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Digitalization in Bulgarian science education: a comparative analysis of the state of the art

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The paper discusses the use of digital technologies (DT) in Bulgarian school science education through a review and analysis of national and international studies. Both the strengths and weaknesses of the application of DT in the Bulgarian school in a comparative plan with other European countries are highlighted. The findings show that the digital competence of Bulgarian students and teachers related to DigComp and DigCompEdu frameworks is generally lower than the European average despite the confidence in their digital skills. Problematic areas include creating and modifying digital content, collaboration among teachers, identifying fake news, assessing student progress, implementing constructivist approaches in e-learning. The quality of continuing teacher education for digital competences is also a concern. Nevertheless, many Bulgarian teachers express satisfaction with their work in distance learning and believe that the use of DT enhances their lessons. Analysis of digital technology use and student learning achievements in science education shows no clear evidence of a correlation. However, there are potential positive effects of using computers as a supplement to traditional instruction rather than as an alternative to it.

Keywords: DigComp; DigCompEdu; digital competence; science education.

INTRODUCTION

Data on the state of digitalization in Bulgarian school education can be found in some national and cross-national studies, as well as in research papers by individual authors. Some of these data are also valid particularly for science education – in physics, chemistry and biology. These three subjects are primarily experimental sciences as they are based on the collection and analysis of data from empirical studies. With the rapid development of digital technology, it has become possible to visualize and conduct some of the observations and experiments using digital devices and resources. As in other subjects, the search for and systematization of reliable and trustworthy information, the processing of data, and their presentation in the form of tables, charts, diagrams and other representations are important. It is taken, somewhat for granted, that digitalization supports science education and facilitates the work of both teachers and students, which would lead to better achievements in science education. In this paper, sources from national and international studies will be presented and analysed, which provide information on the state of digitalization in science education in Bulgarian schools.

Research aim and research questions

The aim of the present work is to highlight the strengths and weaknesses of the application of digital technologies in the Bulgarian school in a comparative plan with other European countries through a review and analysis of studies on the digital competences of teachers and students. In line with this aim, two research questions were set:

1) To what extent do the digital competences of Bulgarian teachers and students in the context of science education correspond to the European Digital Framework for citizens (DigComp) and the European Digital Framework for educators (DigCompEdu)?

2) Is there a correlation between the application of digital technologies and students' learning achievements in natural sciences?

Research methodology

In search of answers to the research questions we followed three stages: 1) Review of the European frameworks for digital competence; 2) Search and selection of scientific literature, national and supranational studies on the application of digital technologies in Bulgarian schools and particularly in science education and 3) Data analysis of literature sources and conclusions.

Overview of the European digital competence frameworks – DigComp for citizens and DigCompEdu for educators

These frameworks have been designed by the European Commission (EC) and are used to evaluate and develop people's digital skills.

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DigComp is the Europe-wide framework for developing and measuring citizens' digital skills. It was created in 2013 [1], and describes key components of digital competence, grouped into five areas: 1) Information and data literacy: 2) Communication and collaboration; 3) Digital content creation; 4) Security; 5) Problem solving. DigComp defines digital competence as „the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society".

The components of digital competence, also referred to as competences, are total 21 and distributed across the five areas of the framework. They are denoted by two numbers, the first indicating the area and the second showing the competence, e.g. 2.4 is the competence C*ollaboration through digital technologies* which is pertinent to area 2. Communication and collaboration.

The content of the framework is structurally presented in 5 dimensions: Dimension 1: the areas in which digital competence is manifested; Dimension 2: the titles and descriptions of the competences in each area; Dimension 3: the levels of proficiency for each competence; Dimension 4: examples of knowledge, skills and attitudes applicable to each competence; Dimension 5: use cases of the competence in different contexts. Dimension 3 includes three levels of proficiency (foundation, intermediate and advanced). Dimensions 4 and 5 give examples of different possible manifestations and applications of the competences of dimension 2, but do not claim to be exhaustive.

The rapid development of digital technologies, the skills to create them and work with them has led to several versions of DigComp, each of which, updates some elements of the Framework and complements it. The first of the updated versions, labeled DigComp 2.0 [2] updates Dimension 1 (the five areas) and Dimension 2 (the titles and descriptors of the 21 competences) in line with the fast development of digitalization. The descriptors of the competences use the terms digital technologies and digital environment. This facilitates the descriptions so that it is not necessary to specify a particular technology, software or app, as well as a particular device. This way, all types of computers and all mobile devices such as smartphones, media players, e.g. game consoles, e-book readers, etc. are included. These terms now also include sensors and all kinds of information transmission devices, more recently known as the Internet of Things – a system of interconnected devices, objects, animals or people that have unique identifiers (UID) and can transmit data by a network without the need for human-human or human-computer interaction.

The next version DigComp 2.1 [3] details the proficiency levels and they become 8 for each of the 21 competencies, therefore 168 in total. Progress in mastery of the competencies is reported in terms of three components: 1) the complexity of the tasks, 2) the independence with which the tasks are performed, and 3) the need for guidance in completing the tasks.

At the end of 2020, the next update of the DigComp – DigComp 2.2 begins, focusing on Dimension 4, which is complemented by examples of knowledge, skills and attitudes for each of the 21 competences. What is new in this latest version is the consideration of emerging technologies such as artificial intelligence (AI), Internet of Things (IoT), datafication – converting information about subjects, objects, processes into digital data. DigComp 2.2. also reflects the new conditions for remote working, which requires new digital skills of citizens that are different from the previous ones [4]. Dimension 5 is enriched with use cases of digital competences in the context of learning and education.

DigComp 2.2 includes over 250 new examples of knowledge, skills and attitudes to help citizens to engage with digital technologies. Due to the short period since the publication of version 2.2 of the DigComp, we have not yet found any relevant publications on the topic of the present study, so we will refer to previous versions.

The DigCompEdu [5] describes teacher specific digital competences within a progression model that allows teachers to identify and to gradually improve their competencies. 22 core competencies are described and grouped into six areas that focus on different aspects of educators' activities: 1) Professional engagement, 2) Digital resources, 3) Teaching and learning, 4) Assessment, 5) Empowering learners, 6) Supporting learners' digital competence.

The aim of DigCompEdu is to promote the development of digital skills among teachers and to stimulate innovation in education. The core of the DigCompEdu framework is defined by areas 2-5. Together, these areas represent the digital competencies that educators need to use digital technologies effectively and innovatively, and to create and share digital learning resources. Area 1 focuses on educators' own professional development of digital skills in their professional interactions with colleagues, students, parents, and other stakeholders. Area 2 describes the competencies needed to create and share digital resources for learning. Area 3 addresses the pedagogical skills for managing and organizing the use of digital technologies in learning. Area 4 looks at using digital strategies to improve assessment in education. Area 5 focuses on the potential of digital technologies for learner-centred teaching and learning strategies to promote active and creative engagement in their learning. Area 6 details the specific pedagogical competencies required to support the development of learners' digital competence to use digital technologies effectively and responsibly to find information and resources in digital environments, to communicate, collaborate and actively participate.

Search and selection of scientific literature, national and supranational studies on the application of digital technologies in Bulgarian schools, in particular in science education

For articles in scientific journals the international databases (academic databases) ERIC, JSTOR, Scopus, Web of Science with keywords "digital technologies, science education, Bulgaria" and in the National Reference List of Contemporary Bulgarian Scientific Publications with Scientific Review were consulted. Information was also sought from the website of the Ministry of Education and Science of the Republic of Bulgaria, as well as from the websites of the Organisation for Economic Cooperation and Development (OECD), primarily its educational programmes: Programme for International Student Assessment (PISA), Education at Glance (EAG), Teaching and Learning International Survey (TALIS), as well as from UNICEF publications for Bulgaria. Of the huge number of literature sources found, the ones of interest for our study are only those that refer to the first secondary school stage (grades 8-10) and the second secondary school stage (grades 11-12) of secondary education and provide directly or indirectly reliable information about the digital skills of students and/or teachers in the field of science education in the Bulgarian context over the last dozen years. After a careful review and selection of the publications, it turned out that those of them that meet the set criteria are not many, but some of them are of considerable interest for outlining the situation in Bulgarian schools.

Review and analysis of publications on the digital competences of Bulgarian science teachers and their students according to the European digital frameworks

In this section, the findings of studies of key relevance for science education according to the DigComp and DigCompEdu requirements will be followed in turn.

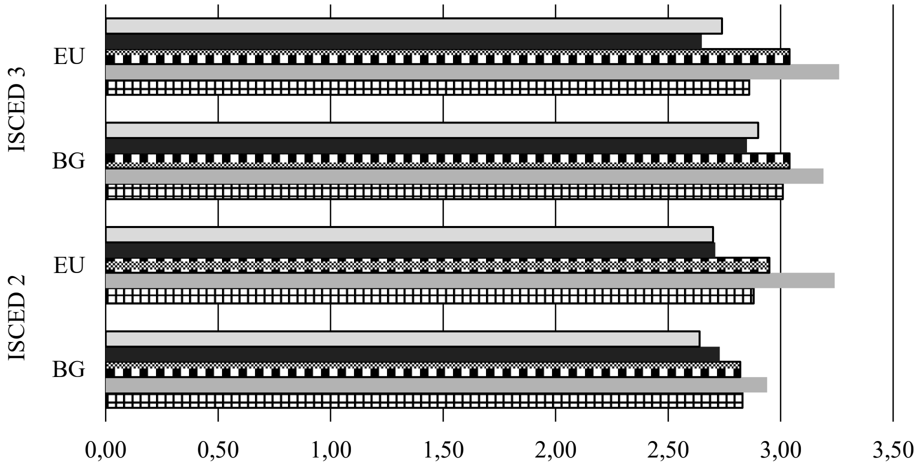
The *2nd survey of schools: ICT in Education* [6] provides information on access, use and attitudes towards the application of technologies in education through an online survey of principals, teachers, students and parents from the EU-28, Norway, Iceland and Turkey, covering three levels of the International Standard Classification of Education (ISCED): ISCED 1 - primary education, ISCED 2 - lower secondary education and ISCED 3 - upper secondary education.

In Bulgaria, the number of schools invited to take part in the survey was 2305, selected at random. Interviews were conducted with 325 principals, 81 primary teachers (ISCED 1) 272 and 217 lower secondary and upper secondary teachers, respectively (ISCED 2 and 3), 2583 students and 1653 parents.

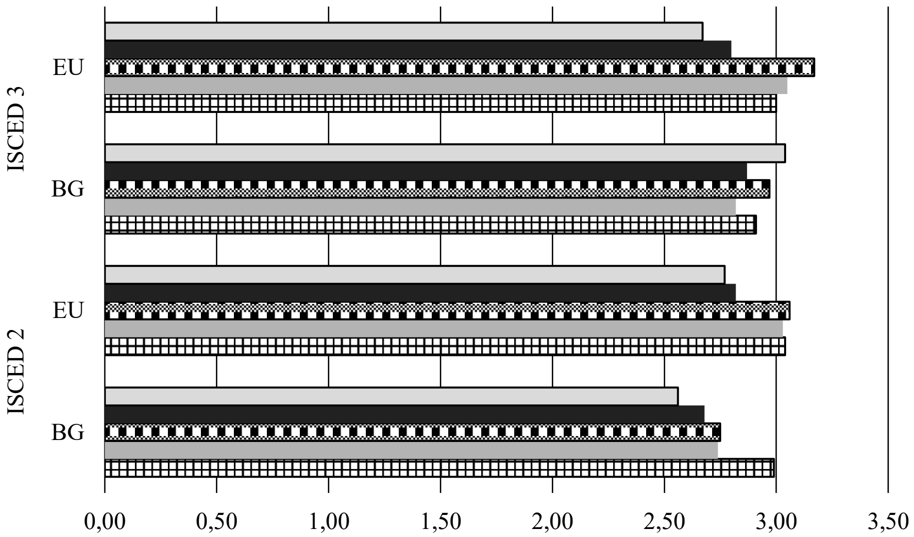
The EC study for Bulgaria, [7] has collected data on the following ten indicators: 1. Highly digitally equipped and connected schools; 2. Schools with high-speed Internet; 3. Students who use a computer at school at least once a week for learning; 4. Use of own digital equipment for learning purposes; 5. Schools supporting digital technology; 6. Students' confidence in their digital competence; 7. Coding/programming activities for female *versus* male students; 8. Teachers' confidence in their digital competence; 9. ICT related teacher professional development; 10. Parents' confidence in teaching their child how to use the Internet safely and responsibly.

In Bulgaria, the number of schools with a high level of digital equipment and connectivity is significantly lower across all ISCED levels compared to the European average, but the share of owned digital devices (tablets, laptops and smartphones) for ISCED levels 2 and 3 is higher in Bulgaria compared to the European average.

Students' confidence in their digital competence (indicator 6) is determined according to the areas of the DigComp framework: 1) information and data literacy; 2) communication and collaboration; 3) digital content creation; 4) safety; 5) problem solving. The data show a lower confidence of students in Bulgaria at ISCED 2 level in all areas of digital competence compared to the European average, but a higher confidence of Bulgarian students at ISCED 3 level in all areas of digital competence except for the areas of "Communication and collaboration" and "Information and data literacy" compared to the European average (Fig. 1).



1 a. STUDENTS



1 b. TEACHERS

Confidence: 1 – Not at all, 2 – A little, 3 – Somewhat, 4 – A lot

Fig. 1. Confidence of students (1a) and teachers (1b) in their digital competence

Despite the declared confidence of Bulgarian students, it turns out that in reality their digital competence is not very high. In his study, Tsankov [8] found "a significant discrepancy between students' self-assessment of their digital competence at the entrance to university education and the actual assessment of their knowledge and skills as basic constructs of their competence", and "significant deficits in students' cognitive and practical skills in the context of the application of information and communication technologies and working in a digital environment.", (p. 338).

Bulgarian teachers' confidence in their digital competence is lower for all ISCED levels in all areas of digital competence, except for digital content creation (ISCED 3) and problem solving (ISCED 3), compared to the European average. On the 4-level scale, it is between "Somewhat" and "To some extent", being lower than that of students, except for "Creating resources", and there is no significant difference in the area of "Problem solving" (ISCED 3), as well as in "Security" for ISCED 2.

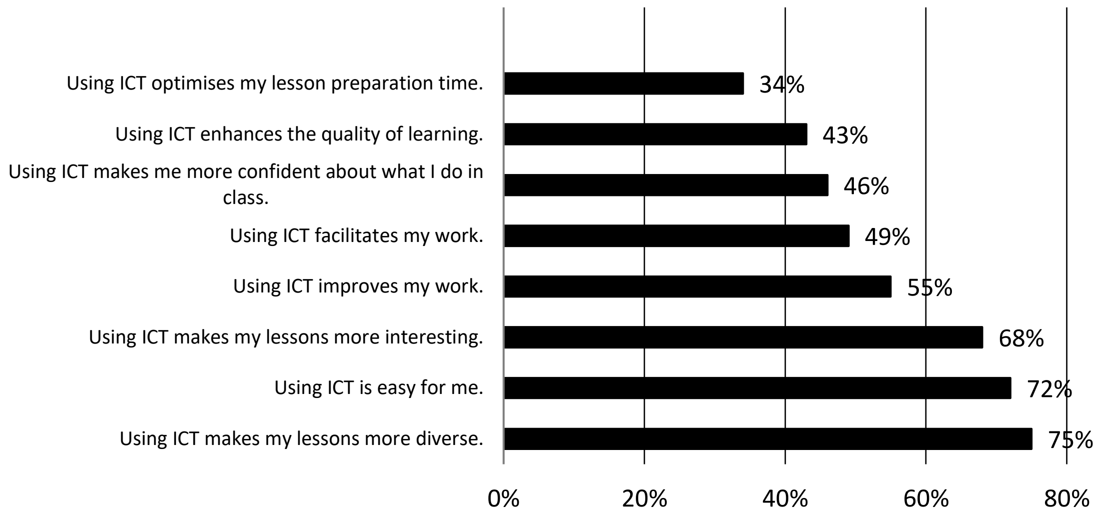


Fig. 2. Percentage of teachers who agree or strongly agree with the statements

For coding/programming activities in DigComp area 3 Digital content creation: both female and male students score between 20% and 30% lower than other European countries.

Data on the Bulgarian teachers' critical reflection of their own digital and pedagogical practice (Area 1. Professional Engagement, Indicator 1.3. Reflective Practice: "To individually and collectively reflect on, critically assess and actively develop one's own digital pedagogical practice and that of one's educational community") are presented in a national survey conducted by the Institute for Research in Education (IRE) [9] among 1885 teachers, a quarter of whom are science teachers. A high proportion of teachers (69%) was found to be satisfied with their own work during distance learning, and 22% were critical of their work.

To assess teachers' self-efficacy in using ICT in the educational process, a 5-point Likert scale was applied in several aspects: self-assessment of the use of digital technology (DT) in the educational process (Fig. 2) and self-assessment of their ability to use DT for specific purposes (Fig. 3). As can be deduced from Fig. 2, most teachers are confident that the use of ICT diversifies their lessons and makes them more interesting. Almost one half believe that ICT is a way to facilitate and improve their work.The findings of the study lead to the important conclusion that teachers' attitudes towards DT have a significant impact on the achievement of good outcomes, according to both teachers themselves and their students: "a strong linear relationship was found between teachers' attitudes about the benefits of using technology in the learning process and their self-efficacy in using ICT ($r=0.74$, $p<0.001$). This means that the more positive teachers are about the use of ICT in learning and teaching, the more optimistic they are about their own ability to work with technology and to achieve good results (for themselves and their students)" [9, p. 100]. In terms of student achievement, the correlation analysis of the researchers cited above shows "moderately positive linear relationships" between teachers' self-efficacy for ICT use on the one hand and students' interest in distance learning ($r=0.48$, $p<0.001$) and their motivation to learn ($r=0.43$, $p<0.001$) on the other. These correlations were slightly weaker in terms of students' adaptation to the distance learning organization ($r=0.42$, $p<0.001$), their acquisition of the learning content without difficulty ($r=0.41$, $p<0.001$) and their engagement with the learning process ($r=0.39$, $p<0.001$).

A study over ten years old [10], presents the results of a nationally representative survey of the competencies and attitudes of science teachers from different types of schools and regions in Bulgaria on the use of ICT in teaching. The aim of the study is to build a general picture of the competences and views of Bulgarian science teachers on the use of ICT in teaching and learning in secondary school. The data show that the share of teachers using their computer skills in almost all activities (word processing, spreadsheets, working with electronic databases, presentation software, e-mail, Internet) is relatively small (less than 25%). These data are also consistent with teachers' lack of confidence in their ability to use ICT in teaching practice. Teachers' confidence to use digital technology in the presentation of learning content is also low. A small number of teachers surveyed could create and use animations, develop their own presentations and select teaching situations appropriate for ICT use. Comparatively higher (but below 40%) is the number of those who state that they can use ready-made teaching resources from the Internet. It is noteworthy that teachers see a variety of opportunities for integrating ICT into students' activities. According to the authors of the survey, the low results are due to the fact that in Bulgarian schools there is no practice of using external experts for help, although with the development of videoconferencing technologies such activities are quite possible within the school environment.

A comparison with other similar studies shows that some of the data and results, unfortunately, have not changed, and the authors' recommendations for improving digital skills in specific pedagogical contexts are still relevant today. In the first study carried out for the EC [11], one of the main prerequisites for effectively exploiting the benefits of ICT applications to create opportunities for high quality learning for everyone was "teachers' positive attitudes towards ICT applications and their confidence in their own abilities to use them", as well as students' access to ICT. These findings are consistent with the results of the study by Kirova *et al*. [10]. Six or seven years later, however, in the second study for the EC [6], analysed at the beginning of this paper, the findings are similar.

What is noticeable in the literature reviewed is the discrepancy between teachers' self-assessment of the ease with which they deal with DT and their students' opinions. According to the study cited above [9] the proportion of teachers who think that they easily cope with ICT is high (72%). This proportion is even higher according to a nationally representative UNICEF survey [12] on e-distance learning conducted with 1229 Bulgarian students nationwide (594 aged 5 to 7 grade and 635 aged 8 to 12 grade). 11.7% of them attend specialised science schools. At the same time, however, it is worrying that a relatively high percentage of students indicated that their teachers did not cope well with distance working (28.7%), in contrast to the confidence of almost all teachers (over 98%) that they deal easily with e-learning. Students in the capital are more likely to state that their teachers cannot work well remotely. Nearly 40% of the parents of students surveyed shared a similar opinion: "teachers are not sufficiently prepared to work remotely", and almost half felt that "the teaching content is not adapted to be taught online".

Hristova *et al.* [9] show that according to the DigComp competence 5.4 Identifying digital competence gaps, half of the students stated that they did not need help to work in electronic environments. This is more the case for specialised natural sciences schools which could be explained by the fact that students in these schools are admitted after selection – by passing exams in Bulgarian language and mathematics with relatively high grades. Students over the age of 16 most often need help with an online tutoring platform and assistance in preparing lessons or homework suitable for specialized online learning software. Despite the confidence of at least half of the respondents, there was a significant discrepancy between students' self-assessment of their digital competence at the entry to university and the actual assessment of their knowledge and skills.

The findings of the same survey related to teachers' ability to use ICT for specific purposes are of particular interest. Fig. 3 presents some of them, in terms of the proportion (%) of teachers who are unconfident or slightly confident in carrying out certain DT activities. Area 2. Digital Resources of DigCompEdu notes that teachers should share resources through links or as attachments e.g. to emails; on online platforms and personal or organisational websites/blogs; to share their own resources database with others, managing their access and rights appropriately. The relatively high proportion of teachers are not confident in fairly simple activities (Competence 2.2. Creating and modifying digital content, Area 2. Digital Resources), e.g., Create a presentation with simple animation functions (24%) and Using ICT to carry out experiments (27%). Slightly less than a third of teachers are unconfident in spotting fake news. Regardless of the subjects they teach, spotting fake news is very important. For science teachers, this is a key issue as their work should be focused on shaping a scientific worldview and developing students' scientific literacy.

Another important skill for science teachers, especially in chemistry and physics, is the use of spreadsheets to create graphs. Natural sciences deal with laws and patterns, plotting research data graphically, interpreting graphs, and drawing relevant conclusions. Despite the fact that the research [9] is not focused only on the skills of science teachers, it is seen that nearly 38% of teachers have difficulties in such activities. A study by Boiadjieva [13] shows similar results, with around 35% of chemistry teachers having difficulties using spreadsheets, and less than 30% able to use animations only to some extent or to select situations appropriate for ICT use. This study also has found that around 40% of chemistry teachers are not confident in using ICT to organise activities involving participation in discussion forums with students as well as with colleagues.

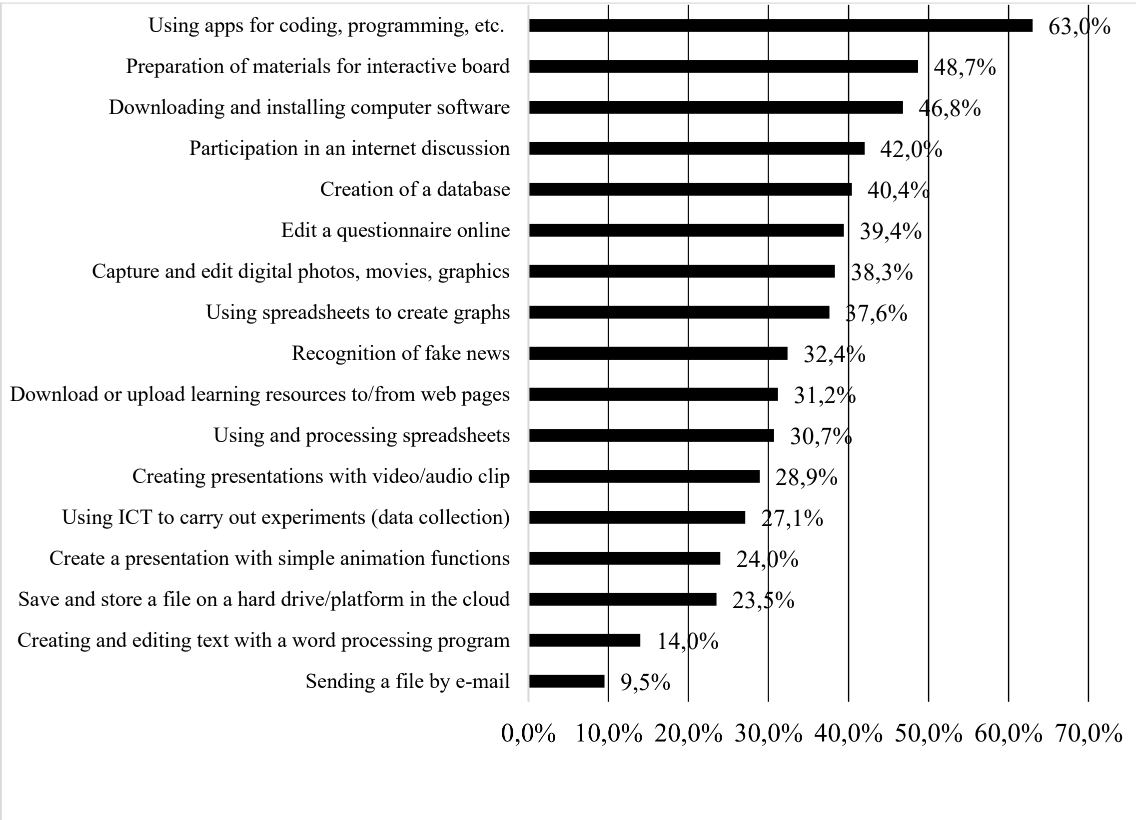


Fig. 3. Self-assessment of teachers' use of ICT for specific purposes.

Obviously, in terms of these particular activities, the situation has not positively changed. The need for training in these fields continues to be on the agenda. Special attention should be paid to the skills outlined above as they play an important role in science education.

The continuing professional education of teachers is also included in Area 1 of DidCompEdu. The effectiveness of distance learning in an e-environment is not just about having equipment, provision of digital devices, internet, and available high-quality electronic platforms. An important condition is the qualifications and experience that teachers have, as well as their commitment, behaviour and attitudes. All of them are related to effective use and integration of technologies, opportunities for active involvement and support of students in learning, adequate and timely feedback [14].

Based on the data in Fig. 3, it can be concluded that despite participation in trainings, there is a deficit in teachers' ability to use DT. A study conducted with 348 Bulgarian biology teachers [15] shows that the highest proportion of teachers experienced difficulties in creating diagnostic and assessment electronic materials (over 85%), followed by the proportion of teachers who had difficulties in developing audio and video resources (over 67%). Over 90% of teachers felt that they needed training to implement innovative methods using DT. These results confirm the conclusions about the need for targeted qualification courses tailored to the content of the subject area.

A survey of the views of 79 Bulgarian chemistry teachers [16] in two areas: opportunities for ICT application in chemistry classes, and chemistry teachers' competences for integrating ICT in the classroom. The results do not reveal a clear relationship between teachers' views and attitudes on the one hand, and on the other hand with opportunities for using computer technology in chemistry classes in for problem solving; improving communication and collaboration; and developing critical thinking and creativity (Area 6, DigCompEdu). Findings from the study point to the need for further training for chemistry teachers to help them more fully unlock the potential of ICT to enhance teaching and develop key skills for students in a digital society.

According to the Teaching and Learning International Survey (TALIS) of teachers and school leaders on school environments [17], the participation of Bulgarian teachers (ISCED 2) in ICT-related training is 63.3%, which is the same as the average for all teachers who participated in TALIS 2018 (63%). At the same time, 23% of Bulgarian teachers state that they need DT-related training in teaching, while the average for TALIS

2018 is 20%. According to TALIS, even if teachers received professional qualifications in this area years ago, due to the rapid development of ICT and the increasing penetration of digital technologies in teaching, they need to continuously update their knowledge and skills. Distance learning during the pandemic of COVID-19, showed that developing DC should have the highest priority in teachers' professional development.

The IER monitoring report [9] also poses research questions related to an examination of teachers' use of educational resources that meet Area 2. Digital resources from DigCompEdu. Appropriate didactic materials and resources are crucial for the implementation of effective teaching in both traditional and electronic environments. Nearly 15% of the Bulgarian teachers surveyed used available educational resources, with only 17% using educational resources created by colleagues teaching the same subject in their own school.

Other important requirements for this area are: sharing digital content by respecting intellectual property and copyright; complying with any copyright restrictions on the use, reuse and modification of digital resources; citing sources appropriately when resources are shared or published under copyright. The literature search found no evidence for Bulgaria in these aspects. Clearly these requirements are important and could be a subject not only for research but also for targeted training of both teachers and students.

An online survey compiled under the DigCompEdu framework [18] has found that the predominant level of digital competence of 81.8% of teachers surveyed on almost all criteria was A2 Explorer. Teachers identified at A2 level should be aware of the potential of digital technologies and are interested in exploring and mastering them to enhance pedagogical and professional practice. This conclusion coincides with the findings of the international studies presented above as well as the Education and training monitor report on Bulgaria of EC [7].

Many requirements in Area 3. Teaching and Learning of DigCompEdu: 3.1 Teaching; 3.2 Guidance; 3.3 Collaborative learning and 3.4 Self-regulated learning are at the heart of the constructivist approach. Learning in a constructivist environment is the focus of current educational standards and curricula in many countries, including Bulgaria. Researchers find a deep connection between the effective use of ICT in the educational process and the application of constructivist approach in teaching practice. In the spirit of constructivist ideas, therefore, some of the questions in the IER survey [9] have been selected, while at the same time they can be related to Area 3 of DigCompEdu, namely (a) the way the learning content is presented; (b) the opportunity for students to work independently; (c) the stimulation of students to participate in the construction of knowledge; (d) practices for checking students' work and monitoring their progress; (e) practices for providing additional support to students who are experiencing difficulties. The responses of the Bulgarian teachers on the opportunities they have had to use educational resources and different teaching methods are of particular interest. More than 70% of them say that they had used more educational resources and that they had experimented with using more different teaching methods in the online environment than in face-to-face teaching. However, there is a certain inconsistency in the responses of these teachers with their answers concerning the teaching practices and methods applied. More than 70% of the teachers have declared that they presented and explained the learning content. The same percentage of teachers have sent ready-made learning materials for independent work. The result is similar for teachers who have sent and checked the completed tasks photographed or scanned. A significant proportion of teachers used platforms for these activities, but a relatively small proportion of teachers implemented elements of constructivist learning in an e-environment, and as would be expected, these were most prevalent at the high school level.

Similar results were found in the TALIS 2018 survey [17]: the least common teachers practices in ICSED 2 are using IT in class or for a project – 44.2% of Bulgarian teachers vs. 51.3% on average for TALIS, and having students work in small groups to solve a problem – 48.6% of Bulgarian teachers vs. 52.7% on average for the survey.

Regular assessment of student progress and good quality, relevant and timely feedback are seen as key factors in the process of learning and have one of the most significant impacts on student learning achievements. DT extend opportunities for both summative and formative assessment, feedback and self-assessment skill formation (DigCompEdu, Area 4. Assessment: 4.1. Assessment strategies; 4.2. Analyzing evidence; 4.3. Feedback and Planning). According to the IRE survey [9], almost 70% of teachers have carried out assessment-related activities, but the percentage of teachers who have rarely engaged in assessment of their students is not small, at around 30%. E-learning allows the use of different ways to develop self-assessment skills. The IER study mentioned above reports some hesitancy and uncertainty among teachers about the objectivity of the grades they give students for various reasons, e.g., copying, help from other persons. This feedback from a significant number of practicing teachers casts serious doubt on the real contribution of regular student assessment. In this context, the use of different tools for both assessment and self-assessment can have a positive impact on the effectiveness of monitoring and diagnosis of distance learning.

Understanding the real situation regarding DC is particularly important to develop the digital competences needed for the near future in a society we now call Society 5.0. A study at the University of Maribor, Slovenia has shown that "neither teachers nor students are sufficiently qualified to work in the society of the future, in society 5.0." [19, p. 118]

Digital technologies and students' academic performance in science

Digital technologies undoubtedly facilitate teaching and learning in many cases. Without them, distance learning during the COVID-19 pandemic could not have taken place given the extent and duration of school closures. Yet, despite the obvious advantages of DT use in education, it turns out that, in many cases, the use of DT does not improve students' academic performance and sometimes even worsen it.

An OECD [20] study based on PISA 2015 presents data on the availability of digital resources, their use in teaching and learning, and the relationship between ICT use and achievement among 15-year-old students. It may seem a paradox, but the PISA data show that for a given level of per capita gross domestic product (GDP), and after accounting for the initial level of performance, countries that invested less in introducing of computers in schools improved their performance faster on average than countries that invested more. The results are similar for reading, mathematics and science [20, pp. 150-151]. As will become clear later from the analysis of publications of a number of researchers, there is no correlation between student achievement and the use of digital resources. The achievement-digitization relationship in education is multi-component and therefore complex and difficult to study, which is why the results of different studies are contradictory. An analysis of Trends in International Mathematics and Science Study (TIMSS) data [21] compare differences in computer use in mathematics and science with differences in student achievement. It was found that math scores are unrelated to computer use, while science scores are positively linked only in cases such as looking up ideas and information, and the effect is "detrimental" when DT is used to practice skills and procedures. The authors conclude that the "policymakers and educators all over the world rush to bring computers into every classroom but such enthusiasm and costly investment is hard to reconcile with the available evidence that computer use in schools has little if any effect on student achievement." After all, "the overall effect of using computers in schools is generally close to zero" (p. 22).

A 2023 literature review [22] has listed a number of studies, some from 2022, that have found positive impacts of DT on science learning and also on subjects in STEM (science, technology, engineering, and mathematics) disciplines.

Another literature review [23] on the impact of computer simulations on science process skills has found that simulations help more in the presentation and understanding of science concepts than traditional teaching methods, but without combining them with other teaching methods they are not effective enough. Virtual laboratories pose problems, e.g. students do not acquire the skills for practical work in a real laboratory environment and the uptake of science process skills is at a low level.

According to Hristova *et al.* [9] "very few teachers, between 4% and 9% strongly agree that distance learning was more effective than face-to-face learning in terms of student outcomes." Between 21% and 28% of teachers did not express a definite opinion about the effects of distance learning on student interest and motivation. These, as well as the findings of other studies [14, 24], lead to the conclusion that the more positive attitudes teachers have towards the use of ICT, the easier their students adapt to distance learning in an electronic environment, having a greater interest, motivation and engagement in the learning process and learn the teaching material more easily.

Hattie and Yates [25, p. 274] report that if computers are not used as an alternative to traditional teaching, but rather complement it, their impact on student performance is stronger. According to these authors, positive effects were achieved in activities that applied the same instructional principles as traditional teaching. There are topics in science subjects that have abstract or theoretical content where visualization through digital resources helps considerably in understanding and learning. Interactive methods such as computer simulations, animations, and YouTube videos increase interest and understanding of difficult concepts. A common practice in Bulgarian schools is to use You Tube channels such as Khan Academy (https://www. khanacademy.org). However, in these channels, sometimes there are a lot of gaps and inaccuracies in the visualization and explanation of information from a scientific point of view, which can lead to misconceptions. These digital resources should serve as supplementary rather than core didactic material, as is sometimes observed in practice.

Hu *et al.* [26], as well as Petko *et al.* [27], have found that students who use ICT devices at home for entertainment achieve higher science scores while ICT use by students at school correlates negatively with their academic performance. This result seems paradoxical at first, but quite a few other researchers have reported a similar effect. For students from 25 European countries in PISA 2015, medium and high ICT users scored lower in science than those with little ICT use [28]. Other authors [29] have also found that ICT use for entertainment at home is positively correlated with science scores in Turkey but this is not the case in Finland.

In their article "The Relation between ICT and Science in PISA 2015 for Bulgarian and Finnish Students", Canadian researchers [30] examine the extent to which ICT helps or hinders students' school achievements in science and the relationship between ICT and student performance in science in two European countries – Bulgaria and Finland. The choice of the two countries – Finland and Bulgaria, for the comparative analysis the authors justify as follows: Finland is considered a digital leader due to its high level of DT, the small gap between high and low technology users, and good welfare in general. In Bulgaria, the gap between high- and low-tech users is large, the DT are relatively late entrants to the free market, and student achievements in school are relatively low. Referring to European Commission reports the authors note that in the high-performing country Finland, the digital competence of students and teachers is higher than both the European and Bulgarian average. Finland is much better equipped with digital technology than Bulgaria, but when it comes to computer use, the two countries show similarities. This study investigates whether ICT-related factors such as availability of digital devices, their use, independent work, interests and competence in DT, and social interactions are associated with higher or lower science scores of Bulgarian and Finnish students. PISA 2015 data for 5,928 Bulgarian students and 5,882 Finnish students aged 16 years 3 months and 16 years 2 months were used. In general, the authors' literature review shows that the results are inconsistent. In both Bulgaria and Finland, students who perceive themselves as competent and capable of working independently with ICT, for whom ICT is among their topics of conversation and have a strong interest in DT are positively linked to higher science scores, while the use and availability of ICT technologies at home and at school for academic work or leisure are negatively related to science scores. The study finds no association between science scores in Finland and the availability of ICT devices, and that ICT use does not contribute to higher science scores for the majority of students in Finland.

Why does the use of ICT for learning purposes at school and at home lead to lower science scores? Possible explanations are that students are distracted by ICT while engaged in an activity, or spend more time on extracurricular ICT activities that take them away from academic tasks; or the time spent on ICT is at the expense of academic work. Excessive computer use, especially for non-academic purposes (social media, gaming, etc.), can lead to distractions and decreased focus on students' learning impacting negatively academic performance. Another possible explanation is that students do not sufficiently mobilize their own mental capacity and knowledge, but rely only on easily accessible information using the Internet, artificial intelligence, and various digital applications.

The only component of ICT for which all studies have found a positive relationship with science achievement is the ability to work independently with ICT. ICT competence is the second factor with a positive relationship. Therefore, the authors believe that it is important to determine which ICT component has a greater impact on student achievements in science and this can serve as a first step in identifying the sources of some of the conflicting results between ICT and science.

CONCLUSION

The forced shift to e-learning due to the Kovid 19 pandemic has revealed both positive and negative aspects of students' and teachers' digital technology skills. It cannot be denied, though, that the situation has resulted in an acceleration of the use of digital resources and technologies and an increase in the digital competencies of teachers and students.

The analysis of the literature has largely made it possible to answer the research questions posed.

Overall, the analysis shows that despite Bulgarian students and teachers declared relatively high confidence to work with DT, in reality their digital competence is lower in most areas reflected in the DigComp and DigCompEdu frameworks compared to the European average.

The survey results outline several problematic areas of digital competences for Bulgarian teachers according to DigCompEdu. In addition to the difficulties found in activities related to creating and modifying digital content, the lack of collaboration between teachers that is highlighted in much of the research is of concern. The fact that a similar outcome is observed among Bulgarian students is not to be overlooked. From a science perspective, teachers' difficulties in identifying fake news also stand out, which is particularly important for developing a scientific worldview and scientific literacy in their students. Activities related to assessment of students' progress and ensuring high-quality, relevant, and well-timed feedback also emerged as a serious problem.

The quality of continuing teacher education aimed at the development of digital competences is also a problematic area. Regardless of the data on the participation of a high percentage of teachers in such trainings, the existing skills deficit in the use of technology requires training in which DT is targeted to the specific subject area.

However, a large proportion of Bulgarian teachers express satisfaction with their own work during distance learning and this is also evident in their self-efficacy ratings. A good sign is the declared confidence of most teachers that the use of ICT diversifies their lessons and makes them more interesting.

Regarding the second research question related to identifying a correlation between the use of digital technologies and students' science learning achievements, the analysis of the publications does not provide a definitive answer to this question without pretending to the completeness of the study. Much of the studies show a lack of correlation between student performance and the use of digital resources. The reason for this can be sought in different aspects of the achievement-digitalisation relationship, which makes the field complex and difficult to study. The focus is rather on the possible positive effect when computers are used to complement traditional teaching and not as an alternative to it.

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