enrolled in critical thinking lessons simultaneously.

2.4. Psychodiagnostic methods of critical thinking assessment

The level of critical thinking development was assessed using the method designed by Mishina (2018) based on research by Diane Halpern, Igor Zageshev, and Sergei Zair-Beck. In the course of the experiment, the students were asked to solve as many tasks designed to evaluate their critical thinking as possible within 40 min. The technique developed by Mishina consists of three components: affective (evaluating students' perceptions of critical thinking and understanding of its value), cognitive (performing tasks with a high degree of uncertainty), and reflexive (self-assessment). The cognitive component has 17 tasks (verbal and drawing tests) the solution of which requires logical thinking, ingenuity, non-standard approach, and critical approach. They allow one to evaluate logical skills, the ability to determine regularities and avoid stereotypes, and the capacity to specify the implicit conditions of the task and justify one's position. These tasks aim to assess different macro-skills and micro-skills of critical thinking. An example is the ability to distinguish meaningful similarities and differences, check or evaluate assumptions, and distinguish relevant and irrelevant factors. The tasks also help students to learn how to draw valid conclusions, make predictions (preliminary evaluations) or suggest interpretations. The students can better recognize contradictions and analyze explicit and implicit premises and consequences. They develop skills of comparing similar situations (transferring understanding to a new context), generating or evaluating solutions, and critical reading (clarifying or parsing texts). The tasks can be nominally subdivided into the following types: searching for regularities, checking the truth of the conclusion, finding a non-standard solution, and constructing assumptions from premises (Mishina, 2018).

Each task had a different complexity coefficient assigned. The most difficult tasks (complexity coefficient 3) were tasks No. 1. 9, 12, 14, 16; medium difficulty tasks (complexity coefficient 2) were No. 4, 10, 11, 13, 15, 17; the easiest tasks (complexity coefficient 1) were No. 2, 3, 5, 6, 7, 8. The total score was the sum of all solved tasks multiplied by the corresponding complexity coefficient. The formula is given below:

X=nE x 1 + nM x 2 + nH x 3, where X is the total score, nE is the number of simple problems that were solved, nM is the number of problems with the medium level of complexity that were solved, nH is the number of complex problems that were solved (Mishina,

2018).

The test started with a 5-minute instruction explaining the purpose and the course of the experiment. The next 15 min were dedicated to interview, and then the students spent 40 min independently solving the problems. Respondents were assigned three levels of critical thinking according to their total score: high (15–30 points), medium (10–14 points), and low (4–9 points).

2.5. Statistical data processing

Statistical data processing was performed using the online calculator on medstatistic.ru. The unpaired and paired Student's t-tests were used to compare the baseline data and results of the experiment. The outcomes of statistical analysis allowed testing the hypotheses about the equality of general means in cases where a variable follows normal distribution in each group and variances are equal in both groups (Grzybowski, 2008).

2.6. Limitations

The limitations of the study are associated with methodology constrains (only two out of many digital tools have been involved) and a small sample size. Nevertheless, the results can be considered representative at least for the digital tools chosen, as the students represent two different universities from different regions with different approaches to teaching. Furthermore, they are enrolled in different fields of study and different programs (undergraduate and graduate). They also belong to different age groups (19-years-olds and 22-years-olds). The study follows the ethical principles of voluntary participation, anonymity, and informed consent.

3. Results

The project-based method refers to a joint activity of a teacher and a student aimed at finding a solution to an arising problem. It is one of the most advanced learning approaches, as it promotes the ability to adapt to the rapidly changing environment in a post-industrial society (Pegov & Pyanikh, 2010). The project-based method allows one to structure the acquired knowledge and develop the skills for its practical application, which contributes to the development of critical thinking. The creation of tests and logical tasks helps to consolidate and improve the key necessary competencies.

The authors assessed the level of critical thinking in two groups of pedagogical students – group A (undergraduate students) and group B (graduate students) before and after the digitally enabled experiment (critical thinking lessons), respectively. The baseline levels of critical thinking in respondents are presented in Table 1.

As can be seen from this table, initially the majority of undergraduate students (45.1%) had an average level of critical thinking. In addition, a significant number of undergraduate students studied (23.2%) had insufficient levels of critical thinking. Despite the fact that the curricula are focused on the development of critical thinking as a key competence, its initial indicators among master's students were also predominantly of an average level (in 42.3% of cases), and in 16.2% of master's students the level of critical thinking remained low.

The following Table 2 compares the change of the critical thinking level of the students at [BLINDED] Institute of [BLINDED] University before (A) and after (A1) lessons Table 3. shows the dynamics of the critical thinking level of students at [BLINDED] University before (B) and after (B1) classes.

The indicators presented in this table indicate that the classes conducted contributed to a significant increase in the critical thinking of undergraduate students, with a predominance of a high level of development of critical thinking (46.3%) and a decrease in cases of low level from 23.2% to 13.5%.

As can be seen from this table, in this group of respondents, the level of critical thinking after the classes increased even more significantly than that of undergraduate students, with a predominance of high indicators (in 55.4% of cases) and a significant decrease in the number of low ones (from 16.2% to 6.8%), with a statistically significant difference between the data of the initial and repeated studies ($p < 0.05$).

For greater clarity, the change of the pedagogy students' critical thinking levels before and after the experiment is graphically presented in Fig. 1.

This figure shows a significant increase in the number of students with a high level of critical thinking after the experiment. Correspondingly, there is a decrease in the number of students with a medium, and more significantly, with a low level of critical thinking, which proves the effectiveness of digital tools in critical thinking development as a key competence a future teacher should possess.

Table 1
Baseline levels of critical thinking in undergraduate (A) and graduate (B) students.

Level of critical thinking	A		B		Student *t*-test	P
	n	%	n	%		
High	26	31.7	27	36.5	4.24	<0.05
Medium	37	45.1	35	42.3	19.80	<0.05
Low	19	23.2	12	16.2	49.50	<0.05
Total	82	100	74	100		

Table 2
Critical thinking levels in undergraduate students before (A) and after (A1) classes in improving the skill.

Level of critical thinking	A		A1		Student *t*-test	P
	n	%	n	%		
High	26	31.7	38	46.3	5.112	<0.05
Medium	37	45.1	33	40.2		
Low	19	23.2	11	13.5		
Total	82	100	82	100		

Table 3
Critical thinking levels in graduate students before (B) and after (B1) classes in improving the skill.

Level of critical thinking	B		B1		Student *t*-test	P
	n	%	n	%		
High	27	36.5	41	55.4	5.38	<0.05
Medium	35	42.3	28	37.8		
Low	12	16.2	5	6.8		
Total	74	100	74	100		

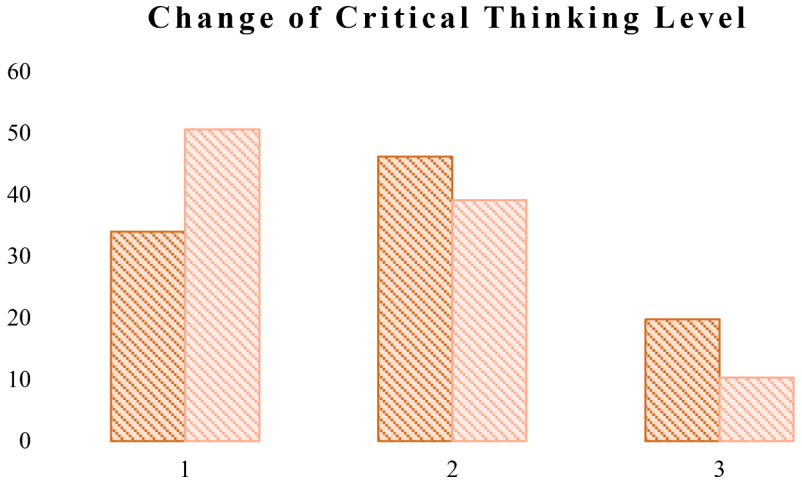

Fig. 1. The change in critical thinking level among pedagogy students: column 1 - baseline levels, column 2 - levels after the experiment; 1 - high level, 2 - medium level, 3 - low level.

4. Discussion

The course towards the digital economy, in which digital education plays a key role, is considered as the basis for qualitative changes in production and in world markets aimed at automation and robotization (intellectualization) of all types of production processes (Uvarov & Frumin, 2019). The informatization of society sets the task for education, as a consumer and producer of information, not only to transfer knowledge, but also to develop students' ability to understand, apply, analyze, synthesize, evaluate and navigate the information flow, which is an indicator of critical thinking (Pegov & Pyanikh, 2010). Supporting digital transformation processes should also focus on the development of critical thinking and include innovative education models using digital resources, tools and services (Uvarov & Frumin, 2019). Critical thinking is defined as a system of judgment used to analyze things and events with the formulation of valid conclusions that allows one to make valid assessments, interpretations, and apply the obtained results to different situations and problems (Ennis, 2015). Critical thinking allows a person to question and subsequently analyze both information coming from the outside and his or her own beliefs. The digitalization of modern society makes critical thinking a necessary quality, helping a person to navigate the increasing flow of diverse information and allowing him or her to adapt to the socioeconomic processes of the digital revolution.

The rapid pace of technological progress requires new approaches to the organization of education. The continuous improvement of cultural information tools created with the help of digital technologies is a response to the increasing complexity of the social and industrial environment. For example, mobile applications that run on any digital device, including smartphones, and emerging cultural information tools (Uvarov & Frumin, 2019). In the modern educational process, digital tools (packages, shells, systems, complexes, environments, platforms) allow you to create educational resources without the use of programming languages, which makes the learning process interesting and exciting (Panyukova, 2020).

A sudden universal transition to online learning due to quarantine restrictions caused by the COVID-19 pandemic proved to be the most powerful stimulus for the transformation of the educational paradigm based on information and communication technologies. The appropriately trained teaching staff is needed to build a new educational system aimed at individualization of learning, development of student's needs and ability to learn independently and acquire both theoretical knowledge and practical skills, formation of creativity and critical key competences. In order to develop students' critical thinking, teachers themselves must have a high enough competency in it. Modern educational technologies aim to translate the most effective traditional methods of developing key competencies into an online format by providing teachers with reliable and convenient digital tools. The core idea of digital transformation of education is to achieve the necessary learning outcomes and move towards personalization of the education process through the use of digital technologies, which are considered as a variety of cultural tools in the information sphere and are both new elements of educational content and a means of changing its organization (Uvarov & Frumin, 2019).

Digital tools have many benefits. First, they help visualize ideas and make it easier to communicate them to others. Second, they create a space for the exchange of complex information while working together, while at the same time allowing the use of separate personal workplaces. Finally, it is a platform for visual organization of causal relationships between complex ideas or events and the ability to comment on posted information and ask audience questions in real time (Panyukova, 2020; Zhiyenbayeva, Belyanova, Petunina, Dmitrichenkova & Dolzhich, 2021). To solve the problem of developing critical thinking in future teachers, the authors chose two digital tools most relevant to the design of our study out of the many digital tools that exist today. Some of the criteria for choosing these digital tools were accessibility, simplicity in use, and the ability to create the necessary educational resources without special knowledge of programming languages. In addition, these digital tools allow for the development of teaching, testing, modeling, and demonstration programs at a fast pace (Panyukova, 2020). The Online Test Pad was used so that students could independently construct test tasks and logic problems, which allowed them to consolidate the acquired knowledge, train their practical application skills, and stimulate the development of critical thinking. The Mindmeister digital tool (Panyukova, 2020) was used for teamwork in real-time brainstorming. The graphic representation of information in the form of mental maps allowed the participants to see changes, comment and discuss ideas instantly.

The respondents' level of critical thinking was determined twice: at the beginning of the study and after the learning sessions using the project-based method and digital tools. In the primary study, most students (46.2%) had an average level of critical thinking. The percentage of graduate students who showed a high level of critical thinking (36.5%) was statistically significantly higher than that of undergraduate students (31.7%). This result could be explained by the gradual development of critical thinking level while studying at the university. Therefore, master students as senior students have more developed critical thinking skills compared to undergraduate, or junior, students. The specifics of teaching at different universities, such as the international learning environment at [BLINDED] University, may also be of importance. However, it should be noted that in general, the baseline level of critical thinking was quite high in both groups of respondents (4/5 students had high and medium levels of critical thinking), which indicates that the education process already focuses on critical thinking development. Moreover, depending on the educational objectives, both universities may choose from a variety of digital tools. The use of such tools has increased significantly due to COVID-19-induced digital transition. [BLINDED] University is actively using the capabilities of digital education technologies to teach students foreign languages and other special disciplines. In contrast to the routine education process, this research relied on intensive online lessons to develop critical thinking with the help of the project-based method. The lessons were simultaneously attended by both groups of respondents in real-time (in addition to the ordinary class schedule) and used two specific digital tools, the main criteria of which were simplicity and compliance with the goals and objectives of the study.

After the practical exercises designed to develop critical thinking with digital tools, there was a statistically significant ($p < 0.05$) increase in its level in both groups of students. The changes were more prominent among graduate students (55.4% vs 46.3% of high-level critical thinkers among undergraduates). The difference between the initial and subsequent number of high-level critical thinkers was 14.6% for undergraduates and 18.9% for graduates. Thus, there was a more rapid increase in the level of critical thinking among senior students compared to junior students. Perhaps, considering the age difference (the average age of undergraduate and graduate students was 19 years and 22 years, respectively), this result was a reflection of the greater cognitive maturity of senior students. The data are consistent with the findings of national and foreign researchers about the importance of developing critical thinking and digital literacy of teachers (Gunawardena & Wilson, 2021; Kazhikenova et al., 2021; Rets et al., 2020; Viberg et al., 2020; Xu et al., 2020). The results confirm the original hypothesis about the positive impact of digital tools on students' critical thinking.

5. Conclusions

The accelerating pace of technological progress requires new approaches to the organization of education with appropriately trained educators who know how to use a variety of digital learning tools. The study has shown that the use of Online Test Pad and Mindmeister digital tools is an effective way of solving the problem of critical thinking development in future teachers and lawyers. These tools are accessible and simple to use. They provide the ability to create educational resources without special knowledge of programming languages. The use of the Online Test Pad to create test tasks and logic problems allowed the students to consolidate the acquired knowledge, test their practical skills, and develop critical thinking. Mindmeister, a digital tool that helps to show information in a graphical format, proved to be a good choice for real-time brainstorming.

The baseline level of critical thinking of master students (high-level thinking was observed in 36.5% of respondents) was statistically reliably ($p < 0.05$) better than that of bachelors (31.7% of all students demonstrated the ability to solve complex tasks), which can be explained by the gradual development of critical thinking during the learning process. The experiment aimed at critical thinking development resulted in a statistically significant ($p < 0.05$) increase of its level in both groups of students, with more rapid growth in

senior students compared to junior students. This result could reflect greater maturity of psychological and physiological cognitive activity mechanisms in senior students. The study findings are in line with the works of foreign researchers on the importance of developing critical thinking and digital literacy for teachers and lawyers. The results confirm the original hypothesis about the positive impact of using digital tools on students' critical thinking.

The technological digital revolution, transforming the paradigm of education toward active implementation of information and communication technologies, provides unlimited opportunities for the use of digital tools in the educational process. This determines the prospects of research on their improvement and the relevant changes in the organization of education, its regulatory and methodological frameworks.

Statement

A.M. – Formal analysis, investigation, resources, writing – original draft preparation, and validation. I.M. – Conceptualization, software, formal analysis, writing – review & editing, and validation. Z.G. – Methodology, software, investigation, writing – original draft preparation, and validation.

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Data availability

Data will be available on request.

Conflict of Interests

Authors declare that they have no conflict of interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tsc.2022.101023.

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