The State of ICT Implementation in Ukrainian General Secondary Education Institutions in 2019 and 2020

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Abstract: The use of digital technology in various fields of education today is one of the most important trends in the educational process in the world. The article presents the results of the analysis of the current state of implementation of ICT in the educational process of institutions of general secondary education in Ukraine. For this purpose, a survey was conducted among students of the first year of the Zhytomyr Polytechnic State University of 2019 and 2020 years of admission, within which 17 questions were asked to students related to the use of information and communication technologies in the educational process. As a result of the research, the introduction of the discipline "Educational technologies and digital education" into the training of future information technology specialists was substantiated, as well as the certification educational program "Information systems and cloud technologies in the educational process", designed for general education teachers, educators for higher education institutions, experts in the field of additional educational services, and other professionals. Besides, the course "Application Packages" for specialties 121 "Software Engineering", 122 "Computer Science", 123 "Computer Engineering", 125 "Cybersecurity" and 126 "Information Systems and Technologies" at the Zhytomyr Polytechnic State University has been expanded for study some cloud services that can serve as an alternative to the usual MS Office. In conclusion, we can conclude that the positive dynamics in the use of various ICT tools in education is present (in comparison with school graduates in 2019 and 2020). This means that teachers are increasingly turning to such tools when teaching their subjects.

1 INTRODUCTION

The Law of Ukraine "On Education" states that the formation of information and communication competence in students is mandatory (Verkhovna Rada of Ukraine, 2017) because digital competence is recognized by European Union as one of the key competencies (Moiseienko et al., 2020). As a result, as stated in the conceptual framework of the digitalization of Ukraine, target audiences in the implementation of the state program on digital literacy are an elementary school, secondary school, vocational school, and higher education institutions (HEI) (HiTECH-office, 2016).

The use of digital technology in various fields of

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education today is one of the most important trends in the educational process in the world (Hlushak et al., 2020; Leshchenko et al., 2020; Ovcharuk et al., 2020; Pinchuk et al., 2019). Such technologies allow making the learning process more qualitative and interesting because using the media and interactive tools the teacher can introducing the different methods of working in the classroom: project method, research and development work, educational games, etc. (Demirbilek and Koç, 2019; HiTECH-office, 2016; Tokarieva et al., 2019).

Also, the latest situation with the pandemic spread of COVID-19 and corresponding measures that cause disruptions in the educational process around the world one more time emphasizes the importance of ICT in Education.

The issues of computerization and informatization of the educational process are widely consid-

ered in (Bondarenko et al., 2020; Bykov et al., 2001, 1994; Chorna et al., 2019; Fedorenko et al., 2019; Iatsyshyn et al., 2020; Lavrentieva et al., 2020; Mintii and Soloviev, 2018; Nechypurenko et al., 2020; Popel et al., 2017; Rakov et al., 2009; Rashevska and Soloviev, 2018; Seidametova, 2020; Spivakovsky et al., 2019; Struik et al., 2018; Talyzina, 1974; Trius et al., 2004; Zhaldak and Franchuk, 2021).

Also, the issue of the introduction of various ICT in the educational process of educational institutions is considered by foreign scientists.

In particular, Shakeabubakor et al. (Shakeabubakor et al., 2014) considering cloud computing services and applications to improve the productivity of university researchers.

Almerich et al. (Almerich et al., 2016), Kuzminska et al. (Kuzminska et al., 2019) analyzed teachers' information and communication technology competences. The use of cloud computing in higher education is considered in (Bansal et al., 2012; Biswas, 2011; Britto, 2012; Dineva and Nedeva, 2012; Ercan, 2010).

Dzikite et al. (Dzikite et al., 2017) investigated lecturers' competencies in ICT for effective implementation of ICT-integrated teaching and learning in textiles and clothing degree programs. Hanson-Baldauf and Hughes (Hanson-Baldauf and Hughes, 2009) reveal issues in the information and communication technology competencies of students enrolled in school library media certification programs. Kaplan and Haenlein (Kaplan and Haenlein, 2016) analyze the problem of higher education and the digital revolution.

The *purpose* of this article is to establish the current state of implementation of ICT in the educational process of institutions of general secondary education in Ukraine in 2019 and 2020 years.

2 RESEARCH METHODS

To find out the current state of implementation of various ICT in the educational process of institutions of general secondary education, as well as to form a group of selective disciplines, a survey of students of the first year of the Zhytomyr Polytechnic State University was conducted. In total, 167 respondents participated in the survey in the 2019 year, and 214 respondents in the 2020 year.

Students were asked to answer the following questions (Vakaliuk, 2019):

1. Do you know what application packages are?
2. Did you study application packages at school/college?

3. What kind of application packages have you studied/reviewed?
4. From which package did you study office application packages (text editors; spreadsheets; database management systems; demo tools)?
5. Do you know what "cloud services" is?
6. Which of the following programs and services is cloud-based?
7. Do you know what massive open online courses are?
8. Do you use these courses at school/college?
9. If the answer to the previous question is "Yes", which one?
10. Have you used massive open online courses for self-study?
11. Did teachers use any other tools when studying programming in Computer Science?
12. If the answer to the previous question is "Yes", what are the tools?
13. Did any information and communication technology tools (curricula, multimedia, simulators, games, virtual laboratories, etc.) be used in the school/college by non-CS teachers?
14. If the answer to the previous question is "Yes", in what lessons did the teachers use such tools?
15. Which one did you enjoy the most and why (also indicate the item on which it was used)?
16. Was the teaching of this subject more interesting using a variety of tools than without using them?
17. What additional services would you like to consider and explore how to use them?

3 RESULTS

Let us analyze the answers to each question. First question "Do you know what application packages are?" the purpose was to establish whether the first-year students have basic concepts of the school course in Computer Science (CS). The results of the survey indicate that 91% of students have basic concepts, 9% do not in the 2019 year, and 2020 year – 87,4% of students have basic concepts, 12,6% do not (figure 1).

Regarding the second question, "Did you study application packages at school/college?", in the 2019 year 18% said no and 82% said yes, and in the 2020 year 21% said no and 79% said yes (figure 2). This indicates that either the teacher did not adhere to the standard of general education, or the first-year students do not understand the basic concepts of CS.
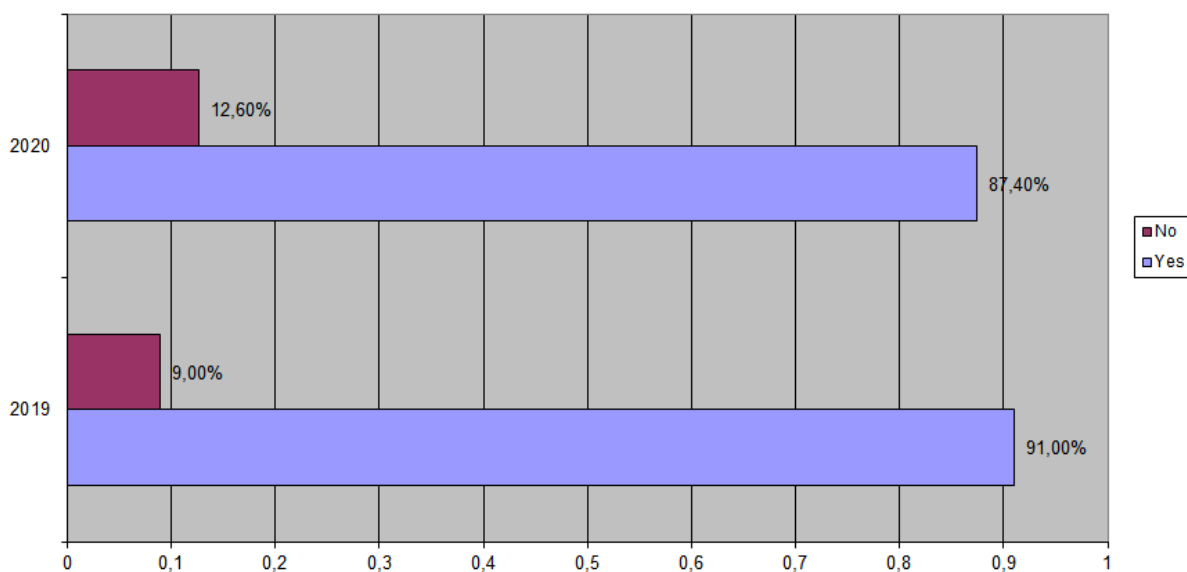
Figure 1: Percentage of answers to question # 1 "Do you know what application packages are?" (comparison of 2019 and 2020).
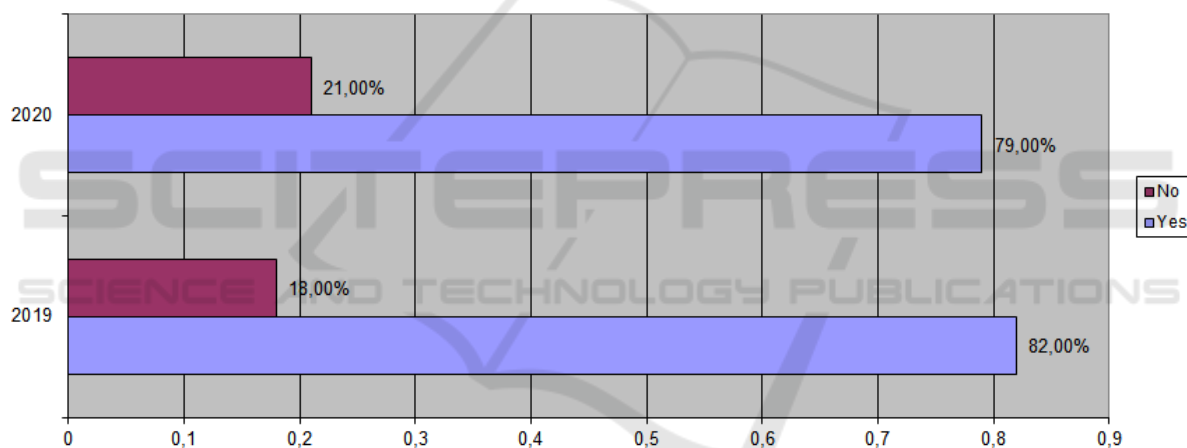

Figure 2: Percentage of answers to question # 2 "Did you study application packages at school/college?" (comparison of 2019 and 2020).

The answer to what exactly served as this distribution of answers to the previous question is to analyze the answers to the following. In response to the question "What kind of application packages have you studied/reviewed?", all 167 respondents in the 2019 year and in the 2020 year – all 214 chose least one of the suggested options, which means that as a student they studied everything they needed, they just did not have the necessary terminology. In this case, in the 2019 year, 88% of respondents noted that they studied text editors, 77,8% – spreadsheets, 65,3% – tools for creating demonstration material, 38,3% – database management systems, 32,3% – graphic editors, 22,2% – educational programs, 16,8% – multimedia systems and computer games (figure 3). And in

the 2020 year, 93,9% of respondents noted that they studied text editors, 84,6% – spreadsheets, 74,3% – tools for creating demonstration material, 38,3% – database management systems, 51,4% – graphic editors, 23,4% – educational programs, 27,1% – multimedia systems and computer games (figure 3).

During the informatization of society, new ICT are constantly appearing, which are replacing the usual applications. One of such ICT is cloud technology – a service that allows remote use of data processing and storage tools.

The next question was to find out whether schools use the standard MS Office suite, or whether some teachers use cloud services. Results of the answers to the question "From which package did you study of-
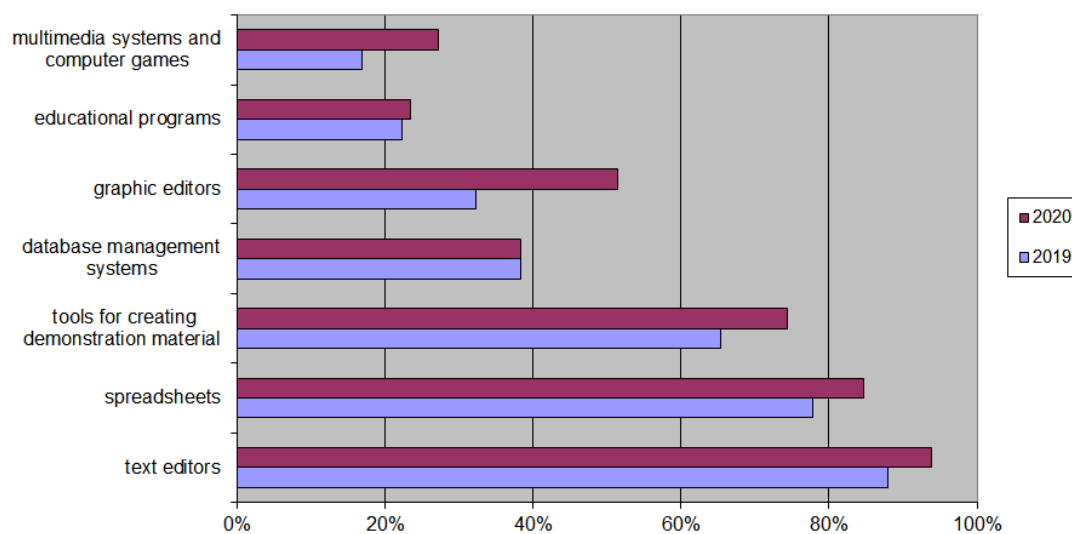
Figure 3: Percentage of respondents' answers to question # 3 "What kind of application packages have you studied/reviewed?" (comparison of 2019 and 2020).

fice application packages (text editors; spreadsheets; database management systems; demo tools)?" in the 2019 year are: 80,2% of those surveyed had studied MS Office, 22,2% had studied Office 365, and 24% had studied Google services, and in the 2020 year: 79,4% of those surveyed had studied MS Office, 28% had studied Office 365, and 31,3% had studied Google services (figure 4). In particular, 59,3% (99 people) in the 2019 year and 51,9% (111 people) in the 2020 year of the proposed list chose MS Office only. It is worth noting that in 2020 there were isolated cases of choosing the WPS Office.

That is why the next question was "Do you know what "cloud services" is?", to which 84,3% answered "yes" and the other 15,7% answered "no" in 2019, and in the 2020 year 88,3% answered "yes" and the other 11,7% answered "no" (figure 5). Although the study of cloud services is also included in the CS curriculum, not all school teachers adhere to the relevant document.

Answers to the following question "Which of the following programs and services is cloud-based?" are quite interesting as in the 2019 year 13,4% of respondents said that MS Office is a cloud service, and in the 2020 year – 7,5% gave the same answer. Also in 2019, 12,7% said Office 365 was cloud-based, 82,6% noted Google services, and 7,6% noted Prezi, and in the 2020 year 20,4% noted that Office 365 was cloud-based, 86,1% chose Google services, and 16,9% selected Prezi (figure 6). It's worth noting that Office 365, Google, and Prezi are among the cloud ones listed. The positive dynamics in the correct answers indicate that since 2020, graduates have met in

the school curriculum with cloud services more often than graduates of 2019.

As Zhytomyr Polytechnic State University actively introduces massive open online courses, the following question "Do you know what massive open online courses are?". The survey results in the 2019 year indicate that 74,3% know what it is, the other 25,7% do not, and in the 2020 year – 78% know what it is, the other 22% do not (figure 7).

In doing so, in response to the question "Do you use these courses at school/college?" in the 2019 year 88,6% of students (percent of those who answered "yes" to the previous question) answered, "yes", and in the 2020 year – 92,5% (figure 8).

To find out what kind of open online courses are used in the educational process of general secondary education institutions, the following question was analyzed: "If the answer to the previous question is "Yes", which one?". The analysis of the results shows that in most cases 50% in the 2019 year are Cisco Academy courses, but in the 2020 year, this indicator is 23,8%. In some cases (13,6% in the 2019 year and 28,6% in the 2020 year) are Prometheus, and all others are isolated cases of other courses. It should be noted that Zhytomyr Polytechnic is closely cooperating with Cisco Academy, as a result of cooperation in the institution of higher education actively used courses of the said academy in the educational process (when studying courses "Computer Networks", "Python Programming", "Cybersecurity").

Also, to facilitate the use of massive open online courses (MOOC) in students' independent work, the following question "Have you used massive open on-
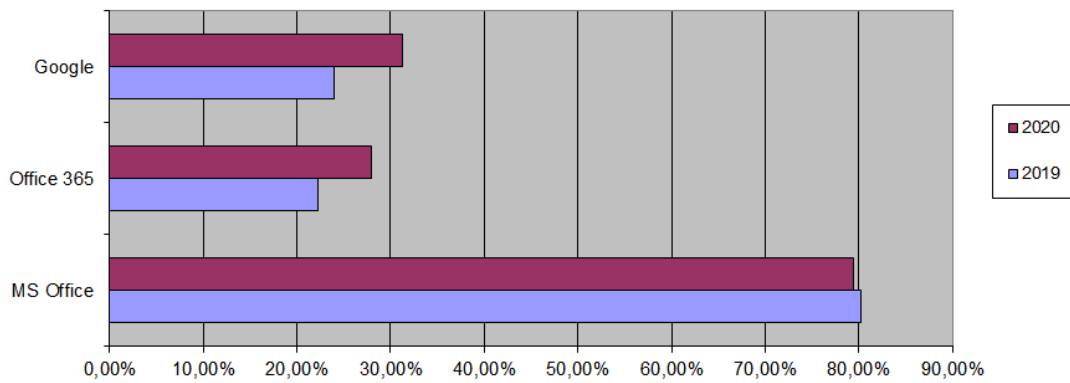
Figure 4: Percentage of respondents' answers to question # 4 "From which package did you study office application packages (text editors; spreadsheets; database management systems; demo tools)?" (comparison of 2019 and 2020).
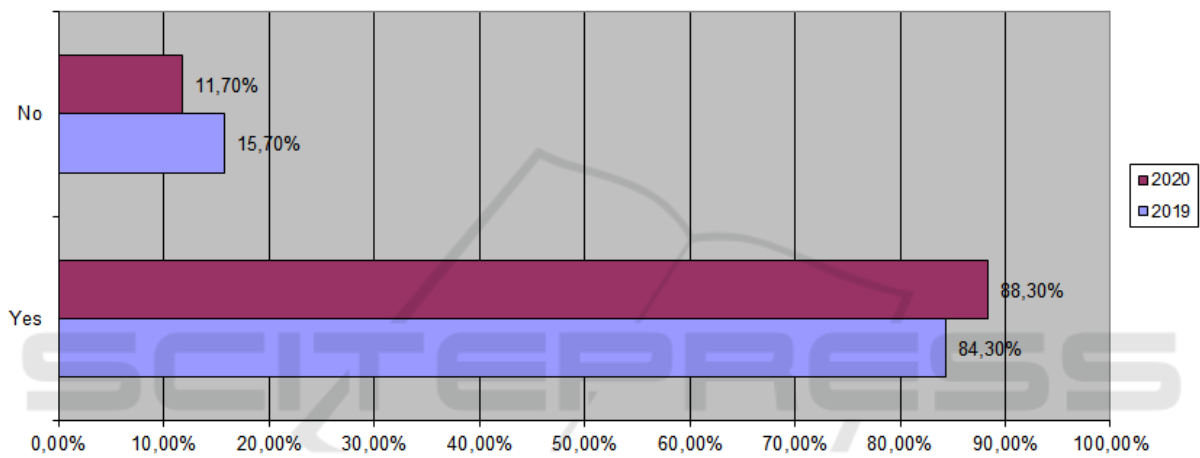

Figure 5: Percentage of respondents' answers to question # 5 "Do you know what "cloud services" is?" (comparison of 2019 and 2020).
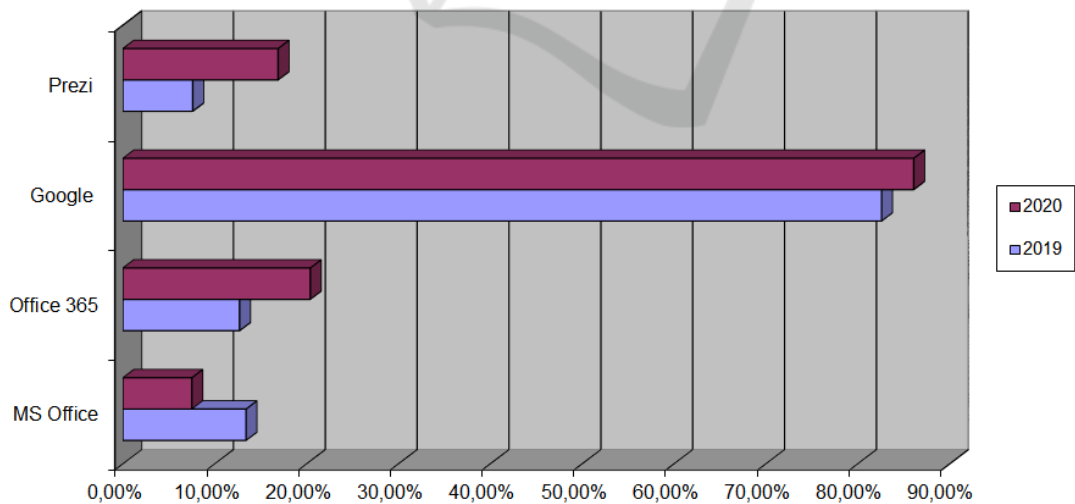

Figure 6: Percentage of respondents' answers to question # 6 "Which of the following programs and services is cloud-based?" (comparison of 2019 and 2020).

line courses for self-study?". The results of the survey (in the 2019 year – 67,1% – yes, 32,9% – no, in the 2020 year – 74,1% – yes, 25,9% – no, see figure 9) indicate that not all students used MOOC for indepen-
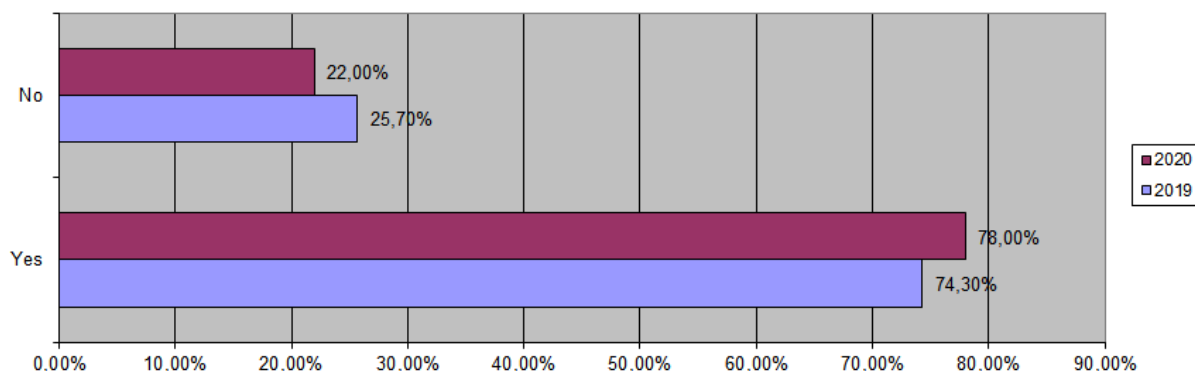
Figure 7: Percentage of respondents' answers to question # 7 "Do you know what massive open online courses are?" (comparison of 2019 and 2020).
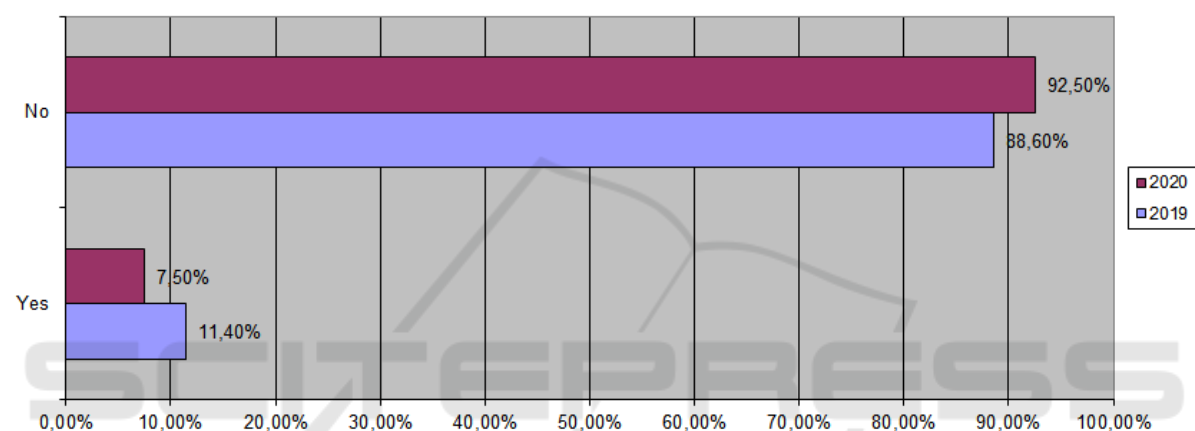

Figure 8: Percentage of respondents' answers to question # 8 "Do you use these courses at school/college?" (comparison of 2019 and 2020).

dent work, and therefore, before using these courses, it is worth conducting coaching for students who do not know how to use such MOOC.

Also, an important question was, "Did teachers use any other tools when studying programming in Computer Science?", in which 49,1% said "yes, they used", 50,9% – no in the 2019 year, and 51,9% said "yes, they used", 48,1% – no in the 2020 year (figure 10).

To find out what kind of tools were still used in CS lessons, the following question was asked: "If the answer to the previous question is "Yes", what are the tools?". The results (figure 11) indicate that in the 2019 year 32,2% of the respondents worked with online compilers, and in the 2020 year, this indicator is 21,6%, 33,3% in 2019, and 34,5% in the 2020 year with automated programming tasks, 50,6% in 2019 and 58,6% in the 2002 year – with simulators, 52,9% in 2019 and 53,4% in 2020 – with training games. According to previous research (Vakaliuk et al., 2020), it is with online compilers and automated systems for checking programming tasks that computer teachers

want to work on in the educational process, but for some reason, they are not used yet. However, as can be seen from the studies of 2019 and 2020, teachers are beginning to use simulators more often in their work.

As ICTs can be used not only in CS lessons, the next question was "Did any information and communication technology tools (curricula, multimedia, simulators, games, virtual laboratories, etc.) be used in the school/college by non-CS teachers?".

Survey results indicate that in 48,5% in the 2019 year and 50,9% in the 2020 year of cases ICT was used in other lessons, in 51,5% in the 2019 year and 49,1% in the 2020 year it was not (figure 12). This shows that even the conditions created for non-CS teachers through quarantine do not contribute to the development of their competence in the use of ICT.

Among those who answered "yes" to the following question "If the answer to the previous question is "Yes", in what lessons did the teachers use such tools?" were distributed as follows (figure 13): 50% in 2019 and 49,1% in 2020 – ICT used in language
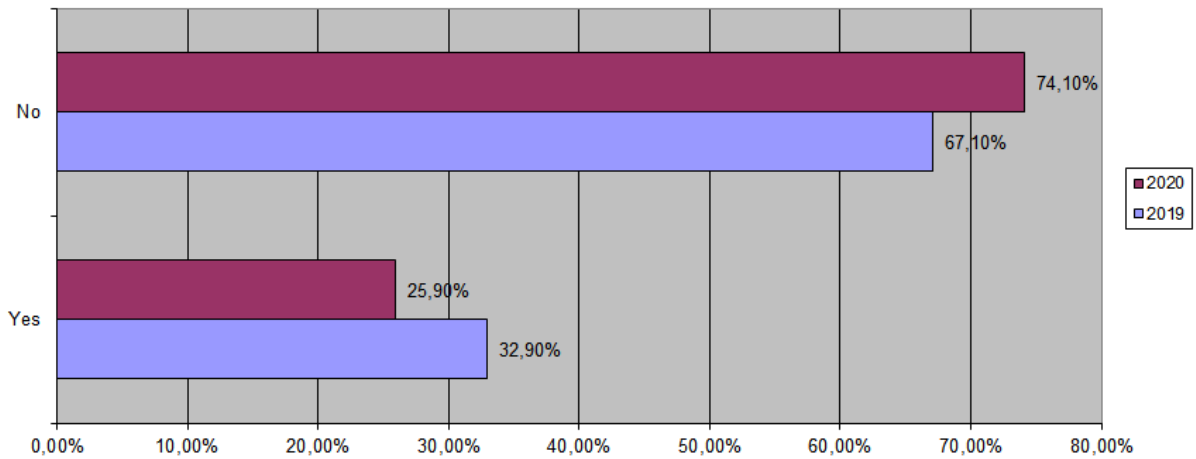
Figure 9: Percentage of respondents' answers to question # 10 "Have you used massive open online courses for self-study?" (comparison of 2019 and 2020).
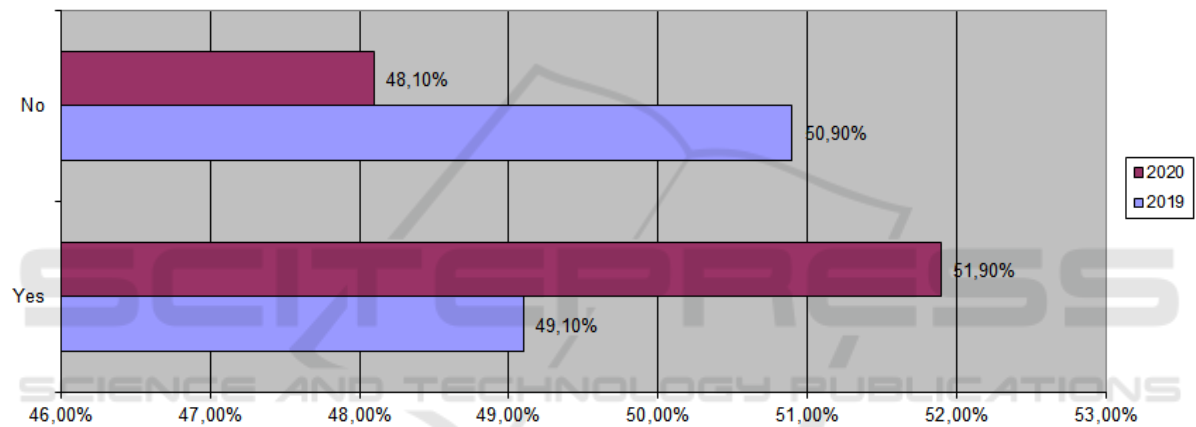

Figure 10: Percentage of respondents' answers to question # 11 "Did teachers use any other tools when studying programming in Computer Science?" (comparison of 2019 and 2020).
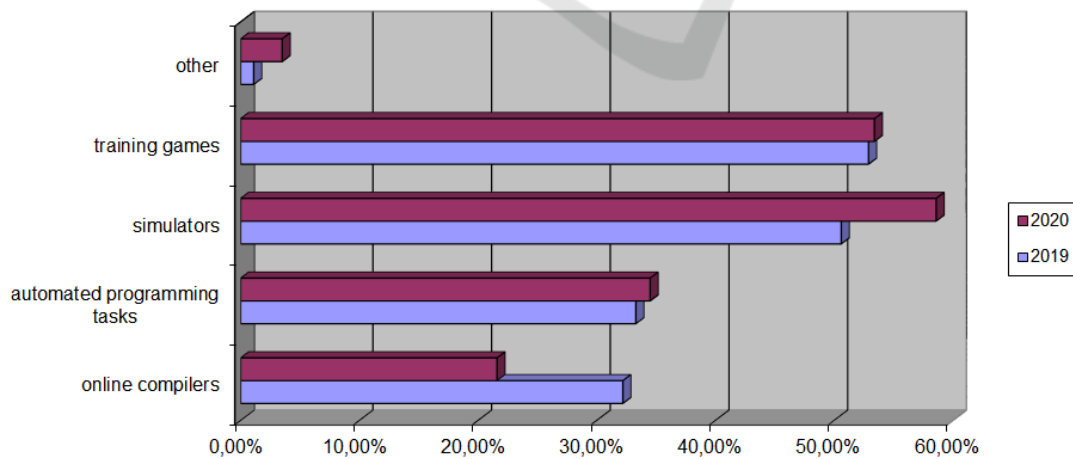

Figure 11: Percentage of respondents' answers to question # 12 "If the answer to the previous question is "Yes", what are the tools?" (comparison of 2019 and 2020).

and literature lessons; 48,8% in 2019 and 48,2% in 2020 – in mathematics lessons; 43,8% in 2019 and 57,3% in 2020 – physics; 38,8% in 2019 and 27,3% in 2020 – history; 33,8% in 2019 and 39,1% in 2020 –
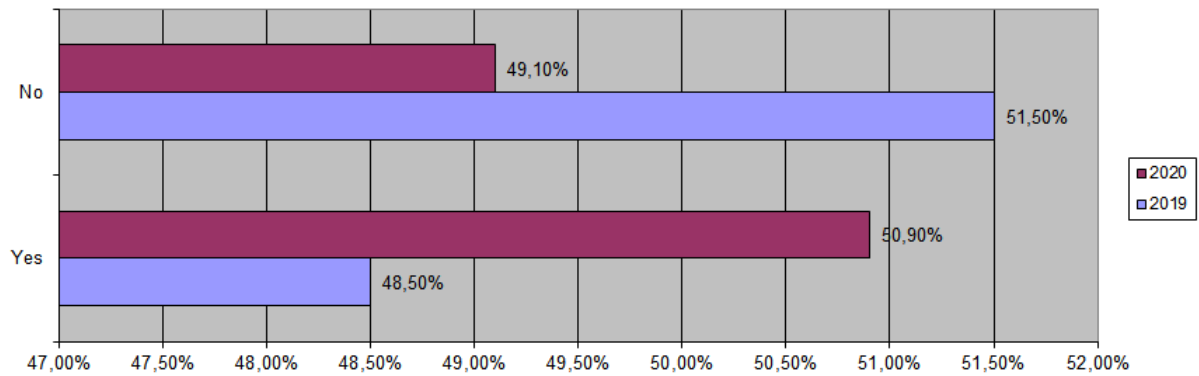
Figure 12: Percentage of respondents' answers to question # 13 "Did any information and communication technology tools (curricula, multimedia, simulators, games, virtual laboratories, etc.) be used in the school/college by non-CS teachers?" (comparison of 2019 and 2020).
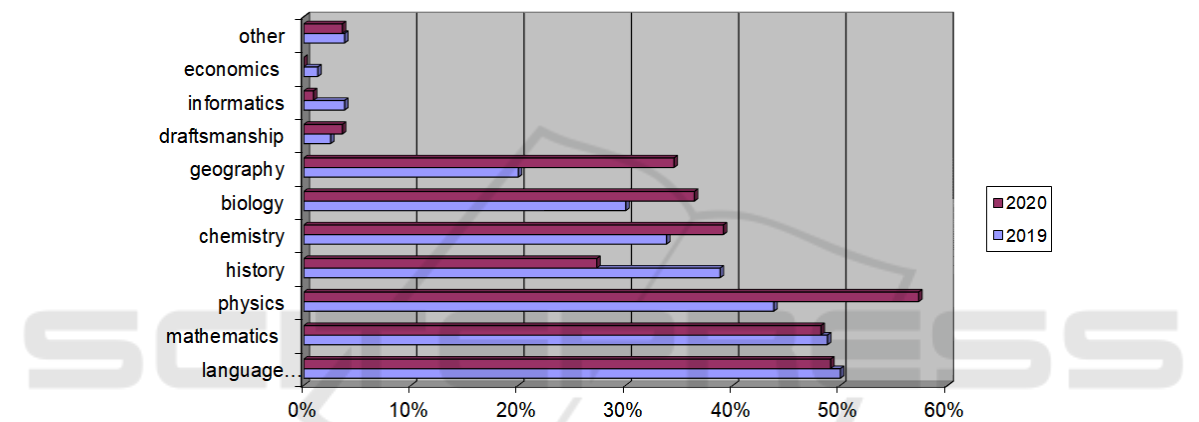

Figure 13: Percentage of respondents' answers to question # 14 "If the answer to the previous question is "Yes", in what lessons did the teachers use such tools?" (comparison of 2019 and 2020).

chemistry; 30% in 2019 and 36,4% in 2020 – biology; 20% in 2019 and 34,5% in 2020 – geography, etc.

This indicates that most teachers still do not use different ICTs in their activities, although there are currently many tools that can be used in the educational process of a general secondary education institution.

The next question is, "Which one did you enjoy the most and why (also indicate the item on which it was used)?" made it possible for teachers to use the following ICT tools in their activities: multimedia, presentations, games, documentary, online quiz, educational films, simulators, and automated verification systems.

Analysis of the distribution of answers to the question "Was the teaching of this subject more interesting using a variety of tools than without using them?" (figure 14) indicate that it is still more interesting for students to use ICT in the educational process than not use in both cases.

To determine what other services could be consid-

ered with students, the answers to the question "What additional services would you like to consider and explore how to use them?" were analyzed. The results show that students want to study game simulators in detail – 62,3% (2019) and 57,5% (2020), cloud services for collaboration on documents – 59,9% (2019) and 65% (2020), educational games – 45,5% (2019) and 41,6% (2020), tools for learning programming – 43,7% (2019) and 60,3% (2020), simulators – 41,3% (2019) and 80% (2020), computer network modeling tools – 35,3% (2019) and 53,7% (2020), virtual labs – 34,7% (2019) and 37,9% (2020), massive open online courses – 29,9% (2019) and 33,6% (2020), statistical data processing tools – 25,7% (2019) and 34,1% (2020), cloud services to build distance courses – 24,6% (2019) and 35,5% (2020), collaboration tools for project activity – 23,4% (2019) and 41,6% (2020), mathematical services – 22,8% (2019) and 30,8% (2020), mind maps – 19,8% (2019) and 24,8% (2020) (figure 15). This indicates that computer science teachers are increasingly using different ICT tools in
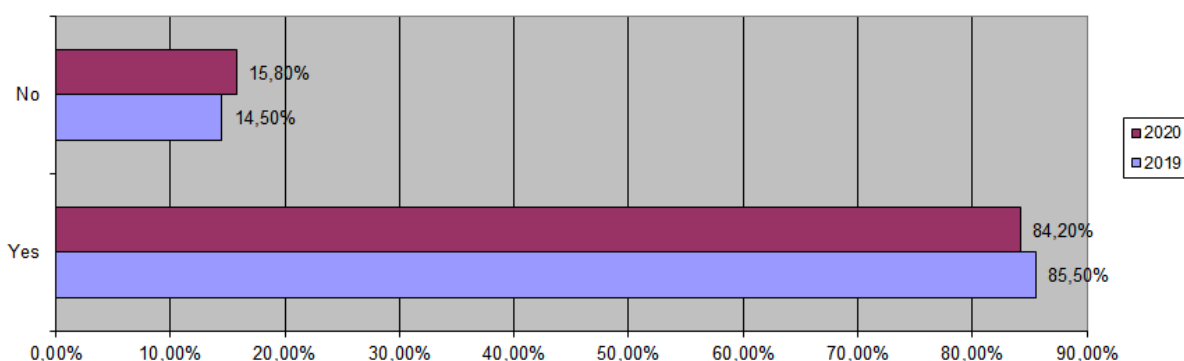
Figure 14: Percentage of respondents' answers to question # 16 "Was the teaching of this subject more interesting using a variety of tools than without using them?" (comparison of 2019 and 2020).
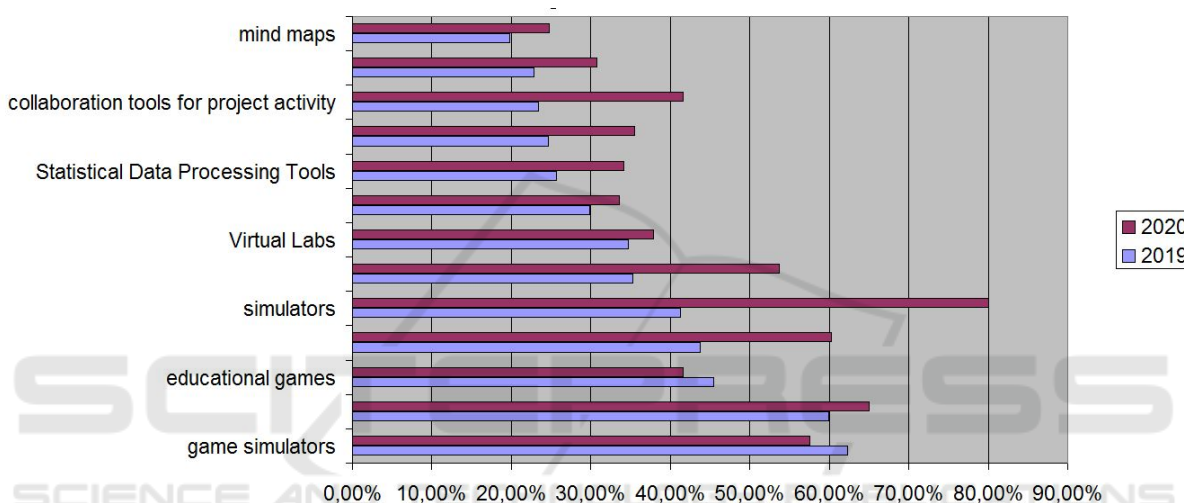

Figure 15: Percentage of respondents' answers to question # 17 "What additional services would you like to consider and explore how to use them?" (comparison of 2019 and 2020).

the learning process.

4 DISCUSSION

Besides, the course "Application Packages" for specialties 121 "Software Engineering", 122 "Computer Science", 123 "Computer Engineering", 125 "Cybersecurity" and 126 "Information Systems and Technologies" at the Zhytomyr Polytechnic State University has been expanded for study some cloud services that can serve as an alternative to the usual MS Office.

As a result of the research, the introduction of the discipline "Educational technologies and digital education" into the training of future information technology specialists was substantiated (Vakaliuk et al., 2019a), and the certification program "Information systems and cloud technologies in the educational process" was developed (Vakaliuk et al., 2019b), which is aimed at teachers of general schools, teach-

ers of HEI, specialists in the field of additional educational services, and other specialists.

Certified educational program "Information Systems and Cloud Technologies in the Educational Process" aims at forming knowledge about the peculiarities of using information systems and cloud technologies in the educational process of educational institutions, forming the ability to plan, develop courses at the methodological and information-technical levels using modern information systems and cloud technologies, to organize various forms of higher education by applying modern information systems and cloud technologies.

As a result, the "Cloud Technologies in Distance Learning in Quarantine" course was launched in several waves during 2020, aimed at raising teachers awareness of various IT and learning tools.

5 CONCLUSION

In conclusion, we can conclude that the positive dynamics of the use of various ICT tools in the educational process are present (compared to school graduates in 2019 and 2020).

In this case, the positive dynamics mean that compared to the previous year, more and more teachers are increasingly turning to various ICT and relevant services, tools, teaching their subjects. This, in turn, promotes students' interest in studying a subject.

REFERENCES

Almerich, G., Orellana, N., Suárez-Rodríguez, J., and Díaz-García, I. (2016). Teachers' information and communication technology competences: A structural approach. *Computers & Education*, 100(C):110–125.

Bansal, S., Singh, S., and Kumar, A. (2012). Use of cloud computing in academic institutions. *International Journal of Computer Science & Technology*, III(I):427–429.

Biswas, S. (2011). How can technology help in education? http://www.cloudtweaks.com/2011/02/how-can-cloud-computing-help-in-education.

Bondarenko, O. V., Pakhomova, O. V., and Lewoniewski, W. (2020). The didactic potential of virtual information educational environment as a tool of geography students training. *CEUR Workshop Proceedings*, 2547:13–23.

Britto, M. (2012). Cloud computing in higher education. *Library Student Journal*. http://www.librarystudentjournal.org/index.php/lsj/article/view/289/321.

Bykov, V., Dovgiallo, A., and Kommers, P. (2001). Theoretical backgrounds of educational and training technology. *International Journal of Continuing Engineering Education and Life-Long Learning*, 11(4–6):412–441.

Bykov, V., Gurzhiy, A., and Kozlakova, G. (1994). Development of computer education in ukrainian higher technical schools. *IFIP Transactions A: Computer Science and Technology*, A-52:678–681.

Chorna, O. V., Hamaniuk, V. A., and Uchitel, A. D. (2019). Use of YouTube on lessons of practical course of German language as the first and second language at the pedagogical university. *CEUR Workshop Proceedings*, 2433:294–307.

Demirbilek, M. and Koç, D. (2019). Using computer simulations and games in engineering education: Views from the field. *CEUR Workshop Proceedings*, 2393:944–951.

Dineva, S. and Nedeva, V. (2012). Cloud computing and high education. In *The 7th International Conference on Virtual Learning ICVL*, pages 171–176.

Dzikite, C., Nsubuga, Y., and Nkonki, V. (2017). Lecturers' competencies in information and communication technology (ICT) for effective implementation of ICT-integrated teaching and learning in textiles and clothing degree programmes. *International Journal of Educational Sciences*, 17(1–3):61–68.

Ercan, T. (2010). Effective use of cloud computing in educational institutions. *Procedia – Social and Behavioral Sciences*, 2(2):938–942.

Fedorenko, E. H., Velychko, V. Y., Stopkin, A. V., Chorna, A. V., and Soloviev, V. N. (2019). Informatization of education as a pledge of the existence and development of a modern higher education. *CEUR Workshop Proceedings*, 2433:20–32.

Hanson-Baldauf, D. and Hughes, H. S. (2009). The information and communication technology competencies of students enrolled in school library media certification programs. *Library & Information Science Research*, 31(1):3–11.

HiTECH-office (2016). Digital agenda of Ukraine – 2020 project (Digital agenda – 2020). Conceptual principles (version 1.0). Priority areas, initiatives, projects of "digitalization" of Ukraine until 2020. https://ucci.org.ua/uploads/files/58e78ee3c3922.pdf.

Hlushak, O. M., Semenyaka, S. O., Proshkin, V. V., Sapozhnykov, S. V., and Lytvyn, O. S. (2020). The usage of digital technologies in the university training of future bachelors (having been based on the data of mathematical subjects). *CEUR Workshop Proceedings*, 2643:210–224.

Iatsyshyn, A. V., Kovach, V. O., Romanenko, Y. O., Deinega, I. I., Iatsyshyn, A. V., Popov, O. O., Kutsan, Y. G., Artemchuk, V. O., Burov, O. Y., and Lytvynova, S. H. (2020). Application of augmented reality technologies for preparation of specialists of new technological era. *CEUR Workshop Proceedings*, 2547:181–200.

Kaplan, A. M. and Haenlein, M. (2016). Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. *Business Horizons*, 59(4):441–450.

Kuzminska, O., Mazorchuk, M., Morze, N., Pavlenko, V., and Prokhorov, A. (2019). Study of digital competence of the students and teachers in ukraine. *Communications in Computer and Information Science*, 1007:148–169.

Lavrentieva, O., Pererva, V., Krupskyi, O., Britchenko, I., and Shabanov, S. (2020). Issues of shaping the students' professional and terminological competence in science area of expertise in the sustainable development era. *E3S Web of Conferences*, 166:10031.

Leshchenko, M., Hrynko, V., and Kosheliev, O. (2020). Methods of designing digital learning technologies for developing primary school pre-service teachers' 21st century skills. *CEUR Workshop Proceedings*, 2732:1044–1057.

Mintii, I. S. and Soloviev, V. N. (2018). Augmented reality: Ukrainian present business and future education. *CEUR Workshop Proceedings*, 2257:227–231.

Moiseienko, M. V., Moiseienko, N. V., Kohut, I. V., and Kiv, A. E. (2020). Digital competence of pedagogical university student: Definition, structure and didactical conditions of formation. *CEUR Workshop Proceedings*, 2643:60–70.

Nechypurenko, P. P., Stoliarenko, V. G., Starova, T. V., Selivanova, T. V., Markova, O. M., Modlo, Y. O., and Shmeltser, E. O. (2020). Development and implementation of educational resources in chemistry with elements of augmented reality. *CEUR Workshop Proceedings*, 2547:156–167.

Ovcharuk, O., Ivaniuk, I., Soroko, N., Gritsenchuk, O., and Kravchyna, O. (2020). The use of digital learning tools in the teachers' professional activities to ensure sustainable development and democratization of education in european countries. *E3S Web of Conferences*, 166:10019.

Pinchuk, O. P., Sokolyuk, O. M., Burov, O. Y., and Shyshkina, M. P. (2019). Digital transformation of learning environment: Aspect of cognitive activity of students. *CEUR Workshop Proceedings*, 2433:90–101.

Popel, M., Shokalyuk, S., and Shyshkina, M. (2017). The learning technique of the SageMathCloud use for students collaboration support. *CEUR Workshop Proceedings*, 1844:327–339.

Rakov, S., Gorokh, V., and Osenkov, K. (2009). *Mathematics, computer mathematical systems, creativity, art*, pages 253–279. Handbook of Research on Computational Arts and Creative Informatics.

Rashevska, N. V. and Soloviev, V. N. (2018). Augmented reality and the prospects for applying its in the training of future engineers. *CEUR Workshop Proceedings*, 2257:192–197.

Seidametova, Z. (2020). Combining programming and mathematics through computer simulation problems. *CEUR Workshop Proceedings*, 2732:869–880.

Shakeabubakor, A. A., Sundararajan, E., and Hamdan, A. R. (2014). Cloud computing services and applications to improve productivity of university researchers. In *3rd International Conference on Electronics Engineering and Informatics (ICEEI 2014)*, pages 33–37. https://www.researchgate.net/publication/311574468_Cloud_Computing_Services_and_Applications_to_Improve_Productivity_of_University_Researchers.

Spivakovsky, A., Petukhova, L., Kotkova, V., and Yurchuk, Y. (2019). Historical approach to modern learning environment. *CEUR Workshop Proceedings*, 2393:1011–1024.

Striuk, A., Rassovytska, M., and Shokaliuk, S. (2018). Using Blippar augmented reality browser in the practical training of mechanical engineers. *CEUR Workshop Proceedings*, 2104:412–419.

Talyzina, N. F. (1974). Cybernetics and pedagogy. *Soviet Education*, 16(5):69–77.

Tokarieva, A. V., Volkova, N. P., Harkusha, I. V., and Soloviev, V. N. (2019). Educational digital games: Models and implementation. *CEUR Workshop Proceedings*, 2433:74–89.

Trius, Y. V., Solov'ev, V. N., Serdyuk, O. A., and Piskun, O. V. (2004). Regional educational portal as the main information resource for supporting continuous education and open learning. *Upravlyayushchie Sistemy i Mashiny*, 4:74–81.

Vakaliuk, T. (2019). First year student survey. https://forms.gle/M6eVpZqRBD7Medra8.

Vakaliuk, T., Morozov, A., Yefimenko, A., and Antoniuk, D. (2019a). The expediency of introducing "education technologies and learning in the digital age" course into educational plan of the future professionals of information technologies. *Naukovi zapysky Berdianskoho derzhavnoho pedahohichnoho universytetu. Seriia: Pedahohika*, 2:160–169.

Vakaliuk, T. A., Antoniuk, D. S., and Soloviev, V. N. (2020). The state of ICT implementation in institutions of general secondary education: A case of Ukraine. *CEUR Workshop Proceedings*, 2643:119–133.

Vakaliuk, T. A., Morozov, A. V., Lobanchykova, N. M., and Antoniuk, D. S. (2019b). Certificate program 'information systems and cloud technologies in the educational process'. https://drive.google.com/file/d/141yQaDYzZScfzZQ1gBMjOpVHboPKwNvr/view.

Verkhovna Rada of Ukraine (2017). Law of Ukraine 'On education'. http://zakon2.rada.gov.ua/laws/show/2145-19.

Zhaldak, M. I. and Franchuk, N. P. (2021). Some applications of the GRAN1 to analyze two-dimensional continuous probability distributions. *Journal of Physics: Conference Series*, 1946(1):012002.