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CLOUD TECHNOLOGIES IN EDUCATION: THE BIBLIOGRAPHIC REVIEW

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Abstract. *The paper considers the use of cloud technologies in education through the prism of bibliographic analysis. The article characterizes the current state of cloud technologies in education, summarizes the trends, and forecasts the directions of recent scientific research. The leading research methods were bibliographic (visual and quantitative) analysis of keyword networks and qualitative discussion. The bibliographic analysis is based on publications indexed by the scientometric database Web Of Science over the past 20 years. The sample for analysis was formed by searching for the words cloud technology, education, learning, and teaching. The results of the study showed: a significant increase in the popularity of cloud technologies in education in recent years; an increase in the number of studies related to various aspects of educational activities under the influence of Industry 4.0; a gradual increase in the number of studies on the virtualization of the educational process and the use of artificial intelligence in education; dissemination of research on the effectiveness of various types of training using cloud services and teaching methods based on artificial intelligence; the relevance of the trend of visualization of educational material and visual analysis in education. The qualitative discussion provided grounds to identify general trends regarding future research directions.: development of mass online courses and learning technologies (immersive, the use of virtual, augmented, and mixed reality, gaming learning technologies, BYOD approach); further virtualization of universities; development of inclusive education, educational analytics, and assessment (formative and adaptive computer assessment); early training of teachers to use cloud technologies and specialized services in subject learning; research related to visualization (big data, design, simulation, simulation of various processes, etc.) and the designing of relevant new academic disciplines; research of STEM and STEAM education.*

Keywords: cloud technologies, education, learning, teaching

TECHNOLOGIE CHMUROWE W EDUKACJI: PRZEGLĄD BIBLIOGRAFICZNY

Abstrakt. *W artykule omówiono wykorzystanie technologii chmurowych w edukacji pod kątem analizy bibliograficznej. W artykule scharakteryzowano obecny stan wykorzystania technologii chmurowych w edukacji, podsumowano trendy i prognozy kierunków odpowiednich badań naukowych. Wiodącymi metodami badawczymi były wizualna i ilościowa analiza sieci słów kluczowych oraz dyskusja jakościowa. Analiza bibliograficzna została przeprowadzona na publikacjach indeksowanych przez scjentometryczną bazę Web Of Science przez ostatnie 20 lat. Próbkę do analizy tworzy się poprzez wyszukiwanie słów words cloud technology, education, learning, teaching. Wyniki analizy wykazały: znaczący wzrost popularności technologii chmurowych w edukacji w ostatnich latach; wzrost liczby badań związanych z różnymi aspektami działalności edukacyjnej pod wpływem Przemysłu 4.0; stopniowy wzrost liczby badań nad wirtualizacją procesu edukacyjnego i wykorzystaniem sztucznej inteligencji w edukacji; upowszechnianie badań nad efektywnością różnego rodzaju szkoleń z wykorzystaniem usług chmurowych oraz metod nauczania opartych na sztucznej inteligencji; znaczenie trendu wizualizacji materiałów edukacyjnych i analizy wizualnej w edukacji. Dyskusja jakościowa dała podstawy do przewidywania kierunków odpowiednich badań: rozwoju masowych kursów online i technologii uczenia się (immersyjne, wykorzystanie rzeczywistości wirtualnej, rozszerzonej i mieszanej, technologie uczenia się w grach, podejście BYOD); dalsza wirtualizacja uczelni; rozwój uczenia się włączającego, analityki edukacyjnej i oceny (formatywna i adaptacyjna ocena komputerowa); proaktywne szkolenie nauczycieli w zakresie korzystania z technologii chmurowych i specjalistycznych usług w zakresie uczenia się przedmiotów; badania związane z wizualizacją (big data, projektowanie, symulacja, symulacja różnych procesów itp.) oraz rozwój nowych dyscyplin akademickich do prezentacji różnych danych; badanie edukacji STEM i STEAM.*

Słowa kluczowe: technologie chmurowe, edukacja, uczenie się, nauczanie

Introduction

The use of information technology (IT) in education today is commonplace. Scientists explore the features of the use of specialized software in teaching individual disciplines, simplify the organization of the educational process through IT, and automate the control of academic progress. The impact of IT on education has become much more noticeable due to the pandemic. The educational industry was forced to respond due to restrictions on direct communication under external circumstances. School teachers and university professors have begun to master cloud technologies, which today have become the leading tool for providing educational services. The pedagogical literature actively discusses the problem of introducing cloud technologies in learning [32], analyzed the implementation of the BYOD approach [27], analyzed the solution of social, pedagogical, and technical problems that may arise during the implementation of distance [25], mobile and blended learning [42], discusses the feasibility of using cloud data storage (for example, MS OneDrive) [22], experience in using IT to knowledge control (for example, Plickers as a mobile application for reading QR codes [11]). Subject cloud services are studied separately, in particular, such as Geogebra (http://www.geogebra.net) [29], PhET (https://phet.colorado.edu/uk/) [9], Open Source Physics (https://www.compadre.org/osp) [43], Wolfram Demonstrations Project (https://demonstrations.wolfram.com) [38], Virtual Lab (http://chemcollective.org/) [30] etc. These results are accumulated in a significant number and systematized on the use of IT in education in general, which is confirmed by studies: [1] – for the academic environment, [40] – for high school, [34] – for preschool education, [33] – for secondary education and teachers, [20] – for intellectual academic environments, [21] – for the educational sector as a whole in the transition to education 4.0. At the same time, the scientific results of using cloud technologies in education as a type of information technology are not generalized and therefore require a comprehensive analysis.

The article aims to characterize the current state of existing research on the use of cloud technologies in education and identify general trends in future research.

1. Material and methods

The bibliographic (quantitative and visual) analysis of keyword networks and qualitative discussion of the results were used to characterize the landscape of cloud technology use in education. The bibliographic analyses were carried out through the VOSviewer application (https://www.cwts.nl). This app visualizes bibliographic data and builds the set of keywords and their relationships.

The type of analysis – Co-occurrence. The unit of analysis – All keywords.

We took publications from the Web of Science database for analysis. The publications were dated 2004-2023 and related to the use of cloud technologies in education. Keywords used to search for publications in the database Web Of Science: cloud technology, education, learning, teaching. The search date in the Web of Science database is July 5, 2023.

The conducted research is limited to publications presented in Web Of Science over the past 20 years. It does not include articles from other databases, as well as articles written not

in English. At the same time, the analysis expresses the trends in using cloud technologies in education. It gives an idea of the impact of cloud technologies on the educational industry as a whole and the possibilities of using cloud technologies for learning and teaching.

2. Results of research

We realized the search the database for the words "education, modern education, contemporary education, current education", which could be found in the annotations to publications. In total, 1279 results were found. After 2016, there were more than 100 of them annually. The total number of keywords is 4312. If you make a limit of 10 to the depth, then only 59 keywords form a network, and each word occurs at least ten times (Fig. 1).

The network has several clusters: green – education (history, skills, critical thinking, training); yellow – technology (teacher, learning, innovation); violet – simulations (model, control); light blue – digitalization (creativity, school, influence, educational policy); red – higher education (distance learning, educational systems, educational reforms); blue – curriculum (student, teacher training, inclusion, inclusive education, quality).

The network analysis shows a strong connection between "education" with the keywords "technology, teacher, distance learning, and higher education".

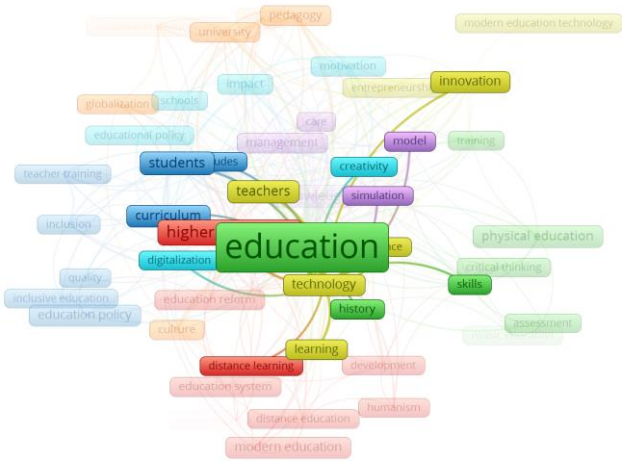
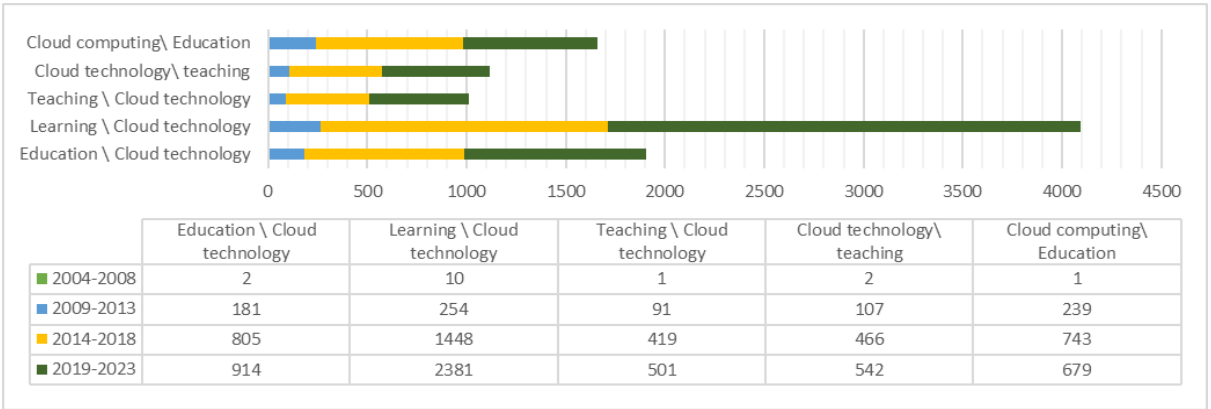


Fig. 1. Network by searching "education, modern education, contemporary education, current education"

Table 1. Quantitative search characteristics

No	Topic\ Abstract	1*	2*	3*	4*	5*	Main clusters	
1	Education \ Cloud technology	1870/5380	20	49	**A**	5	*Violet cluster*: *Green cluster*: *Red cluster*:	cloud services, IT, innovations cloud computing, mobile learning, education technology, virtualization, online, mobile learning internet, big data, artificial intelligence, system, management, augmented reality
2	Learning \ Cloud technology	4093/12214	40	50	**B**	5	*Violet cluster*: *Green cluster*: *Blue cluster*: *Red cluster*: *Yellow cluster*:	Industry 4.0 security, optimization, edge computing machine learning, IoT, big data higher education, education technology, online, motivation Internet, IoT, technologies, 5G, cloud
3	Teaching \ Cloud technology	1012/2955	10	43	**C**	6	*Violet cluster*: *Green cluster*: *Blue cluster*: *Red cluster*: *Yellow cluster*:	cloud technology, mobile learning, distance learning, virtual reality artificial intelligence, Industry 4.0, IoT, big data cloud computing, virtualization, flipped classroom education, education technology, e-learning, performance, teaching, students, higher education technology, innovation, pedagogy
4	Generally	6975/14765	40	73	**D**	3	*Red cluster*: *Green cluster*: *Blue cluster*:	cloud computing, education, information technology, management, simulation, design, mobile learning, Industry 4.0, virtualization internet, IoT, cloud, fog computing, security machine learning, algorithm, system, big data
5	Cloud technology\ Teaching	1117/3332	10	60	**E**	5	*Red cluster*: *Green cluster*: *Blue cluster*: *Yellow cluster*: *Violet cluster*:	cloud computing, education, information technology, management, simulation, design, mobile learning, Industry 4.0, virtualization, flipped classroom internet, big data, augmented reality, artificial intelligence, IoT, gamification, university system, cloud technology, management, design, model, systems technology, higher education, e-learning, online
6	Cloud Computing \ Education	1662/4603	10	105	**F**	7	*Yellow cluster*: *Red cluster*: *Green cluster*: *Blue cluster*: *Light blue cluster*:	cloud computing, technology, higher education, PAAS, SAAS, computer science, education cloud, virtualization, distance learning, information technology adoption, cloud computing adoption, extension, social media, behavioral intention internet, IoT, machine learning, artificial intelligence, virtual reality, learning big data, implementation technology, higher education

1* Number of search results\ Number of keywords; 2* Network depth (number of keyword repetitions); 3* Number of network keywords; 4* Network of connections; 5* Number of clusters in total



	Education \ Cloud technology	Learning \ Cloud technology	Teaching \ Cloud technology	Cloud technology\ teaching	Cloud computing\ Education
2004-2008	2	10	1	2	1
2009-2013	181	254	91	107	239
2014-2018	805	1448	419	466	743
2019-2023	914	2381	501	542	679

Fig. 2. Quantitative data on publications based on search results

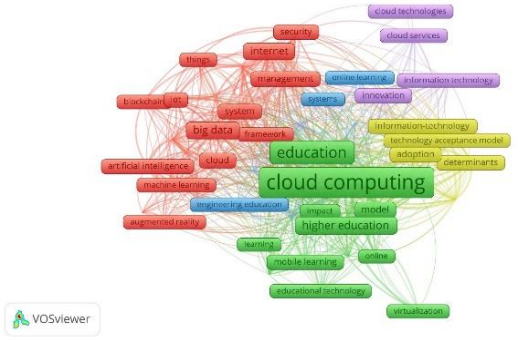


Fig. 3a. Networking for the searchable "Education \ Cloud technologies"

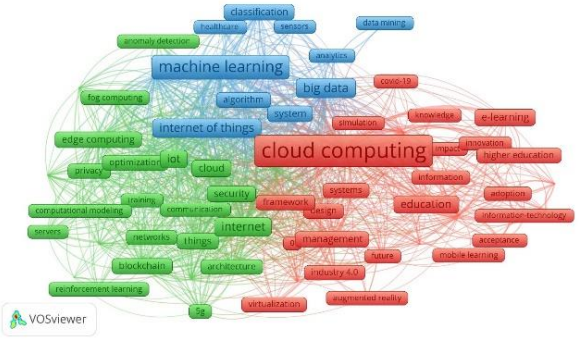


Fig. 3d. Networks general

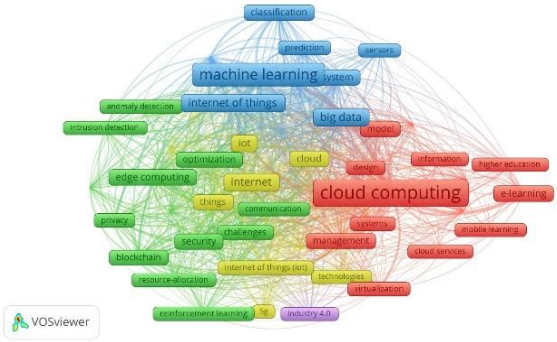


Fig. 3b. Networking for the searchable "Learning \ Cloud technology"

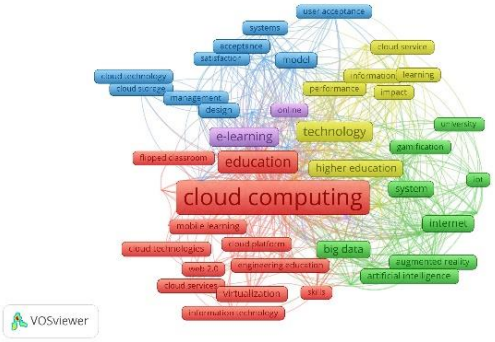


Fig. 3e. Networking for the searchable "Cloud technology\ Teaching"

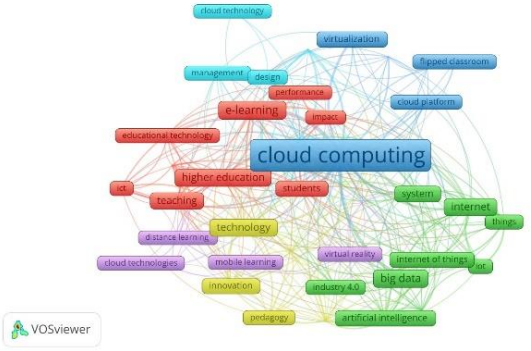


Fig. 3c. Networking for the searchable "Teaching \ Cloud technology"

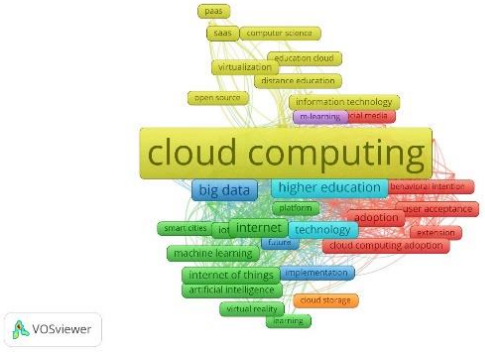


Fig. 3f. Networking for the searchable "Cloud Computing \ Education"

Refinement of the search provides other networks and more detailed accents to characterize the bibliographic landscape of using cloud technologies in education (table 1). The figure (Fig. 2) shows the number of relevant publications by year.

Analysis of the number of published studies in the Web of Science database shows that:

– Over the past ten years, the number of scientific results has increased significantly (almost ten times) – at the beginning of 2014, there were 254 publications on cloud technologies in teaching, and at the beginning of 2023 – 20381. We explain this by the robust development of cloud technologies and their demand in education in the last five years (including during a pandemic);

– The most popular are studies related to learning as one of the directions of cloud technology development – more than 4 thousand publications over the past 20 years. At the same time, the use of cloud technologies by teachers in the educational process is not quantitatively distinguished from other similar searches, which indicates the widespread use of cloud technologies (teachers and students, educational process management, organization of control, independent work, project collaboration, etc.);

– A relatively equal number of studies is presented on education in general as a direction for the development of cloud technologies and on the use of cloud technologies in education – 1662 and 1902 publications, respectively. That indicates the simultaneous interest of educators (in the use of such technologies in educational activities) and IT specialists who offer separate developments/solutions for the field of education;

– Almost the same number of studies is recorded for cloud technologies and teaching: teaching using cloud technologies is described in 1012 publications against 1117 publications related to the development of cloud educational solutions.

– The analysis of the most used keywords and clusters in the built networks (the last column of table 1, Fig. 3) revealed trends in the use of cloud technologies in education:

- research various types of training (mobile, distance, electronic, online) based on cloud technologies;
- research on the impact of Industry 4.0 technologies (Internet of Things (IoT) and 5G technologies, big data, and the Internet) on education and its development;
- research on the use of artificial intelligence in teaching, research on machine learning;
- research of educational process management (management), pedagogical design (design, environment), organization of training by the method of "flipped classroom" and gaming learning technologies (gamification);

- exploring the possibilities of virtualization of education and the use of different types of reality "virtual reality, augmented reality" for training;
- research of problems of visualization of educational material based on cloud technologies and services, which confirm the keywords "performance, model, modeling, simulation".

So, we have identified the following characteristics of the landscape of cloud technology use in education: over the past five years, a significant digital transformation of education due to the growing popularity of cloud technologies in education, teaching, and learning; increasing the number of studies related to various aspects of educational activities under the influence of Industry 4.0 (training, management, design, learning technologies, etc.); a gradual increase in the number of studies on the virtualization of the educational process and the use of artificial intelligence in education; expanding research on the effectiveness of various types of training and teaching methods based on cloud services; the relevance of the trend of visualization of educational material and visual analysis in education.

3. Discussion

The presented results are consistent with the review studies of the use of information and digital technologies in education in recent years. The digital transformation of education due to the growing popularity of cloud technologies in education is recorded by many other publications on various aspects of the implementation of educational activities. Article [12] explores the virtual image of universities. The authors emphasize that today only one in four universities has a balanced digital strategy and prove that digital transformation can provide high-quality and competitive education based on advanced analytics, cloud technologies, and artificial intelligence. Another aspect of the digital transformation of education is presented in [13], which analyzes the development of smart campuses and universities under the influence of key technologies of society. The article describes communication architectures and explores the use of blockchain in university educational programs. The paper [23] is devoted to analyzing the concept of a smart city, in which one of the leading places is occupied by SMART education based on advanced computing technologies (IoT, artificial intelligence, blockchain, big data, and cloud computing). The review of research in [8] addresses the problems of integrating Blockchain and IoT technologies and demonstrates the development of reliable distributed applications in smart education. Another aspect of the digital transformation of education, the use of social networks, is analyzed in the article [6]. The generalization of more than 700 publications on the use of Facebook confirmed this trend. It showed that the use of social media in education is due to external factors and behavioral intentions of subjects of the educational process (user, social and technological aspects). The authors of the publication [39], according to the analysis of more than 1 thousand sources and keywords, identified the educational perspectives of digital learning, including online learning and the development of digital learning environments built using cloud technologies.

The impact of Industry 4.0 on various aspects of the educational process (management, design, learning technologies, etc.) is confirmed by the review works of other scientists. Thus, in [2], it was concluded that Industry 4.0 positively influenced the number and quality of training courses that are distributed online and are considered massive. The authors note the perspective of machine learning, blockchain, and gamification technology to provide students with a richer individual experience. Another aspect of education development under the influence of Industry 4.0 is described in [16]. The authors note society's demand for the formation of autonomous work skills and therefore emphasize the importance of using simulation, horizontal and vertical integration, augmented reality, cybersecurity, and big data and analytics in university professional training programs. The problem of assessing academic progress is raised in [41]. The authors, after analyzing the available scientific results, taking into account the widespread use of digital technologies of Industry 4.0 (big data, cloud computing, and artificial intelligence) in higher education, predict a new approach to the assessment system – the transition to interactive transfer\assessment of knowledge with the organization of space for the exchange of ideas.

The scientific papers also show a gradual increase in the number of studies on using artificial intelligence in learning. The article [5] analyzes the impact of artificial intelligence on higher education. The authors conclude: artificial intelligence is in its infancy for education, but in the future, it will influence the solution of educational problems. In another paper [14], the authors analyze the use of ChatGPT in education, note the ambiguity of perception of this tool by teachers, and at the same time prove that the emergence of AI has already influenced the educational space and, therefore more in-depth studies of its use are needed. The impact of AI, machine learning, and deep learning methods on the organization of the educational process (admission to university, scheduling, and creating courses) is analyzed in [19]. According to the analysis results, 195 original scientific authors raise ethical issues about using artificial intelligence in education.

The educational process's virtualization trend is justified in [26]. The review finds results that show that the research community is most interested in new learning environments, collaboration platforms, and virtual labs. Other work [3] confirms the potential of virtual reality (VR) technologies in developing educational technologies and the organization of educational activities. At the same time, the authors state that the use of VR technologies in architectural and design education still needs to be improved. The article [26] provides an overview of innovative methods, techniques, and learning tools based on cloud computing. The authors prove the promise of such approaches but note the small number of relevant empirical studies (only 17% of 940 publications are based on empirical data). In [24], the Technology Acceptance model was investigated. Based on the analysis of more than 100 publications, the authors stated the need for more internal motivation of the subjects of the educational process to use digital solutions. They confirmed the need for further study of mixed teaching methods.

The expansion of research on the effectiveness of various types of training and teaching methods based on cloud services as a trend is also consistent with the findings of many publications. Thus, in [37], according to the analysis of 429 research articles, it was proved that cloud technologies could become the basis for distance learning and positively affect the quality of education in developing countries. Another paper [4] summarizes scientific findings related to hybrid learning. The authors discuss the revolutionary nature of artificial intelligence to offline and online education through a radical change in communication between the subjects of the educational process and a fundamentally new vision of building an academic environment. The publication [15] provides an overview of the scientific results of applying information technology in vocational education. The review results suggest that using ICTs for vocational education institutions is negligible, especially for monitoring and evaluating learning outcomes. The authors emphasize the need to study robotics, data sciences, artificial intelligence, and cloud computing. The work [31] is devoted to improving the methodology of teaching English. The authors concluded that AI positively impacts learning outcomes by optimizing English language skills, translation, assessment, recognition, attitude, and satisfaction. The studies noted the feasibility of using machine learning, neural networks, genetic algorithms, deep learning, data mining, cloud computing, etc.

The trend of visualization and visual analysis in education is consistent with the conclusions of other studies. Thus, the article [35] is devoted to analyzing trends associated with the visual representation of big data. The authors emphasize that virtual and augmented reality create a new basis for visualization, presentation, and understanding of data. In [17], results were obtained based on visual analytics (visual data, visual networks, and word clouds). The effectiveness of information visualization is proved in the article [18], where the authors demonstrate the effectiveness of using visual materials created based on cloud services. The study [7] analyzes the links between visual and computer thinking. The authors, on the example of contemporary art teaching, show that it can be based on algorithmization and programming principles within the STEAM education framework. The development of visual thinking today can develop using cloud technologies, as noted in [35], and the importance of developing visualization skills for teachers is justified in [36].

Teachers are only sometimes ready to use cloud technologies in their professional activities. Preparing future teachers to use cloud technologies and services is often slowed down by the need for more access to the Internet and the unsatisfactory technical condition and level of computerization of educational institutions. The UNESCO "Global education monitoring report, 2023: technology in education: a tool on whose terms?" [36] is noted that only 10% of high school students use cloud technology for more than an hour a week. The same report notes that the amount of educational content is increasing, but there are no factors that ensure its quality. The report's authors note that society needs more time to accumulate sufficient factual data, which would confirm the nature of the impact of technology on education.

4. Conclusions

The analysis gives grounds for some conclusions.

The development of information technology led to the emergence of cloud computing, which qualitatively influenced the educational industry. Due to quarantine restrictions, cloud technologies have become the driving force for the development of academic learning technologies and have actualized the development of informal and non-formal education. Thanks to the development of digital technologies, mass online courses are more accessible and provide adaptive learning. The increase in online courses will inevitably lead to their new quality. Therefore, we consider the perspective direction of research that will be associated with the development of mass online courses and learning technologies for them:

- immersive technologies;
- the use of virtual, augmented, and mixed reality;
- gaming learning technologies;
- the BYOD approach.

As of today, they have been studied fragmentarily and require additional study and systematization.

Industry 4.0 will accelerate the increasing virtualization of universities, the provision of online learning, and the digitalization of management and organizational decisions at the administrative level. An important aspect will be the continuity of education along with the digital security of each subject of the educational process, so research on the use of blockchain technologies will be relevant. Increased interest in artificial intelligence, machine, and deep learning will determine a new quality in the individualization of the educational process. Inclusive education will develop, and academic analytics and assessment of personal academic results (formative assessment and adaptive computer assessment based on individual results) will become relevant

Education today requires digital skills of the 21st century for everyone, and therefore the current trend will be the advanced training of teachers to use cloud technologies. Educational and professional teacher training programs should include mastery of cloud technologies. It will be essential to develop ideas about cloud technologies in the subject area. Therefore, it will be a perspective to study the use of specialized services in subject education. The spread of artificial intelligence in education will lead to the study of the effectiveness of relevant teaching methods. Therefore, the actual trend is for teachers' advanced preparation for the effective use of AI in pedagogical activities. The challenge for working teachers may be the problem of motivation to use cloud technologies in their professional activities. The search for effective online models of teacher internships will become another promising research trend.

Analysis of any processes today faces the problem of processing big data that can be visualized using cloud technologies. Therefore, studies related to their visualization (design, simulation, modeling of various processes, etc.) will remain promising. The need to develop new academic disciplines (for example, "interaction design", "human-computer interaction", and "user experience") for the presentation of various data and design of the dynamics of their interaction is actualized. The trend of visualization in education and the appropriate training of teachers to develop visual images of knowledge models and use them in teaching will remain popular.

Today, the skills of critical, algorithmic, computational, visual thinking, and modeling, which are formed on an interdisciplinary basis, are in demand. Therefore, the trend of STEM and STEAM education research as the development of interdisciplinary connections between natural sciences, mathematics, engineering, and digital technologies will gain popularity. Research in vocational education will also be promising: effective forms, methods, and means of teaching robotics, data sciences, artificial intelligence, and cloud computing with an occupation accent.

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