Article

Teachers' Digital Competencies Before, During, and After the COVID-19 Pandemic

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Abstract: The study examines the impact of the COVID-19 pandemic on the digital competencies of teachers and the educational achievements of students, focusing on Serbia and comparisons with other countries. For this study, a survey was conducted in three phases, completed by teachers. The time periods during which the surveys were filled out are characteristic because they correspond to specific points in time (June 2019, June 2022, and May 2023). The aim of the first study, conducted in June 2019, was for every school in the Republic of Serbia to explore teachers' digital competencies as a recommendation of the Ministry of Education. Later, this survey took on a different purpose with the onset of the pandemic. The pandemic exposed challenges such as insufficient teacher preparation for online teaching, educational inequalities affecting students from lower socio-economic backgrounds, and varying levels of adaptability among students. The hypothesis of this research is as follows: Teachers demonstrate a significantly higher level of digital literacy after the crisis caused by the COVID-19 virus than before the crisis. The findings reveal improvements in teachers' digital skills after the crisis situation, particularly in hardware, software, and internet use, alongside a shift in the primary purpose of digital tools from entertainment to education. The study emphasizes the importance of continuous professional development, standardized e-learning devices, and improved digital infrastructure to enhance the quality of education. The research found that teachers in Serbia showed a significantly higher level of digital competencies after the crisis situation. Key recommendations include integrating digital skills into teacher training, fostering innovative pedagogical practices, and addressing the digital divide to ensure equitable access to education in the future.

Keywords: COVID-19 pandemic; digital competencies; education; crisis situation

1. Introduction

The education system faces growing challenges during crisis situations that require the rapid adaptation of teaching methodologies. Crises such as global pandemics, natural disasters, or political instability can seriously disrupt conventional educational processes and force educational institutions to turn to alternative teaching methods. Traditional classroom teaching, which relies on direct interaction between teachers and students, is

increasingly supplemented or replaced by online education. Online education, utilizing digital platforms and tools, enables both teachers and students to maintain the educational process even when physically distant.

In addition to online education, hybrid models of education that combine elements of traditional and online teaching offer added flexibility and adaptability, allowing students to participate in classes in different ways depending on their needs and circumstances. These changes in educational methods highlight the importance of teachers' digital competencies, which are essential for the successful implementation and management of modern educational technologies.

Teachers' digital competencies are particularly important in different educational contexts—in Serbia, the European Union, and according to UNESCO standards, where approaches and resources for developing digital skills can vary significantly. There are different aspects of digital literacy within digital competencies, models, and instruments [1].

The research question we posed in this paper focuses on the way the crisis situation, which generally had a negative impact on all aspects of life, positively influenced teachers' digital competencies.

After the introduction, the theoretical part follows, providing definitions and explanations of key terms. The overview section includes the results of similar studies conducted in other countries, followed by an overview of the "Framework of Digital Competencies in Serbia", as several questions in the survey are based on these competencies. The paper also presents the methods used in the research, as well as the results obtained, which are displayed in the form of tables and charts. Following that, a discussion of the survey results is provided, along with the key conclusions of the research.

1.1. Theoretical Notes

The crisis related to the COVID-19 virus epidemic has led to significant changes in all aspects of life, including education. This section explains the concepts that will be used throughout the paper, providing a better understanding. The concepts relate to the teaching models used at different periods during the research, the assessment methods recommended by the Ministry of Education of the Republic of Serbia, and teachers' digital competencies in Serbia, neighboring countries, and more distant, economically developed nations.

Crises in education involve teaching during an intense disaster that has affected the community [2]. In this case, online and hybrid teaching were the consequences of a crisis situation caused by the COVID-19 pandemic.

Traditional teaching involves the use of learning methods typically conducted in classrooms/labs, with the teacher leading didactic processes through communication with students, which can be one-way or two-way. In this teaching model, book-based learning and mechanical memorization are emphasized, rather than encouraging students to independently search for and analyze information to derive applicable knowledge. The advantage of this teaching model lies in the teacher's presence, which can direct students, enhancing emotional engagement and socialization. In traditional teaching, the teacher has better control over knowledge assessments. However, the drawbacks of traditional teaching are particularly evident when attempting to individualize teaching and learning, obtain a more realistic and objective assessment of students' knowledge, and enhance intrinsic and extrinsic motivation [3].

The emerging conditions during the COVID-19 threat created the possibility of shifting classroom lectures to online platforms [3]. Online teaching is based on the possibilities offered by the internet and digital technologies. The advantages of online teaching include the flexibility in the time and place of knowledge transfer, removal of barriers related

to shyness and fear of speaking with other participants in the class, increasing students' curiosity and motivation if the digital material is engaging, and providing the ability to participate in lessons using any digital device with internet access.

During certain periods of the pandemic, a hybrid teaching model was used. Hybrid teaching consists of at least two components: traditional lectures and the application of information technologies (online teaching). Traditional and online lectures are combined and complement each other. Hybrid teaching in secondary schools in the Republic of Serbia was organized by dividing students into two groups. Each group attended traditional lessons every other day and online lessons on the remaining days [3].

During the pandemic, special attention was paid to digital literacy, teachers' digital competencies, and e-learning.

Digital literacy is a set of knowledge, skills, and behaviors related to the use of digital devices and a set of human abilities to find, evaluate, analyze, create, and transfer information in digital formats [4]. Digital devices include desktop computers, laptops, tablets, smartphones, and similar devices. Teachers' digital competencies represent teachers' digital literacy, ensuring the thoughtful, safe, and flexible improvement of the process of traditional, online, and hybrid teaching [4].

Teachers' digital competencies are a highly complex concept, interpreted differently in various countries around the world depending on national educational policies and strategies, technology availability, investments in education, socio-economic conditions, teachers' professional development, cultural and societal values, and many other factors. The use of digital technologies in education creates an encouraging and innovative environment that positively influences student motivation. When used correctly, digital technologies can improve student performance and adapt the learning process to their needs. Teachers, through these technologies, develop new skills that enable them to introduce innovative teaching methods, enriching the diversity of teaching styles.

There are many different definitions of teachers' digital skills. While there is considerable research on digital skills in education, confusion remains between basic digital skills for ordinary citizens and teachers' digital skills [5]. This may occur because teachers' digital skills encompass a broad range of knowledge and skills related to digital technologies and their application in teaching practice [6]. In addition to disagreements about the definition of teachers' digital skills, different related terms (e.g., teachers' ICT competencies, ICT skills, digital competencies, digital literacy, digital pedagogy, pedagogical digital skills, professional digital skills) are often used synonymously [7].

Guzman and Nussbaum proposed six domains for teachers' skills: technological, pedagogical, didactic, evaluative, communication, and attitudinal [8]. Another study [9] proposed two subdomains for teachers' digital skills: technological and pedagogical skills. Technological skills also influence pedagogical skills [10]. Teachers' digital skills include their ability to use digital technologies to search, evaluate, and use educational materials online. The term digital skills is often mixed with the concept of e-learning.

E-learning is a system of procedures, processes, and instructional materials supported by information and communication technology (ICT) that ensures the diversity and efficiency of learning as an individual activity (and mental process), as well as an important social activity that is not only a procedure in the school system but also a formative activity for the development of the entire community and part of professional development [4].

Alongside the term e-learning, the concept of electronic teaching (e-teaching) also has its place in the educational system. The precise meaning of the term electronic teaching encompasses a system of student and teacher activities in teaching supported and shaped by the achievements of information and communication technology (ICT) and electronic technological solutions. The term electronic teaching is used in the theory and practice

of e-education, with two meanings—to denote teaching with mutual interaction between the teacher and student and as a synonym for the teacher's activity of teaching using appropriate electronic and computer technology [11].

1.2. Overview

The COVID-19 pandemic, which affected the entire world and, consequently, the Republic of Serbia, created a need for teachers and students to improve their digital skills [12]. To slow the spread of the pandemic, governments around the world implemented quarantine measures that, besides impacting other areas of life, also affected schools. Educational activities were significantly altered in most countries. Schools were closed in more than 160 countries, preventing 87% of students from attending classes in person. More than 60 million teachers had to deliver lessons through digital means, while over one and a half billion students had to participate in online learning from their homes. In most countries, teachers had limited digital skills and limited experience with online teaching and learning [13]. During the pandemic, the closure of schools revealed the urgent need for all teachers to be able to effectively use digital technologies for online teaching and learning. Before the outbreak of the pandemic, more than 60% of teachers in the EU did not feel well or very well prepared to use digital technologies in teaching. Although teachers felt confident using digital technologies for simple tasks, they were less confident in more complex tasks such as coding, programming, or robotics. In OECD (Organization for Economic Cooperation and Development) countries, around 65% of teachers had the necessary technical and pedagogical skills to use digital devices in teaching [14]. The importance of using digital tools among teachers became critical at that moment. Support for initial teacher education and continuous professional development related to digital skills and innovative pedagogies was among the main priorities of the EU. The "Education and Training Monitor" report emphasized that teacher qualifications, professional development, as well as teaching experience and practices, are essential for quality education. Improving teachers through providing quality initial education, along with supporting their continuous professional development and collaboration, can enhance their effectiveness in teaching [15].

According to data from the U.S. Department of Education, many graduates in the early stages of teacher education do not feel qualified to use technology in teaching [16]. Only 60% of teachers underwent training related to digital technologies in the previous year, while 18% of teachers urgently need training in digital technologies, according to an OECD survey [17]. Teachers in the EU requested training on digital skills for teaching. During initial teacher education, in several EU countries (Austria, Croatia, Czech Republic, Denmark, Lithuania, The Netherlands, Portugal, Spain, Sweden), less than half of the teachers used digital technologies in teaching. More than 60% of students in the EU were taught by teachers who had received training in digital technologies during their free time. Thus, most teachers in the EU spent their free time developing digital skills.

The authors Johannes König, Daniela J. Jäger-Biela, and Nina Glutsch, in their paper "Adapting Online Teaching during School Closures due to COVID-19: The Impact of Teacher Education and Competencies among Early-Career Teachers in Germany", first analyzed the extent to which teachers maintained social contact with students and addressed key challenges in teaching during the COVID-19 pandemic. They then analyzed potential factors (information technology in schools, teacher competencies such as technological–pedagogical knowledge, and opportunities for learning digital teaching and learning provided during teacher education). The findings from the regression analysis showed that information and communication technologies (ICT), especially teachers' digital competencies and opportunities for learning digital competencies during teacher education, were

key to adapting online teaching during school closures due to COVID-19. The implications for teacher education and the adoption of ICT by teachers were discussed.

During the COVID-19 pandemic, almost all teachers in Germany continued communication with students and their parents. Most teachers, in addition to assigning tasks and providing feedback, also introduced new teaching content. However, challenges requiring the integration of information and communication technology (ICT), such as online teaching and assessment, were more difficult to overcome.

The analysis found that certain factors were significant predictors of successfully overcoming these challenges. For example, the technological–pedagogical knowledge (TPK) of teachers, measured via a standardized online test, was found to be a significant predictor for maintaining social contact and providing differentiated tasks. Teachers who scored better on the test more frequently succeeded in maintaining communication and offering adaptive online teaching. Additionally, teachers' self-assessment was important for providing differentiated tasks and feedback to students.

The availability of information technology in schools also played a crucial role. For instance, schools that had access to software resources and where teachers were already using ICT in their teaching were better positioned when the school closures began. However, the research shows that schools in Germany lag behind the average of other European countries in terms of software access [18].

Communication media, while relevant for efficient communication and information exchange, were not a significant factor in overcoming key challenges. A national survey conducted just before the school closures showed that almost all teachers (98%) already used digital communication media for their work outside of class, meaning that students and parents had access to digital devices such as mobile phones, thereby facilitating communication [19].

Several Greek scientists wrote a paper regarding teachers' readiness to use digital skills during the COVID-19 pandemic [20]. The participants in the survey, more than eight hundred in total, were Greek teachers who had completed a short training course on the use and application of digital technologies in teaching practices. The responses of 806 teachers from primary and secondary education in Greece revealed that about two-thirds of them widely used digital tools for finding, evaluating, and developing educational resources, as well as for teaching. Nearly half of them used digital tools for self-learning and the formative assessment of students. They also used digital tools for interaction and communication with students. However, they rarely used digital tools for other teaching activities, such as providing feedback, the final evaluation of students, or revising educational resources. Nearly three-quarters of them did not use or used very few digital tools to support and improve schools and education in general. Based on the results, the researchers concluded that as education quickly shifts to a digital mode, teachers and educational authorities should carefully plan for the future. Although their daily teaching duties are urgent, teachers should seriously consider other teaching activities, as well as planning and the future development of digital schools and digital education. Additionally, all teachers should be pre-trained to use and apply digital technologies in all their professional activities [21].

A team of Spanish researchers [22] conducted a study with the aim of providing a systematic literature review in databases such as Web of Science and Scopus to identify, analyze, and classify articles published between 2000 and 2021 on digital competencies, in order to enhance research on digital skills and the future development of university-level teachers. The software SciMAT 2011 was used for the analysis. The initial search revealed more than 343 articles in English, of which 152 were duplicates, and 135 were unrelated to the research topic. After filtering, 56 articles were obtained and analyzed.

The results show that research is more focused on teachers' self-assessment and consideration of their digital competencies. Teachers acknowledge having low or moderately low digital competencies, particularly in areas related to the evaluation of educational practice. Despite numerous studies addressing this topic, the need for continued improvement in this field persists, with a deeper assessment of teachers' digital competencies and the design of practical and personalized training programs that meet teachers' needs in the digital age.

The importance of creating collaborative teacher networks or learning communities is also highlighted. The analyzed literature indicates that teachers often learn independently, favoring self-training and trial-and-error methods, and when they need help, they turn to the internet or informally consult colleagues. In this regard, online support and advice are positively rated as they allow teachers to share knowledge, identify professional problems, seek alternatives, and motivate them to change and improve their educational practices [21,23].

An important aspect would be the recognition, accreditation, and certification of digital competencies. Implementing such processes would require valid and transparent tools, not only for evaluating but also for recognizing and accrediting formal, non-formal, and informal learning. This would address one of the key challenges highlighted by the 2014 Horizon Report, which is the lack of rewards in teaching [23].

Responding to the needs of the digital society we live in and predict the needs of future society presents a challenge for all levels of education. This challenge also applies to teaching staff, who, as part of the educational system, must confront social changes, respond to challenges that have already emerged, and prepare for those to come. Teaching staff are aware that this challenge is part of their work. As the authors of [24] stated: "We never finish learning, students change, knowledge progresses, and it is always necessary to stay up to date. A good teacher, like any professional who wants to stand out, cannot stop with continuous improvement".

The conclusion is that the central pillar of teachers' professional development is continuous improvement and the development of all dimensions of teaching competencies. This is probably the greatest challenge for teachers in the 21st century: not to become complacent but to continue learning and exploring. The first step in understanding teachers' training needs in the digital era is identifying the starting point. There are significant differences in digital competencies among various groups based on different variables, indicating the need to structure personalized training plans in this area. Thus, the training offer must be diverse and cater to different needs.

In this sense, many of the analyzed articles emphasize the need for teachers to enhance their digital competencies through specific training, especially related to the pedagogical use of technology, via more practical and experiential training [25]. Although teacher training programs provide good ways to encourage teachers to develop digital competencies for pedagogical purposes, this aspect does not seem to be sufficiently integrated into actual programs. Therefore, it is crucial to ensure greater coherence between initial and continuous teacher training. Training and professional development for individual teachers should be considered an ongoing task, and organized and financed accordingly.

1.3. Framework of Digital Competencies for Teachers in Serbia

Before the crisis could have been anticipated, in 2017, the Ministry of Education of the Republic of Serbia adopted the "Framework of Digital Competencies for Teachers". The framework represents an added value to existing reform initiatives in this area, such as continuous investments in IT infrastructure to ensure long-term profitability and fairer distribution, curriculum reform where digital competencies are recognized as cross-curricular competencies and where competency development is approached holistically with a focus

on achieving standards and learning outcomes, changes to the curriculum for elementary schools to make Informatics and Computing a mandatory subject, development of a framework for the self-assessment and evaluation of schools' digital maturity, piloting of the electronic diary, and organizing relevant training for education staff [26].

Before it was known that a crisis situation and pandemic would occur, the Ministry of Education of the Republic of Serbia planned the development of digital competencies for various reasons. Some of these reasons relate to correspondence schools for students abroad who are unable to study in Serbian, children undergoing hospital treatment who need online or hybrid teaching, and, above all, the possibility for teachers to track the development of digitalization in education. The purpose of the first survey used in this study (June 2019) was the recommendation from the Ministry of Education to assess the level of digital skills that teachers in primary and secondary schools in Serbia possess.

In 2023, the "Framework of Digital Competencies for Teachers 2017" was revised and updated. In today's world, artificial and human intelligence coexist [27]. Educational systems have the responsibility to develop competent citizens and a competent workforce, relying on scientifically based knowledge. Educational approaches are being transformed to ensure students acquire the necessary knowledge and skills to build a more inclusive society. In addition to developing relevant competencies, it is important that education contributes to the quality of life in a digitalized society. Modern technologies support individualized teaching methods tailored to the needs of students, enabling real-time analysis and better decision-making integration.

Digital technology enhances teaching by allowing teachers to expand their knowledge and improve student outcomes. The meaningful use of technology encourages new learning methods and creates opportunities for higher-quality education. Hybrid teaching, which combines classroom, personalized, and distance learning, becomes crucial for efficient education, while school platforms facilitate better interaction and access for both students and teachers.

The digitalization of education is closely connected to the introduction of artificial intelligence, which changes the educational system and the approach to learning. The introduction of new technologies allows for faster knowledge transfer and the development of competencies, as well as personalized learning. The use of technology in teaching makes lessons more interactive and provides students with easier access to information, while the teacher's role becomes closer to that of a mentor. The development of teachers' digital competencies is essential for the success of the digital transformation of education.

Artificial intelligence is becoming a key factor in education, driving innovations in teaching methods and learning. This technology not only changes how knowledge is transmitted but also shapes future educational trends. The use of digital tutors and chatbots as mentors represents a significant change in education, providing new opportunities for students and teachers.

The "Framework of Digital Competencies for Teachers—Teacher for the Digital Age 2023" in the Republic of Serbia represents an updated version of the previous two frameworks from 2017 and 2019 [26,27]. Before the crisis caused by COVID-19, the Ministry of Education of the Republic of Serbia recognized the importance of digital education for teachers. This framework was created to support teachers in the educational system of the Republic of Serbia in the process of integrating digital concepts, tools, and content into everyday educational practice. The framework aims to cover digital competencies specific to the teaching profession, presenting 25 competencies organized into six categories. Each competency has three levels of complexity, which can help in self-assessment and planning further steps. The criteria for determining complexity are not consistently applied to all competencies, as they are tailored to the nature of each competency, the specifics of the area,

and the current development of digital education in the country. The competencies are divided into general and specific competencies. General competencies refer to a broader group of citizens, not just teachers, while specific competencies include areas such as teaching, assessment, and the use of technology in educational situations. Some competencies overlap, and the framework for digital competencies for teachers is not final, but open to adjustment according to the specific educational context and personal development. This framework is also a useful guide for anyone working with young people, supporting the development of hybrid learning and safe behavior in the digital world.

This section briefly describes the areas covered by these competencies, and later, the competencies will be used in the research related to this paper. Also, in Appendix A, Tables A1–A6, more detailed explanations of the digital competencies framework for teachers in Serbia are provided.

The first area of digital competencies, Digital Environment, focuses on security, the ethical use of digital content, AI, and data protection. At the basic level, students are taught how to behave safely online, understand digital content ownership, and protect their data and devices. At the intermediate level, they learn to recognize online threats, use digital content responsibly, and adjust privacy settings on their devices. At the advanced level, the focus is on creating a supportive environment for students to apply these skills, encouraging the ethical use of digital tools, safeguarding information, and seeking help when needed.

The second area, Digital Resources, involves finding, creating, managing, and sharing digital content. Teachers at the basic level use web browsers for searches and understand the differences in search engine results. At the intermediate level, they refine their search skills, identifying valuable digital resources and using open educational resources. At the advanced level, teachers master advanced search techniques and adapt their search criteria for more targeted results. Regarding Content Creation, at the basic level, teachers modify existing content while respecting copyright, and at the intermediate level, they use tools to create original digital content. At the advanced level, they apply universal design principles to create personalized content tailored to student needs.

Teaching and Learning is about planning and applying digital technologies in the classroom. At the basic level, teachers use models like Revised Bloom's Digital Taxonomy and the SAMR model to integrate technology. At the intermediate level, teachers adapt these models to improve teaching effectiveness based on specific contexts. At the advanced level, teachers collaborate with colleagues to implement digital tools that support active learning, self-regulation, and collaborative projects. Regarding Classroom Technology Use, the basic level involves using digital tools for interactive presentations and active learning. At the intermediate level, teachers encourage students to use devices for individual and group work. At the advanced level, teachers design tasks for collaboration with experts or students from other schools. Regarding Learning Management Systems (LMS), at the basic level, teachers upload resources and design activities. At the intermediate level, they create engaging online environments, and at the advanced level, they use all LMS functionalities to track progress and form groups.

The fourth area, Monitoring Student Development and Achievement, focuses on using digital tools for assessment and tracking progress. At the basic level, teachers use electronic gradebooks for formative and summative assessments. At the intermediate level, they use various digital tools to track progress, selecting tools based on assessment goals. At the advanced level, they use advanced tools, including AI, to assess complex skills like collaboration. Teachers also use e-portfolios and learning analytics to track and improve student outcomes.

Supporting Students in the Learning Process focuses on creating inclusive and individualized learning environments with digital tools. At the basic level, teachers apply universal design principles by selecting accessible digital content. At the intermediate level, they adapt materials to enhance accessibility. At the advanced level, they create and modify content to meet diverse student needs. Regarding Digital Device Availability, teachers at the basic level ensure equal access for all students, considering socio-economic factors. At the intermediate level, they work to bridge the digital divide in schools. At the advanced level, they develop policies and collaborate with the community to ensure all students have access to the necessary technology. In Differentiated Instruction, at the basic level, teachers use digital tools for adaptive assessments. At the intermediate level, they provide customized learning experiences. At the advanced level, they reflect on the effectiveness of digital tools and introduce innovations.

The final area, Professional Engagement and Development, covers communication, collaboration, professional growth, and self-reflection. At the basic level, teachers use digital tools to communicate and share materials. At the intermediate level, they engage in structured communication through digital platforms. At the advanced level, they lead professional discussions and promote inclusive communication within the school and community. In Professional Development, at the basic level, teachers collaborate using digital tools. At the intermediate level, they participate in online development programs. At the advanced level, they contribute to colleagues' growth and promote innovative technologies. In Self-Reflection, the basic level involves using digital tools like self-assessments. At the intermediate level, teachers use e-portfolios to improve their practice. At the advanced level, they analyze their progress and help colleagues integrate digital technologies into their reflection.

2. Materials and Methods

For the purposes of this study, a survey was used, which was completed by teachers in three phases. The survey was anonymous and identical in all phases. The first phase of the research refers to the questionnaire from June 2019, before the crisis situation. The questionnaire was filled out by 64 teachers from the Architectural Technical School, out of a total of 88 teachers currently employed at the school. These included teachers on sick leave as well as their substitutes. In the first phase, the number of teachers who completed the survey accounted for 72.73% of the total number of employed teachers.

The second phase of the research, conducted in June 2022, involved the questionnaire from the first phase, completed by 64 teachers (the same teachers from the first phase). At that time, this represented 71.91% of the total number of teachers employed at the Architectural Technical School.

In May 2023, an identical questionnaire to that from the first two phases was completed by 63 teachers (one teacher left the school), which at that time represented a sample of 69.23% of the total number of teachers employed at the school (91 teachers).

The survey consisted of 5 sections. The first section, which included 4 questions, focused on General Data. The second section of the survey addressed teachers' computer skills and contained 19 questions. The next set of 2 questions was about the types of digital devices used by teachers and their purpose for using these devices. One question was related to the frequency of digital technology usage. The most important set of questions dealt with the Digital Competencies for Teachers recommended by the Ministry of Education of the Republic of Serbia. This set contained 18 questions related to 18 digital competencies.

The questionnaire was designed by a computer science and information technology teacher with twenty years of work experience, an expert associate, and a researcher, in accordance with the recommendations of the Ministry of Education of the Republic of

Serbia outlined in the document "Education and Upbringing Strategy in the Republic of Serbia until 2020" [28]. The questions presented in the questionnaire demonstrate their validity considering the adherence to the recommendations of the Ministry of Education of the Republic of Serbia, which were provided in an official letter sent to all school principals, as evidenced by the research findings outlined in the document "Education and Upbringing Strategy in the Republic of Serbia until 2030" [29].

The survey used a multiple-choice dichotomous scale. The questions were of a closed-ended type. Teachers assessed their level of digital skills through self-assessment, based on their perception of their knowledge and abilities. Additionally, the survey was in paper form during the first phase, which teachers filled out manually, while in the second and third phase, it was conducted through a Google Form.

The goal of the study, in terms of the digital competencies of teachers, is to compare teachers' digital literacy before the transition to online and hybrid teaching, immediately after those types of teaching, and one year after the crisis.

The hypothesis is as follows: Teachers demonstrate a significantly higher level of digital literacy after the crisis caused by the COVID-19 virus than before the crisis [3].

3. Results

3.1. General Data

The general data refer to the teachers' gender, years of experience, education level, and the type of subjects they teach (general education or vocational). The data from before, immediately after, and one year after the crisis are presented in Table 1, and did not significantly change over the past four years [3].

Table 1. General information about teachers before the crisis, immediately after the crisis, and one year after the crisis.

Variables	Category	Basic Information About Teachers Before the Crisis (%)	Basic Information About Teachers Immediately After the Crisis (%)	Basic Information About Teachers 1 Year After the Crisis (%)
Gender	Male	20	20	17.78
	Female	80	80	82.22
Work experience in a school	0–10 years	28.89	26.67	31.11
	11–20 years	37.78	40	35.56
	>20 years	33.33	33.33	33.33
Education	Undergraduate studies	64.44	60	62.67
	Master's studies	35.56	40	33.33
Type of subject	General education subject	31.11	31.11	31.11
	Professional subjects	68.89	68.89	68.89

Before the crisis, the teaching workforce was predominantly female, with males making up 20% and females 80% of the total. This gender distribution remained steady in the immediate aftermath of the crisis, though one year later there was a slight shift—a small decrease in male representation accompanied by a corresponding rise in female figures.

In terms of experience, teachers with more than 20 years consistently made up about one-third of the staff, while those with less experience saw minor, fluctuating changes over the period.

Educationally, there was a brief change right after the crisis when the proportion of teachers with master's degrees increased at the expense of those with only undergraduate studies, but by one year later the balance had nearly returned to its original state.

Meanwhile, the subjects taught—whether general education or professional—remained unchanged, highlighting the resilience of the system despite the external pressures of the crisis.

3.2. Computer Skills

The analysis of the survey regarding teachers' computer skills reveals that they significantly improved their abilities to handle hardware, software, and the internet after the crisis situations (Table 2).

Table 2. Teachers' computer skills.

Question	Before the Crisis		Immediately After the Crisis		1 Year After the Crisis	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	N0 (%)
Do you know the basic difference between hardware and software?	71.11	28.89	84.44	15.56	94.34	5.66
Do you know how to properly turn the computer on and off?	95.56	4.44	97.78	2.22	100	0
Do you know how to properly start a program	95.56	4.44	95.56	4.44	100	0
"Do you know how to minimize, maximize, and move windows on the desktop?	86.67	13.33	95.56	4.44	95.56	4.44
"Do you know how to work with folders and files (delete, rename, etc.)?	71.11	28.89	97.78	2.22	97.78	2.22
Do you know how to install/uninstall a program?	40	60	62.22	37.78	70.22	29.78
Do you know how to save/transfer files, folders, and documents to various devices?	53.33	46.67	91.11	8.89	91.11	8.89
Do you know how to scan the computer and search for potential threats/viruses?	55.56	44.44	62.22	37.78	70.22	29.78
Do you know how to create a simple document in MS Word?	93.33	6.67	97.78	2.22	100	0
Do you know how to create a simple document in MS Excel?	42.22	57.78	62.22	37.78	83.56	16.44
Do you know how to create a simple document in MS PowerPoint?	68.89	31.11	80	20	83.56	16.44
Do you know how to copy, cut, and paste content within a document?	46.67	53.33	77.78	22.22	83.56	16.44

Table 2. *Cont.*

Question	Before the Crisis		Immediately After the Crisis		1 Year After the Crisis	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	N0 (%)
Do you know how to format a text document?	75.56	24.44	93.33	6.67	93.33	6.67
Do you know how to use a photo editing program (resize, edit content, etc.)	64.44	35.56	80	20	80	20
Do you know how to record and add sound?	35.56	64.44	55.56	44.44	55.56	44.44
Do you use email?	95.56	4.44	100	0	100	0
Do you know how to download material/documents from the internet?	68.89	31.11	86.67	13.33	86.67	13.33
Do you know how to use online video tools for conference calls?	13.33	86.67	91.11	8.89	100	0
Do you know how to use digital online learning platforms?	13.33	86.67	95.56	4.44	95.56	4.44

The data reveal a notable improvement in the digital competencies of teachers before, during, and one year after the crisis. Across nearly all areas, there is a clear trend of an increase in "Yes" responses, showing that teachers' digital skills saw significant progress following the crisis.

Before the crisis, only 71.11% of teachers knew the basic difference between hardware and software, but by the end of the year, that number increased to 94.34%. This suggests that teachers became more comfortable with basic technical concepts. In terms of basic computer operations, such as turning the computer on and off, starting programs, and managing windows, teachers showed near-total knowledge right after the crisis, with 100% mastering these tasks one year later. Before the crisis, 95.56% of teachers knew how to properly start a program, and this grew slightly after the crisis, reaching full proficiency after a year.

Teachers also made significant strides in handling files and folders. Before the crisis, 71.11% knew how to perform basic file operations like deleting or renaming. A year later, 97.78% of teachers were proficient in these tasks. When it came to installing and uninstalling programs, the improvement was noticeable, although not as dramatic. Before the crisis, only 40% of teachers knew how to handle this, but by the end of the year, that number had increased to 70.22%, showing that teachers had become more comfortable with this task, though there is still room for growth.

In terms of creating documents, teachers showed strong progress in using MS Word, Excel, and PowerPoint. For instance, the percentage of teachers who could create a simple document in MS Word grew from 93.33% before the crisis to 100% a year later. The ability to create documents in MS Excel saw an impressive increase from 42.22% to 83.56%, and the proficiency in PowerPoint jumped from 68.89% to 83.56%. This indicates that teachers became more proficient with office software tools.

When it came to more advanced skills, like using photo-editing programs or recording and adding sound, the improvement was noticeable, though not as widespread. The

percentage of teachers proficient in photo editing grew from 64.44% to 80%, while sound-recording abilities remained static, with 55.56% of teachers able to do this both before and after the crisis. This suggests that these skills may not have been as high a priority for all teachers.

In terms of email usage, there was little change, as 95.56% of teachers already used email before the crisis, and 100% were using it a year later, indicating that email was already an integral tool in their work. The ability to download materials and use online tools also saw improvements. The teachers who knew how to download materials from the internet grew from 68.89% to 86.67%. The most significant shifts occurred in the usage of online video tools and digital learning platforms. Before the crisis, only 13.33% of teachers used online video tools for conference calls, but a year later, 100% of teachers were using them. The use of digital learning platforms also skyrocketed, rising from 13.33% to 95.56%, illustrating a clear shift toward a more digital learning environment.

Overall, the data reflect a profound enhancement in teachers' digital competencies, driven by the challenges of the crisis and their adaptation to new technologies.

3.3. Use of Digital Devices

Teachers owned digital devices before and after the crisis situation. In all three cases, 25 teachers primarily used desktop computers. Before the crisis, laptops were used by 28 teachers, while after the crisis, this number increased to 42 teachers.

Tablets and other devices were used in approximately the same proportion, whereas smartphones were used by all teachers (Figure 1).
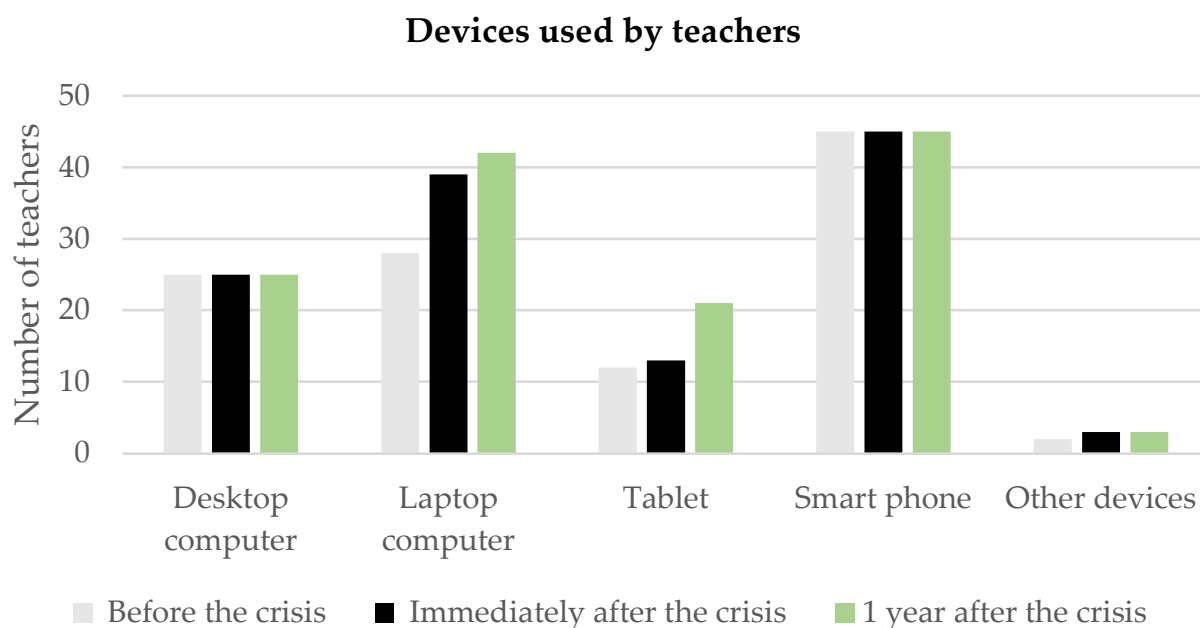

Devices used by teachers

Figure 1. Digital devices.

The diagram illustrates the use of devices by teachers before the crisis, immediately after, and one year later. Desktop computer usage remained stable across all three periods, indicating no significant shift in preference. Laptop usage increased notably after the crisis and continued to rise slightly one year later, suggesting a growing reliance on portable devices for teaching. Tablet usage also showed a gradual increase, though to a lesser extent than laptops, indicating their role as a supplementary tool. Smartphones maintained consistently high usage across all periods, highlighting their established importance in teaching. The category of other devices remained marginal, with only a slight increase post-

crisis. Overall, the data suggest that the crisis accelerated the adoption of portable devices, particularly laptops and tablets, while the use of desktop computers and smartphones remained largely unchanged. Even a year after the crisis, teachers continued to rely on these digital tools, reflecting a lasting shift in their teaching practices.

Additionally, after the crisis, teachers dedicated less time to entertainment, with 12.42% using computers for such purposes compared to a slightly higher percentage of 20% before the pandemic (Figure 2).

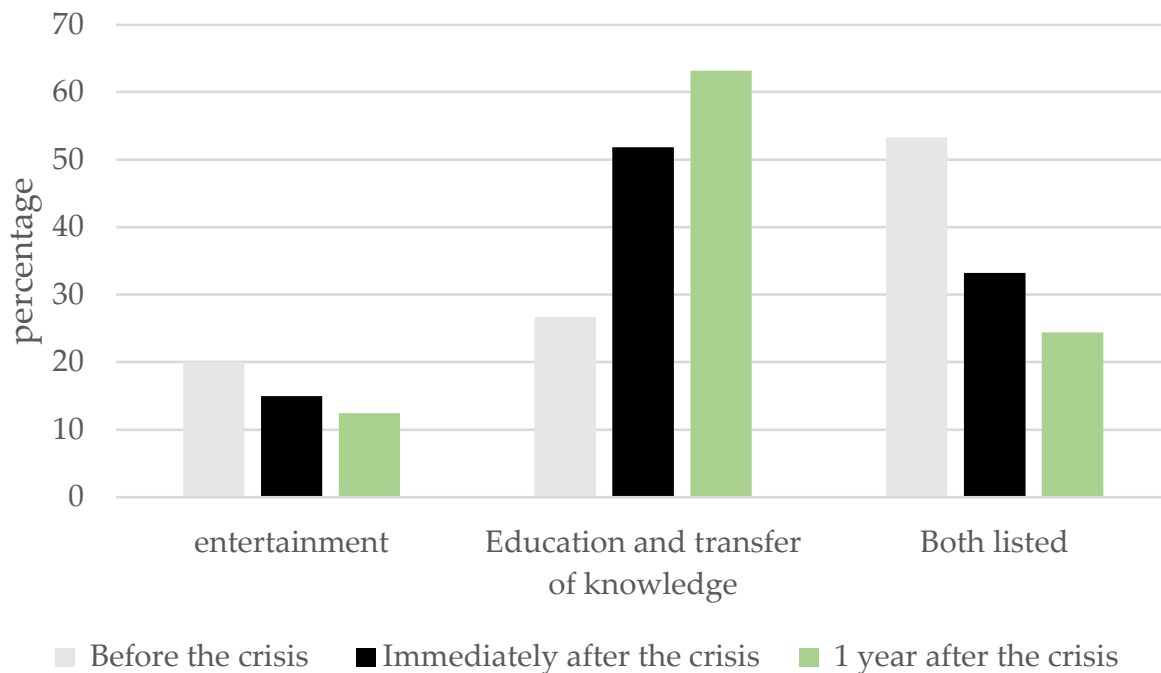## The purpose of using the computer

Figure 2. The purpose of computer use.

The diagram illustrates the purpose of computer use before the crisis, immediately after, and one year later. The percentage of teachers using computers for entertainment decreased over time, with the most significant drop occurring immediately after the crisis. In contrast, the use of computers for education and knowledge transfer increased sharply after the crisis and continued to rise one year later, indicating a long-term shift toward educational purposes. The category combining both entertainment and education saw a decline after the crisis, suggesting that teachers focused more on professional use rather than a mixed approach. Overall, the data reflect a transformation in computer usage patterns, with education becoming the dominant purpose, likely driven by the increased need for digital teaching tools and online learning environments

3.4. Frequency of Digital Device Use

The frequency of digital device usage significantly changed one year after the crisis. Today, teachers use digital technologies to a greater extent. A total of 51.11% of teachers spend more than four hours a day working on a computer or another digital device (Figure 3). This situation can be attributed to the daily use of electronic grade books.
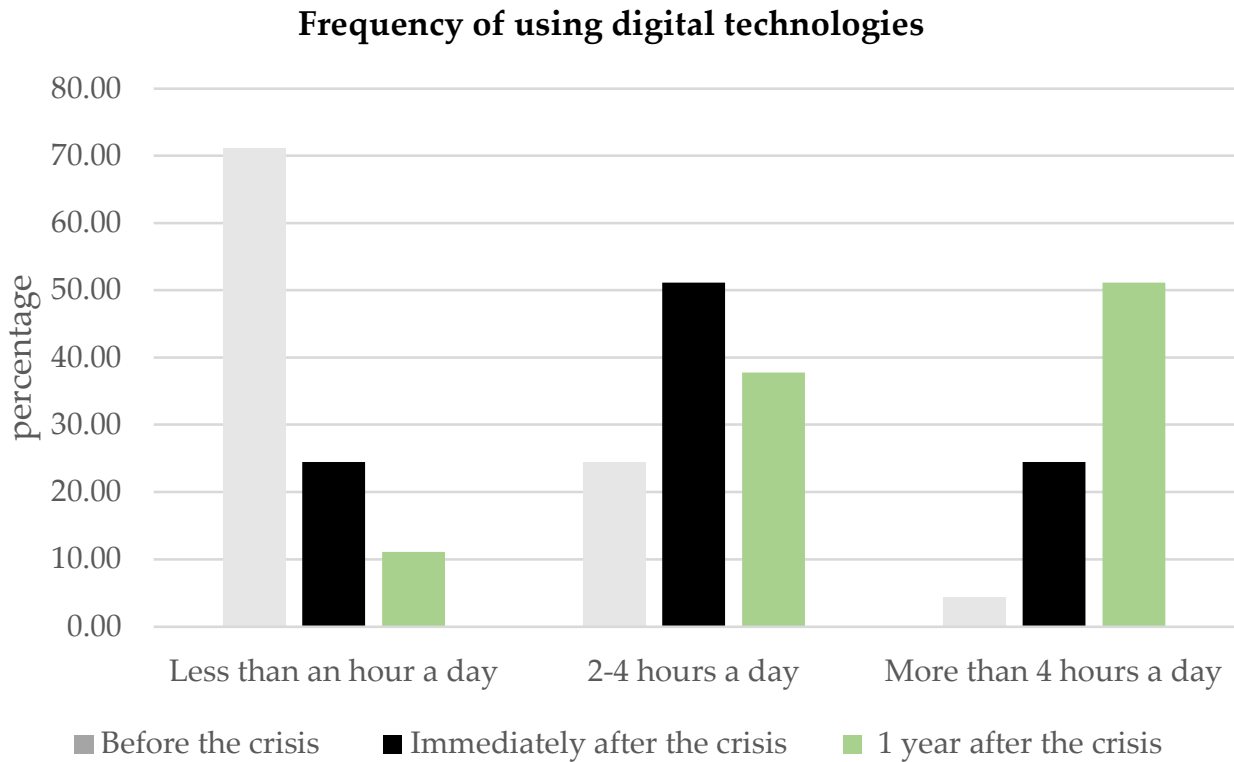
Frequency of using digital technologies

Figure 3. Frequency of computer use.

The diagram illustrates the frequency of digital technology use by teachers before the crisis, immediately after, and one year later. Before the crisis, the majority of teachers used digital technologies for less than an hour a day, but this number dropped significantly after the crisis, with a corresponding increase in longer usage durations. The percentage of teachers using digital technologies for 2–4 h a day rose immediately after the crisis and remained high one year later, indicating a sustained increase in digital engagement. The most notable growth occurred in the category of more than four hours a day, which saw a sharp rise after the crisis and continued increasing one year later. These trends suggest that the crisis led to a significant and lasting shift in digital technology use, with teachers integrating digital tools into their daily routines at much higher levels than before.

3.5. Digital Competencies of Teachers in Relation to the Digital Environment

The paper analyzes the digital competencies established by the Ministry of Education of the Republic of Serbia. Table 3 presents the results of a section of the survey completed by teachers, focusing on the 2017 Digital competence framework.

Table 3. Digital competencies.

		Before the Crisis		Immediately After the Crisis		1 Year After the Crisis	
		Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)
Safety	Basic:	0	77.78	0	53.33	0	33.33
	Medium:		20.00		42.22		57.78
	Advanced:		2.22		4.44		8.89

Table 3. *Cont.*

		Before the Crisis		Immediately After the Crisis		1 Year After the Crisis	
		Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)
Ethical use of digital content and artificial intelligence	Basic: Medium: Advanced:	21.74	74.62 3.64 0	18.2	70.92 9.1 1.82	5.45	69.16 21.84 3.64
Protection and security of data and digital devices	Basic: Medium: Advanced:	20.05	63.24 16.71 0	15.54	70.00 14.46 0	12	70.00 12.36 5.64
Internet searching	Basic: Medium: Advanced:	10	70.00 15.56 4.44	5.66	45.45 42.22 6.67	3.18	39.04 46.67 11.11
Adaptation and creation	Basic: Medium: Advanced:	32.56	60.12 7.32 0	28.55	60.12 11.33 0	28.55	53.10 18.35 0
Management, protection, and sharing	Basic: Medium: Advanced:	10	73.50 16.50 0	8.2	65.00 26.80 0	8.2	56.95 29.85 5.00
The planning of pedagogical application of technology in teaching	Basic: Medium: Advanced:	15	79.36 11.64 0	15.00	63.15 21.85 0	9.15	53.12 32.12 5.61
The application of digital technologies in the classroom	Basic: Medium: Advanced:	72.15	27.85 0 0	63.15	36.85 0 0	54.15	36.85 9.00 0
The use of learning management systems	Basic: Medium: Advanced:	92.15	7.85 0 0	18.56	81.44 0 0	5.65	72.56 21.79 0
Formative and summative assessment	Basic: Medium: Advanced:	21.30	78.70 0 0	15.3	82.16 2.54 0	0	83.15 12.23 4.62
E-portfolio of students and the class	Basic: Medium: Advanced:	100	0 0 0	93.15	6.85 0 0	82.16	17.84 0 0
Learning analytics	Basic: Medium: Advanced:	100	0 0 0	36.12	23.15 12.37 0	12.15	25.30 35.14 27.41
Universal design	Basic: Medium: Advanced:	93.15	6.85 0 0	25.16	65.12 9.72 0	11.2	56.16 25.15 7.49
Accessibility of digital devices	Basic: Medium: Advanced:	100	0 0 0	25.16	65.12 9.72 0	11.2	56.16 25.15 7.49
Differentiated teaching	Basic: Medium: Advanced:	100	0 0 0	72.16	27.84 0 0	56.4	36.12 7.48 0
Communication and collaboration	Basic: Medium: Advanced:	0	35.56 12.15 52.29	0	10.00 37.71 37.71	0	5.32 24.12 70.12

Table 3. *Cont.*

		Before the Crisis		Immediately After the Crisis		1 Year After the Crisis	
		Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)	Not Applied (%)	Applied (%)
Professional development	Basic: Medium: Advanced:	100	0 0 0	0	85.16 14.84 0	0	72.15 27.85 0
Self-reflection	Basic: Medium: Advanced:	100	0 0 0	78.15	21.85 0 0	46.16	53.84 0 0

As shown in Table 3, improvements in the level of digital competencies can be observed across all 18 digital competencies, divided into six areas, compared to the period before the crisis. Notable results are related to competencies involving the application of digital techniques in the classroom, the use of Learning Management Systems (LMS), student e-portfolios, learning analytics, universal design, the accessibility of digital devices, differentiated instruction, professional development, and self-reflection.

Before the crisis, 72.15% of surveyed teachers did not use digital technologies in the classroom at all. This percentage decreased to 54.15% one year after the crisis. Regarding the use of Learning Management Systems, 92.15% of teachers stated that they lacked this competency before the crisis, but one year later, this percentage dramatically dropped to 18.56%, with an increase in the number of teachers utilizing LMS even at an intermediate level. These data clearly show how the crisis accelerated the digitalization of educational practices and how teachers adopted new technologies for teaching.

Unfortunately, 100% of teachers reported not using student e-portfolios before the crisis, and this percentage did not significantly improve after the crisis (82.16%). This indicates that teachers still rarely use e-portfolios.

Additionally, the use of learning analytics was completely unknown before the crisis, while after the crisis, most teachers began using these tools at an intermediate or advanced level. The shift to online teaching likely motivated teachers to use these tools to better track student progress, which is crucial for adapting teaching to the diverse needs of students.

Competencies related to universal design and the accessibility of digital devices showed drastic changes. Nearly none of the surveyed teachers possessed these competencies before the crisis, whereas one year after the crisis, all surveyed teachers had acquired them.

Regarding professional development, no teachers used digital technologies to share ideas with colleagues before the crisis. The crisis led to a transformation, and one year later, 100% of teachers reported engaging in professional development through online networks, online seminars, workshops, and similar activities.

This shift shows how the crisis forced schools to recognize the need for inclusivity in education and to ensure equal access to digital tools for all students.

4. Discussion

This chapter discusses the survey results from the Architectural Technical School, comparing them with the findings of similar studies in other countries.

The computer skills of teachers at the Architectural Technical School were satisfactory before the pandemic. After the pandemic, teachers demonstrated a higher level of proficiency in handling hardware, software, and the internet.

Before the pandemic, teachers primarily used digital devices for entertainment and spent significantly less time on them. After the pandemic, digital technologies were predominantly used for education and teaching purposes.

Teachers exhibit a higher level of digital competencies related to internet searching, online safety, internet ethics, data and device protection and storage, and health awareness after the crisis compared to the pre-crisis period.

Teachers at the Architectural Technical School became significantly more digitally literate after the pandemic. However, further efforts are needed to enhance professional development in digital technologies and to increase the percentage of teachers with advanced digital competencies.

The situation was similar in other countries around the world. Regardless of national education policies and strategies, technology availability, investments in education, socio-economic conditions, the professional development of teachers, and cultural and societal values, the research results regarding the digital competencies of teachers and student achievements are similar in Serbia and the other countries compared in this study. Educational activities significantly changed in most countries due to the pandemic. Schools were closed in over 160 countries, preventing 87% of students from attending in-person classes. Over one and a half billion students transitioned to online learning, and more than 60 million teachers had to adapt to digital teaching [30].

Before the pandemic, most teachers in the EU did not feel adequately prepared to use digital technologies in teaching. While they were confident in using technology for simple tasks, they were less confident in more complex areas like programming. The pandemic highlighted the urgent need for teacher training in the use of digital tools. Quality initial education and continuous professional development are crucial for improving teaching. However, many teachers did not have sufficient training related to digital technologies.

Student achievements were poorer during online learning compared to traditional in-person teaching. Students from lower socio-economic backgrounds were particularly affected, which further deepened educational inequalities. While primary school students faced more difficulties with remote learning, high school students and university students showed varying degrees of adaptation depending on the support they received [30].

Regarding teachers' digital literacy in the EU, most teachers were not prepared for online teaching, while in OECD countries, the situation was better, with 65% of teachers possessing the necessary skills. In countries with a better technological infrastructure, students more easily transitioned to online learning, whereas in other countries, both students and teachers faced greater challenges [31].

In China, where the pandemic began, student success was better before the pandemic than after it, while in Europe, many students experienced a decline in learning quality, particularly those from lower socio-economic backgrounds [30].

"In Saudi Arabia, for the teachers' perceptions, the quantitative results revealed that they had a high level of positive perceptions towards using digital technologies. The findings indicated that all four perception areas including perceived usefulness, ease of use, compatibility, and subjective norms yielded high ratings" [32].

"The results of the Bulgarian study show that Bulgarian teachers use digital technologies in their daily teaching activities to create and provide learning content to students and to provoke their active participation, and is also used as a convenient tool for assessing their knowledge and skills. Another aspect of teachers' use of digital technologies is in various activities that support the learning process, communication with parents as well as administrative activities" [33].

"In Spain, the statistical analysis of the data shows that the greatest difficulties reported by teachers during COVID are deficiencies in their training in digital skills, which caused

them to experience a higher workload during the lockdown, accompanied by negative emotions" [34].

In many European countries, based on the assessment that teachers' digital competencies are insufficient for online teaching, extracurricular training programs for future teachers were implemented, grounded in the DigCompEdu framework [35]. Such training was conducted in Germany from 2021 to 2024, in line with the restrictions imposed by the COVID-19 pandemic. "A total of 242 future teachers applied for the program, and 40 completed it. A comparison of pre- and post-program results showed an improvement only in the participants' self-confidence in using digital technologies for subject-specific needs. Unexpectedly, no other statistically significant differences were recorded. These results point to certain shortcomings of the program, which were further analyzed to identify possible improvements for future programs and integration into the curriculum" [36].

The pandemic revealed significant disparities in the readiness of teachers and students for online teaching, as well as the importance of technical infrastructure and digital skills for successful remote learning. There is a need for standardized electronic devices specifically designed for e-learning to reduce educational inequalities and improve the efficiency of online teaching [30].

5. Conclusions

The aim of the study, regarding teachers' digital competencies, is to compare their digital literacy before the transition to online and hybrid teaching, immediately after these teaching methods were implemented, and one year following the crisis. For the research presented in this paper, three identical surveys were used, completed by teachers at the Architectural Technical School in three distinct phases: before the pandemic, immediately after the pandemic, and one year after the pandemic. During these periods, teachers worked with three teaching models: traditional teaching, online teaching, and hybrid teaching. Prior to this, only a small number of teachers had experience with online teaching.

The survey analysis concerning teachers' computer skills shows a notable improvement in their ability to manage various aspects of digital technology. Teachers enhanced their proficiency in fundamental hardware and software operations, as well as in computer security and troubleshooting. Additionally, their skills in document creation and editing, multimedia and digital content creation, communication and collaboration, and the use of digital learning platforms all advanced significantly.

Teachers had access to digital devices both before and after the crisis. While many teachers initially relied more on desktop computers, the use of laptops increased significantly after the crisis. The usage of tablets and other devices remained relatively consistent, but smartphones were used by all teachers throughout the period. After the crisis, there was a noticeable decline in the time spent on entertainment, with fewer teachers using their devices for leisure purposes compared to before the pandemic.

The frequency of digital device usage considerably changed one year after the crisis, with teachers spending more time working on computers and other digital devices. A large percentage of teachers now use digital technologies for more than four hours a day, a trend influenced by the daily use of electronic grade books.

Digital competencies improved across all areas, with significant progress in applying digital techniques in the classroom, using Learning Management Systems (LMS), managing student e-portfolios, utilizing learning analytics, and implementing universal design principles. Teachers also showed better skills in differentiated instruction, professional development, and self-reflection after the crisis.

Before the crisis, a majority of teachers did not use digital technologies in the classroom at all, but this number decreased substantially one year after the crisis. The use of LMS

saw the most dramatic change, with most teachers lacking this skill before the crisis, but a significant number now using it at an intermediate level. Unfortunately, the use of student e-portfolios remained largely unchanged, as most teachers continued to avoid using them.

Before the crisis, learning analytics were not used at all, but after the crisis, a large portion of teachers started applying these tools at intermediate or advanced levels.

There was a dramatic shift in competencies related to universal design and digital device accessibility, as teachers who had no knowledge of these areas before the crisis now possess these skills.

In terms of professional development, there was no use of digital tools for collaboration before the crisis. However, the situation changed after the crisis, with all teachers now actively participating in professional development activities such as online networks, webinars, and workshops.

It can be concluded that the main hypothesis was fulfilled: teachers demonstrated a significantly higher level of digital literacy after the crisis caused by the COVID-19 virus than before the crisis.

Although the level of digital competencies significantly increased, with the advancement of science and technology, there are more and more demands that teachers have to fulfill in order to keep up with this progress. Based on the presented facts, several key steps can be taken to improve student achievement and the digital competencies of teachers:

- Continuous professional development for teachers: Teachers should have continuous access to training and workshops that enable them to use digital tools, not only for basic tasks but also for advanced digital skills such as programming, coding, and robotics.
- The integration of digital skills in teacher education: Digital technologies should be included in the curricula in future teacher education programs to ensure teachers are prepared for modern educational demands.
- The provision of standardized electronic devices: Governments and educational institutions should provide access to standardized devices specifically intended for e-learning, which exclude games and harmful content to reduce distractions and improve online learning efficiency.
- Technical support: Students and teachers should be provided with technical support for using digital devices and resolving potential technical issues during online lessons.
- Public investment in infrastructure: It is essential to invest in improved digital infrastructure in schools, particularly in rural and underdeveloped areas, so that all students have equal access to technology and internet connections.
- Reducing the digital divide: Special attention should be given to students from lower socio-economic backgrounds to reduce educational inequalities by providing the necessary resources and access to digital tools.
- Innovative pedagogical practices: Curricula should be adapted to include innovative learning methods that combine traditional teaching with online learning (hybrid models), and teachers should be trained to implement these methods.
- The development of digital resources: Quality digital educational resources should be developed and distributed to facilitate remote learning and support various learning styles.
- The regular evaluation of student achievements: Mechanisms should be established to regularly monitor and evaluate student achievements during online classes, to identify issues and implement appropriate corrective measures.
- Adaptability of teaching plans: Teaching plans and programs should be flexible, allowing for adaptation to various circumstances, such as emergencies like pandemics.

Research on teachers' digital competencies in Serbia is highly relevant to other countries, as it provides insights into how educators adapt to digital transformations, espe-

cially in crisis situations. Many nations face similar challenges in integrating technology into education, and Serbia's experience can serve as a valuable case study for understanding the effectiveness of digital tools, professional development strategies, and policy implementations.

By analyzing how Serbian teachers improved their digital skills before, during, and after the crisis, other countries can identify best practices and potential obstacles in fostering digital literacy among educators. This research can help shape global education policies, guide teacher training programs, and enhance the overall quality of digital education. Additionally, the findings from Serbia can contribute to international comparisons, enabling policymakers and researchers to adapt successful models to their own educational systems, ultimately improving digital competencies on a broader scale.

Appendix A

Table A1. The first area of digital competencies: Digital Environment.

Digital Environment	Security
BASIC	Informs students how to behave in an online environment to ensure their own and others' security (using strong passwords, protecting personal data, photos, and videos from misuse, not communicating or meeting unknown people in person, etc.).
INTERMEDIATE	Teaches students specific security measures that help them stay safe in the online environment (e.g., installing apps like video games with appropriate PEGI ratings, critically assessing offers and potential scams online). Continuously empowers students to recognize and report cyberbullying to protect their own and others' security in the online space, advises on the language they use, refrains from sending disturbing content, and avoids hate speech.
ADVANCED	Creates an educational environment that enables students to continuously practice maintaining their own and others' security and encourages them to seek advice and support from teachers and parents regarding the safe use of digital devices.
Digital Environment	Ethical Use of Digital Content and Artificial Intelligence
BASIC	Informs students about types of ownership of digital content (C and CC licenses). Points out that artificial intelligence can be the creator of digital content, and this content should not be downloaded or presented as their own.
INTERMEDIATE	Uses digital content protected by licenses for teaching purposes, ensuring the proper citation of sources. Guides students on how to use generative AI during independent work without compromising the credibility of the created products.
ADVANCED	Creates an educational environment that supports students in publishing digital content they've created and protected with CC licenses. Instructs students to evaluate the quality and reliability of AI-generated content. Promotes responsible behavior and adherence to ethical standards when using AI, especially in homework assignments, highlighting the importance of personal engagement in learning and originality in work.

Table A1. *Cont.*

Digital Environment	Security
Digital Environment	Data Protection and Digital Device Security
BASIC	Familiarizes students with the basic principles of protecting their data and digital devices (creating multiple passwords for different purposes, not sharing passwords, locking devices, learning about privacy policies, etc.).
INTERMEDIATE	Implements basic data protection measures with students in the digital environment (e.g., changing automatically set privacy parameters when using a new app—blocking ads, user activity-tracking, and location-tracking).
ADVANCED	Systematizes and promotes the safe use of digital devices and data storage through school documents and collaboration with colleagues, regardless of whether they are used for personal or professional purposes. Empowers colleagues to make students aware of the risks associated with irresponsible device- and data-handling.

Table A2. The second area of digital competencies: Digital Resources.

Digital Resources	Internet Search
BASIC	Uses various web browsers to find digital teaching content. Understands that different search engines display different results and that the same search engine may show different results to different users.
INTERMEDIATE	Knows how to find digital resources for teaching based on different criteria (e.g., pedagogical value, relevance, reliability, quality, type of license) and the specific needs of the lesson. Accesses specialized forums, open educational resources, portals, and online repositories to find digital teaching content.
ADVANCED	Uses advanced internet search techniques to find digital content for teaching, evaluates search results, and adjusts search criteria for a new, more focused search.
Digital Resources	Customization and Creation
BASIC	Knows how to make basic modifications to digital teaching content created by others and save it while respecting copyright and licensing requirements. Uses basic functions of digital tools to create digital materials (e.g., text, images, presentations, tables, audio, and video files).
INTERMEDIATE	Uses various tools to create digital teaching content made from personal and downloaded materials (while respecting copyright and licensing requirements).
ADVANCED	Applies the three principles of universal design for learning and various tools to modify, adapt, and combine digital content to meet the individual needs of students. Knows how to create and co-create digital content in various formats, on different platforms, and in environments tailored to students' individual needs (identifying needs, designing and co-designing, development, implementation, assessment, adaptation, sharing).
Digital Resources	Management, Protection, and Sharing
BASIC	Can download digital resources in line with the license under which they are published, classify them, and save them on their digital device or cloud storage, protected by a password. Can share digital resources via various applications and services (e-mail, web-mail, large data transfer, etc.).
INTERMEDIATE	Knows how to set up, organize, and securely store digital resources locally or on an online system while respecting privacy and copyright (selecting storage and online services based on applicable data retention policies, terms of use, and security, applying strong passwords, using encryption protocols, and regularly backing up data). Can share a digital resource and enable online collaboration with others by granting appropriate access rights.
ADVANCED	Initiates and promotes a shared digital space at the school level that facilitates safe storage, management, and access to digital content for various users (students, parents, etc.)

Table A3. The third area of digital competencies: Teaching and Learning.

Teaching and Learning	Planning the Pedagogical Use of Technology in Teaching
BASIC	Knows models, concepts, and taxonomies for planning the use of technology in teaching and applies some of them (e.g., Revised Bloom's Digital Taxonomy, the Flipped Classroom concept, the SAMR model, the ADDIE model, Inquiry-Based Learning, Universal Design for Learning).
INTERMEDIATE	Plans the use of technology in teaching by combining and adapting models, concepts, and taxonomies to increase the effectiveness and quality of teaching and learning in a specific context.
ADVANCED	In collaboration with colleagues, plans the use of digital technology to support innovative pedagogical approaches aimed at fostering active learning and the development of self-regulation in learning. Promotes collaborative planning for the application of digital technologies within the school and the broader community (e.g., using synchronous and asynchronous online environments and tools, artificial intelligence, joint teaching projects, opportunities for collaborative online learning, co-designing and creating teaching materials).
Teaching and Learning	Application of Digital Technology in the Classroom
BASIC	Uses technology for the interactive presentation of teaching content (e.g., animations, mind maps, programming, augmented reality, virtual reality), to support active learning (e.g., apps for measurements, experiments, and simulations, for discipline-specific programs, such as solfeggio), and to involve guest lecturers from relevant fields through video conferencing.
INTERMEDIATE	Creates opportunities and encourages students to independently use school or personal digital devices for individual and group work (e.g., reading selected online content, browsing the internet, listening to audio content, participating in reflective activities, writing in an online environment, solving tasks, creating scenarios).
ADVANCED	Designs research and project tasks that go beyond the limitations of the traditional classroom, creating opportunities for collaboration with experts, absent students, and students from other schools (e.g., collaborative work in the cloud with students from other countries guided by a guest expert and/or teacher, with absent students participating due to illness).
Teaching and Learning	Use of Learning Management Systems (LMS)
BASIC	Is present and active in their online classrooms within the school's online learning platform (the school's LMS). Uploads selected resources (e.g., chosen websites, documents), designs learning activities (e.g., interactive lessons, discussions, assignments), and provides frequent and constructive feedback on student progress. The interactive work materials they upload contain quality feedback that contributes to students' understanding of the teaching content.
INTERMEDIATE	Creates an authentic and stimulating online learning environment through various teaching activities that ensure a high degree of student interaction (enabling students to collaborate on tasks, create lessons, assess their peers, etc.).
ADVANCED	Creates and improves their online classrooms by applying most of the functionalities of the school's Learning Management System. Forms groups and teams based on students' individual needs and tracks their progress using embedded learning analytics and gradebooks. Tracks developments in the chosen LMS system and applies them to their work. Understands how an application or learning material based on artificial intelligence can be integrated into the online classroom.

Table A4. The fourth area of digital competencies: Monitoring the Development and Achievement of Students.

Monitoring Development and Achievement of Students	Formative and Summative Assessment
BASIC	Uses the electronic gradebook for formative and summative assessment and monitoring student achievements (e.g., recording grades, providing feedback on activities, achievements, and student behavior, and offering suggestions for improvement).
INTERMEDIATE	Uses digital tools (independent and/or integrated into the Learning Management System) for formative and summative assessment and tracking the process and outcomes of learning. Selects tools in accordance with the goals, learning outcomes, and purpose of assessment. Is aware of the benefits of assessment with digital tools (e.g., flexibility, automatic data collection on students, automated grading, generating group results on tests, graphical representation, etc.) and ethical issues related to assessment with digital tools (e.g., cheating on tests).
ADVANCED	Uses advanced functions of digital tools, including AI-based tools, for formative and summative assessments and tracking student achievement. Assesses more complex student competencies (e.g., collaborative problem-solving) and selects digital tools based on a critical evaluation of pedagogical "added value" (e.g., integrates independent tools, such as games and assessment tools, into subject-specific LMS.
Monitoring development and achievement of students	Student and class E-Portfolios
BASIC	Uses an e-portfolio to collect data on the learning process, share student products, track progress, and display student achievements.
INTERMEDIATE	Enables students to independently share their achievements within a class e-portfolio, which they create and manage in the form of a website or blog (e.g., linking individual student portfolios to the LMS). Uses various digital tools for creating e-portfolios and selects based on student needs and preferences.
ADVANCED	Creates an educational environment in which students assess their own achievements (self-reflection) and track their progress through the creation and development of a personal e-portfolio, using feedback from peers and teachers.
Monitoring development and achievement of students	Learning analytics
BASIC	Knows the functionalities of digital technologies (e.g., the school's Learning Management System and other independent digital tools) that enable the collection and processing of data on activities, individual and group student achievements.
INTERMEDIATE	Uses the functionalities of digital technologies (including the selected Learning Management System) to observe, compare, and consolidate data on student progress (when planning lessons and assessments, is guided by data on group student achievements, test metrics, etc.).
ADVANCED	Analyzes and combines different digital data sources on student progress and takes actions to improve their achievements and the overall working atmosphere in the class (e.g., grades for activities in the online classroom are recorded in the electronic gradebook).

Table A5. The fifth area of digital competencies: Supporting Students in the Learning Process.

Supporting Students in the Learning Process	Universal Design
BASIC	Understands the principles of universal design and applies them when selecting digital content and resources based on individual student needs (e.g., websites with options to adjust the visual environment for students with dyslexia or visual impairments).
INTERMEDIATE	Adapts and makes digital content for teaching and learning available to students in accordance with universal design principles (e.g., when creating teaching materials, uses fonts, background colors, and links that enhance readability and aesthetic quality).
ADVANCED	Creates their own digital content for teaching and learning in line with universal design principles and adapts it to the needs of students with various different needs (students with visual or hearing impairments, dyslexia, etc.).
Supporting students in the learning process	Availability of Digital Devices
BASIC	Understands the importance of ensuring equal access to digital education for all students, aligned with their individual needs and the socio-economic context from which they come (e.g., is aware that students from disadvantaged socio-economic backgrounds may not have desktop or laptop computers at home and may only be able to use a personal or mobile device of their parents/legal guardians).
INTERMEDIATE	Actively addresses overcoming the digital divide when working in a school with limited digital resources. Raises the issue of defining a school policy that outlines the cyclical allocation of existing digital resources, ensuring that each student has the opportunity to use a school digital device.
ADVANCED	Develops school policy and practices for the use of mobile phones, electronic devices, and other tools; involves the local community in solving the problem of acquiring missing equipment and devises innovative strategies to ensure all students have access to the digital tools they need for modern education.
Supporting students in the learning process	Differentiated Instruction
BASIC	Understands the possibilities of digital technologies for creating a learning environment that supports the differentiation and individualization of the teaching process based on student needs (adaptive assessment in a digital environment, where task difficulty can be adjusted to student achievement, students can receive individualized feedback, etc.).
INTERMEDIATE	Applies available digital technologies (e.g., digital textbooks, artificial intelligence systems, open educational resource repositories) to create a learning environment that supports the differentiation and individualization of teaching and learning (e.g., uses games and quizzes where students can choose tasks, solve them at different speeds, and revisit tasks they did not complete correctly).
ADVANCED	Reflects on the application of digital technology in the differentiation and individualization process of teaching and learning, analyzes the suitability and effectiveness of applied pedagogical approaches, and introduces innovations into teaching practice.

Table A6. The sixth area of digital competencies: Professional Engagement and Development.

Area Professional Engagement and Development	Communication and Collaboration
BASIC	Uses digital technologies for communication within the school community, sharing and exchanging teaching materials to support students, parents, and colleagues (e.g., via email, text messages, social media).
INTERMEDIATE	Uses various digital technologies (web platforms, online discussion groups, websites) to exchange information in a structured and responsible manner with different stakeholders.
ADVANCED	Directs the work of professional discussion groups related to teaching and learning in the online environment (collaboration and co-creation, working on joint projects, creating online knowledge communities). Contributes to the development of the application of digital technologies for communication within the school, local, and professional community to ensure communication is safe, responsible, efficient, and inclusive.
Area professional engagement and development	Professional Development
BASIC	Uses digital technologies for collaboration with colleagues and the exchange of teaching materials and information related to pedagogical work, as well as for improving the functions of the school and profession.
INTERMEDIATE	Participates in online professional development programs, professional online networks, and independently finds information and resources for personal professional development.
ADVANCED	Applies digital technologies to contribute to the development of pedagogical and digital competencies of education staff (e.g., through training, webinars, workshops, creating online resources). Tracks changes in the field of digital technology development, proposes the adoption of new technologies to the school and colleagues, and promotes innovations within the educational community.
Area professional engagement and development	Self-Reflection
BASIC	Understands the concept of self-reflection with the use of digital technologies and the process of improving teaching and learning through reflective practice (e.g., using online self-assessment tools, maintaining an online pedagogical practice diary).
INTERMEDIATE	Uses various methods of self-reflection to improve digital professional practice (develops a personal e-portfolio, creates a section within the e-portfolio to guide students, presents evidence of professional achievements, records lessons for analysis, works in teams, etc.).
ADVANCED	Analyzes and evaluates the results of self-reflection on the use of digital technologies in teaching and learning and plans further professional development. Integrates the e-portfolio concept as an integral part of supporting the teaching process. Assists colleagues in integrating digital technologies into their reflective practice.

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