MODERN DIGITAL TECHNOLOGIES IN THE HIGHER EDUCATION INSTITUTIONS ACTIVITIES

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Abstract. Penetrating almost all areas of higher education institutions' activities, innovative digital technologies are transforming them in a significant way, often creating additional competitive advantages. Universities cannot ignore global digital trends and try to quickly master and integrate the latest technologies into their activities. **The purpose of the paper** is to identify and describe the essence of modern digital technologies that contribute to the digitalisation of higher education institutions. **The subject of the study** is modern digital technologies and their impact on the activities of higher education institutions. **The methodology of the study** is based on general research methods of analysis and synthesis, induction and deduction, observation and abstraction, which are used to systematise achievements in the theory and practice of digitalisation of universities. In the course of the study, foreign experience of implementing digital technologies in various areas of university activities was studied. **Results.** The study of foreign experience has shown that blockchain, cloud computing, Big Data Analytics, Artificial Intelligence, and Internet of Things are currently becoming the most widespread in the university environment. Blockchain technology can be effectively used to verify and secure educational documents, as well as to register and protect copyrights for inventions. By adopting cloud computing, universities can build a flexible infrastructure for storing and processing large amounts of data without the need for substantial investment in their own hardware. This technology also

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improves distance learning, grants students access to educational resources from anywhere in the world, and supports collaboration between teachers and students on joint projects. Big Data Analytics helps universities accurately and efficiently analyze students' academic performance, identify factors that influence learning outcomes, and enhance marketing strategies. Artificial Intelligence is valuable for personalizing learning experiences, creating adaptive curricula, automating routine administrative tasks, providing student support, and supporting research. The Internet of Things is utilized by leading universities worldwide to manage campus infrastructure, monitor resource usage, and improve research processes. **Practical implications and value (originality).** Universities should constantly monitor changes and innovations in the field of digital technologies, as well as be flexible and ready to adapt to such changes. The results of the study can be useful for domestic higher education institutions at the stage of their post-war recovery, in particular through the digitalization of their educational, methodological, research, innovation, internationalisation, financial and economic activities.

1. Introduction

Traditionally, the educational sphere is considered quite conservative. However, the turbulence of the modern world dictates new rules – high competitive position in the educational services market requires high dynamism, flexibility and adaptability from higher education institutions. In recent years, one of the main trends in this market is digitization.

The changes in the higher education system in the context of digitalization require scientists to clarify the essence of digitalization process at universities. Kremen V. [1] understands this process as a dual transformation “on the one hand – of the educational process and the pedagogical technologies used; on the other hand – digital technologies and teaching tools". Gurevich R. [2] understands the digitalization of higher education institutions as “the process of transferring the education content in all its forms (graphic, text, sound) into a digital format understandable by modern gadgets (computers, tablets, smartphones, etc.)", emphasizing the changes in methods of obtaining knowledge due digital technologies. Digitization of universities should be considered as a process and result of the integration of digital technologies into the educational and administrative systems of a higher education institution, aimed at achieving qualitative changes in the process

of creating, accumulating, transferring and using knowledge. In addition to the educational process, the administrative component of the higher education institution is also subject to digitization: document management, data storage, communication, accounting, reporting, forecasting, interaction with stakeholders, human resources and information management, etc. [3].

Penetrating almost all areas of activity of higher education institutions, innovative digital technologies significantly transform them, often creating additional competitive advantages. Currently, the following digital technologies have become the most widespread: cloud computing, Big Data Analytics, blockchain, Artificial Intelligence, Internet of Things, and some others. Universities cannot ignore global digital trends and try to promptly master and integrate the latest technologies in educational, methodological, research, innovation, internationalization, financial and economic processes.

2. Application Programming Interface at higher education institutions

The majority of higher education institutions use API (Application Programming Interface). API is a set of tools, protocols and procedures used by various programs to exchange data between themselves. Using API allows to make any program simpler and easier for users. The principle of operation of this technology is as follows: API receives a request from the user, after which it sends this request to the service provider, and the API result generated by the service provider is sent to the user (Fig. 1).

The algorithm for creating an API includes the following stages: 1) determining the goal; 2) definition of the target audience (potential users); 3) design of the API architecture; 4) development and testing of API; 5) monitoring of API functioning; 6) organization of feedback on the work of the API. Implementation of API in higher education institutions ensures fast and flexible provision of services and information to students, teachers, and stakeholders.

In the universities educational activities, API can be used for integration with existing learning management system (LMS – MOODLE, Canvas, etc.), as well as to expand students' access to additional educational resources, online libraries, and assessment tools. API has significant advantages in creating a personalized learning experience for each student, which is particularly ensured by recommending courses to students based

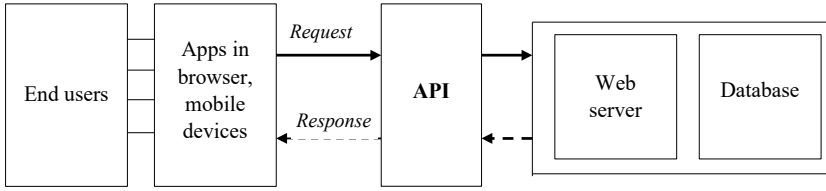

Figure 1. The working mechanism of the API (Application Programming Interface)

on monitoring their interests and previous performance. In addition, from a technical point of view, API has many advantages for the automation of tasks (evaluation, reporting, registration for elective courses, etc.), which significantly frees up the time of pedagogical and administrative staff of the university for more meaningful interaction with students.

Universities libraries can benefit from API to provide students, faculty, and researchers with access to information from government and static databases, data repositories, scholarly journals, and other sources. API allows university library to integrate with other libraries catalogs to expand access to resources, as well as to increase the efficiency and speed of students' search for the necessary information. API can be very useful in automating a number of library services, in particular automating the processes of borrowing, returning and reserving books/journals.

In general, API brings significant advantages and opportunities for higher education institutions in various directions of automation of their activities:

– automating the entry of grades into electronic journals and their synchronization with various systems;

– creation of interactive schedules that are automatically updated and available to students and teachers in real time;

– automation and optimization of the administrative processes of student registration – API can integrate the registration system with other services, for example, to check applicants' data, process payments and issue documents to students;

– management of student applications for financial assistance;

– automation of reservation, settlement, and management processes at hostel;

– integration with various university services to provide students with access to schedules, grades, campus maps, news, important event notifications, etc.

Above are several examples of the use of API technology by universities (Fig. 2). As this technology evolves, it will become a powerful tool for improving the university's services to students, faculty, researchers, and staff.

3. Blockchain at higher education institutions

Blockchain has significant prospects from the point of view of implementation in the field of higher education. Blockchain is a shared distributed ledger in which all transactions are recorded. This registry is protected against unauthorized changes; all authorized members of the

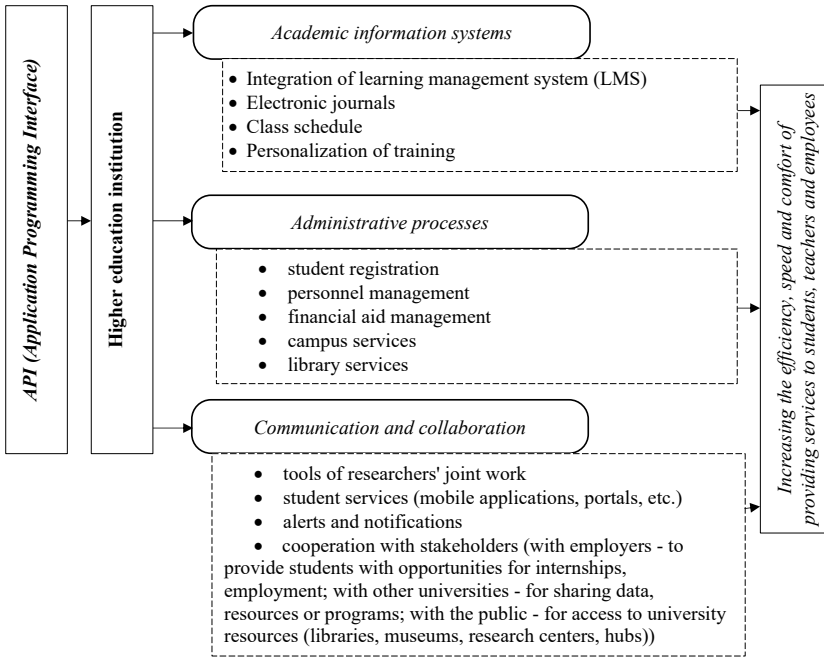

Figure 2. The main areas of use of API at higher education institutions

network have access to the register and the information in it, and can monitor the processes of service provision. None of the participants in the network can make corrections or changes to the transactions recorded in the register, which makes the blockchain technology sufficiently transparent and reliable. If an error is detected in a certain block, then since it is impossible to change it, it is necessary to add a new block – in the end, both transactions will be reflected in the register [6].

Blockchain technology is distinguished by a fairly high level of confidentiality and trust between network participants. This technology is considered one of the most secure in terms of resistance to hacker attacks and hacking. The technology works in such a way that each new transaction is recorded in the ledger as a block of data that joins an existing one in the ledger, and new transactions are added to it, forming a chain of data. The connection between the blocks in the chain is tight enough, and no network participant, not even a system administrator, can change a block or insert an additional block between two already recorded in the registry. When adding a block to the chain, previous blocks are automatically checked, which provides protection against fraud, hacking, and violation of information integrity [6]. The working process of blockchain technology is schematically shown in Fig. 3.

Despite the fact that the blockchain technology has become most widespread in the financial sphere (as the basis of the Bitcoin cryptocurrency), it has strong prospects in the university environment. For example, it can be quite useful in optimizing the processes of admission to a higher education institution. At the stage of submitting documents for

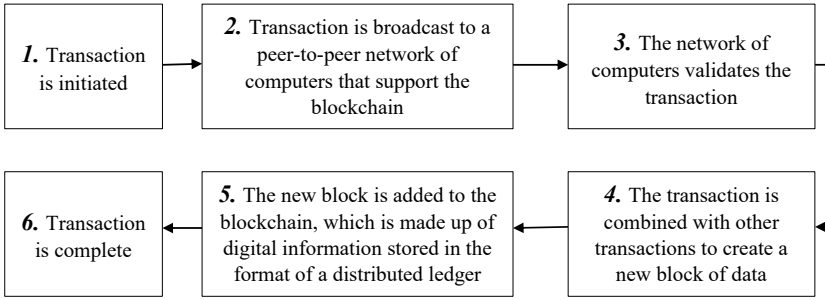

Figure 3. Transaction process within blockchain technology [7]

admission to the university, the blockchain will assign a unique code to each of them, which will make it impossible to forge them. In addition, blockchain can be used to create a digital identification of applicants, simplifying the process of filling out various forms for them at the time of admission [8].

The advantage of blockchain technology for universities is also its ability to record, store and verify diplomas, certificates, transcripts, etc. This makes it possible to create a decentralized and immutable platform for verifying the authenticity of academic documents. The existence of such a platform eliminates the need for manual verification processes and reduces the risk of forgery of documents [8]. This is extremely important, because due to various circumstances, important printed academic documents can be lost, especially in force majeure circumstances (due to the war in Ukraine, some higher education institutions and their archives were destroyed, damaged or turned out to be inaccessible due to the occupation of the territory by Russian troops).

Considerable experience in using blockchain technology in education has Massachusetts Institute of Technology (MIT). In particular, OpenCourseWare provides free online access to the study materials of more than 2,500 courses. This initiative of MIT uses solutions based on blockchain, which allows cataloging and storing educational content for a long period of time available worldwide [9].

Blockchain technology is very useful in the education of foreign students and in mobility. Blockchain-based records are securely stored and easily transferred between higher education institutions, and thus students become more flexible in transferring their credits or educational qualifications [8].

Blockchain technology has significant advantages in the research activities of universities, in particular, it helps storage data for research projects cost-effectively and safely, reduces the risk of information loss, and also exchanges large data sets between researchers around the world [9]. The University of Utah's Scientific Computing and Imaging Institute (USA) uses blockchain to provide interactive processing and research of large data sets without large local resources [9].

Considering the global experience of universities using digital technologies, it should be mentioned the case of Berkeley’s Hub for Blockchain Innovation. The mission of this Hub is to stimulate innovation

in the field of blockchain by creating an ecosystem whose values are innovation, boldness, inclusivity, excellence, and openness. The main activities of the Hub are consulting, education, design, and research [10]. Established in 2019 at Berkeley the University Blockchain Accelerator has accelerated the activities of 85 companies that have raised a total of more than $450 million [10].

Blockchain Center at University of Zurich unites 65 researchers of various profiles in Switzerland. The Center is engaged in the promotion and coordination of interdisciplinary research, the organization and conduct of informative educational events (Deep Dive into Blockchain, Crypto Compliance, International Workshop "Blockchain Kaigi", etc.), as well as the development of partnerships with stakeholders [11].

The conducted analysis demonstrates the existence of significant advantages that blockchain technology can bring to higher education institutions – from university admission processes to conducting high-quality international research (Fig. 4).

Among the priority directions of using this technology are smart contracts that can automate various procedures of interaction with stakeholders. Features and principles of blockchain allow automating the transactions, providing network participants with comprehensive information about the process and its results in real time without intermediaries. The future, in our opinion, is based on smart contracts, because it significantly saves time, increases trust and reliability, protects against cyber attacks, ensures the preservation and accuracy of information, reduces paper paperwork and bureaucracy, and guarantees the transparency of all transactions.

4. Cloud computing at higher education institutions

Among the digital technologies that are actively used in the activities of modern higher education institutions is the cloud computing. This technology refers to the use of hosted services such as data warehouses, servers, databases, networks and software over the Internet [12]. Schematic architecture of cloud computing is presented in Fig. 5.

To understand how cloud computing technology works, it should be noted that data is stored on physical servers maintained by a cloud service provider. The user can access the data stored in the cloud at any time and from any place with the help of cloud software. If there is access to the

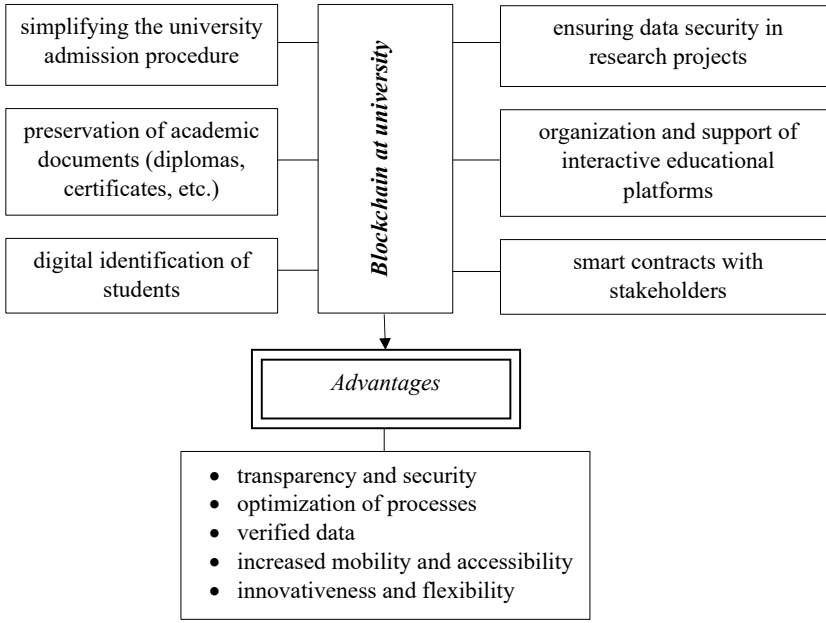

Figure 4. The main directions of using blockchain technology in the activities of higher education institutions

Internet, the user will be able to work with the necessary data in real time [2]. In other words, the data is stored in the cloud, not on a hard drive.

Types of clouds are distinguished: 1) based on deployment, and 2) based on service model. Based on deployment are the following clouds:

– private (internal, corporate) cloud – computing services are provided through a private IT network for special use by one organization (university); managed by internal resources and not available to anyone outside the university;

– public cloud – computing services are provided by third-party providers via the Internet; these services are available to anyone who wants to use or purchase them;

– hybrid cloud – a combination of public and private cloud functions; advantages of public cloud without security risks are offered [12].

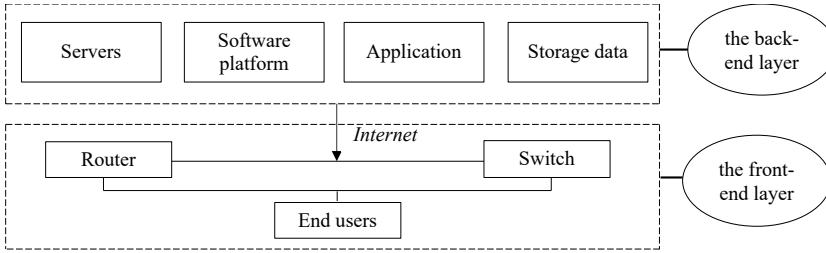

Figure 5. Cloud computing Architecture [12]

The difference between these types of clouds lies in the access to the information placed on them, as well as in the amount of the resource that is purchased by the organization, the responsibilities for the performance of the remaining types of work. Different types of clouds have both their certain advantages and disadvantages (limitations). Private clouds provide a higher level of security, guaranteeing the protection of confidential university data from unauthorized access by third parties. However, at the same time, the university must take responsibility for the management and maintenance of data centers [12].

The public cloud is less resource-intensive for the university because the cloud service provider is responsible for managing the system. With this type of cloud, a higher education institution can save on the purchase, management and maintenance of on-premise infrastructure. However, information in a public cloud is less protected than in a private one [12].

For a higher institution of education, in our opinion, a hydride cloud is more acceptable. In this case, the university pays only for resources that are used temporarily. At the same time, confidential data is available only to university employees and certain information may be publicly available.

Based on service model are the following clouds:

– Infrastructure as a service (IaaS) – the service provider is responsible for providing servers, storage and networks through a virtual interface. At the same time, user does not manage the cloud infrastructure and control the storage, operating systems;

– Platform as a service (PaaS) – providing users with an environment and resources for developing and running cloud applications; users are

not required to manage the main infrastructure (network, servers, storage, operating systems) [12];

– Software as a Service (SaaS) – providing users with access to software in the cloud; the user is not obliged to install (download) the programs on local devices, the programs are placed in a remote cloud network, which the user gets access to via API [12].

Higher education institution can use the following types of cloud technologies (based on service model):

– IaaS – rental of computing resources (servers, data storage) to support various needs of a higher education institution; use of virtual machines for laboratory work, modeling and other computational tasks;

– SaaS – use of cloud applications for managing the educational process (LMS – learning management systems as MOODLE); integration with office applications such as Microsoft Office 365 or Google Workspace.

Most higher education institutions already have experience using cloud computing. Examples include using e-mail, accessing digital resources through the cloud, offering students distance courses based on their interests and schedules [13]. In addition to the above, examples of cloud applications that are actively used in the field of higher education are Microsoft Office 365, Google Apps, Google Apps for Education Dropbox, Google Classroom etc. [15].

American higher education institutions have considerable experience in the field of cloud computing. For example, Purdue University, University of Central Florida and Jacksonville State University have been using for about 10 years cloud-based system Libris for organizing and sharing visual resources; Cornel University uses the subscription-based service Ed Cloud, which provides access to virtual servers and storage on demand [14].

The restrictions caused by the COVID-19 pandemic have significantly increased the interest of universities in digital technologies, including cloud computing. The main areas of application of this technology in higher education institutions activities are the following:

– storage and exchange of large data sets both within the university (among employees, teachers, students) and outside of it (with ministries, local authorities, business partners, employers, the public);

– automated backup and recovery of data in case of loss;

– support of online platforms for distance learning;

– development of virtual classes and interactive educational materials available to students in real time from any location;

– organization of joint work of teachers, researchers, students on projects, documents, presentations using cloud tools (video conferences, chats, forums, interactive boards, documents with shared access, etc.);

– university management (cloud systems for managing student records, grades, schedules; online journals for teachers; ERP systems for managing resources of a higher education institution);

– introducing innovations into the educational process (virtual laboratories for students to conduct experiments online; AR and VR for interactive learning; platforms for simulations and model experiments, etc.);

– student support (online counseling services, automated request management systems, etc.).

The use of cloud computing technologies by higher education institutions (Fig. 6) allows them to store huge amounts of information, reduce the costs of maintaining digital infrastructure, optimize administrative processes due to the simplification and acceleration of employees' access to data in real time. Cloud computing is valuable for organization of distance learning because it allows access to learning materials and resources at any time from any location. This advantage was confirmed by the practice of work of universities in conditions of pandemic and full-scale war.

However, using cloud computing is not without certain risks. In particular, risks of cyber attacks and data leakage, service failures. Access to cloud services requires a stable Internet connection. Due to Russia's war against Ukraine, the risks of blackouts, which cause problems with Internet access, are intensifying. This, in turn, can adversely affect the work of the higher education institution.

It should also be noted the insufficient legislative regulation of the digitization processes of higher education institutions both in Ukraine and in a number of other countries. Accordingly, information from certain areas of university activity cannot be stored and/or processed in the cloud. Legal issues of the use of cloud computing by educational institutions are quite relevant today, failure to resolve these issues will slow down the digitization processes of universities.

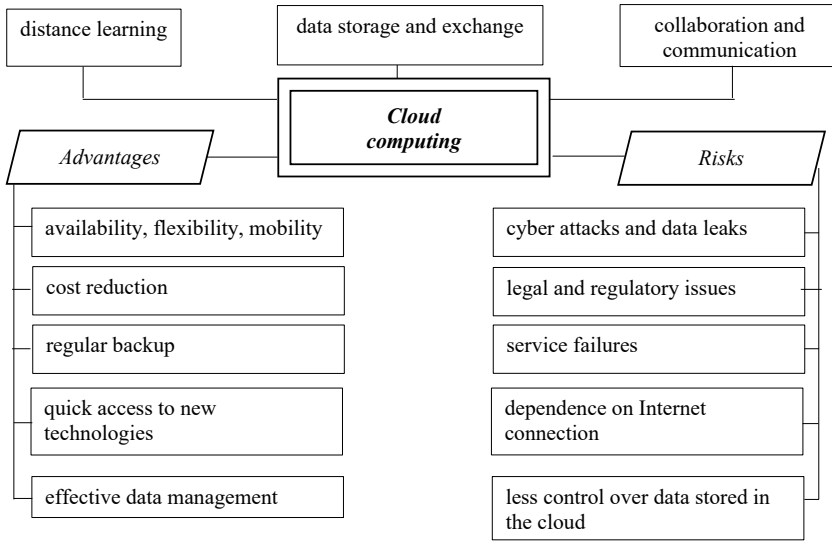

Figure 6. Advantages and risks of using the cloud computing in higher education institutions

5. Big Data Analytics at universities

Special attention should be paid to Big Data Analytics. Any modern higher education institution, its employees, students, and stakeholders generate a large amount of information every day. Data can come in various forms: structured (standard reports, tables, graphs, etc.) and unstructured (photos, videos, audio, images, location markers, etc.). Collecting and storing data is not enough; today it is important to learn how to use it effectively. Big Data Analytics is used for these purposes, which carry out systematic processing and analysis of complex sets of big data. The five V 's of Big Data Analytics:

1) volume (the ability to accumulate huge volumes of information that are permanently increasing);

2) velocity (the ability to process data streams that are updated at a high speed);

3) variety (the ability to process both structured and unstructured data from various sources);

4) veracity (ability to check the reliability of data);

5) value (the ability to transform huge data sets into meaningful information) [16].

Stages of Big Data Analytics functioning is visualized in Fig. 7.

Big Data Analysis is important for today's higher education institutions, as it can generate additional competitive advantages. The analysis of mostly unstructured data, available openly on the Internet (including social media), will allow universities to improve their marketing policies, to better study the actual requests and needs of applicants and students. This will allow university marketing services to create personalized offers with higher value for students, as well as improve universities' marketing campaigns.

It is important that the results of big data analysis require professional interpretation by experts in order to further make more informed management decisions. Such analytics are based on various types of data: personal information, information on students' interaction with digital learning systems; reports on the effectiveness of educational materials; administrative data; prognostic data [18]. Management decisions based on the analysis of the mentioned big data relate to such areas of university activity as the academic success of students, the effectiveness of using digital technologies in the educational process, the development of an

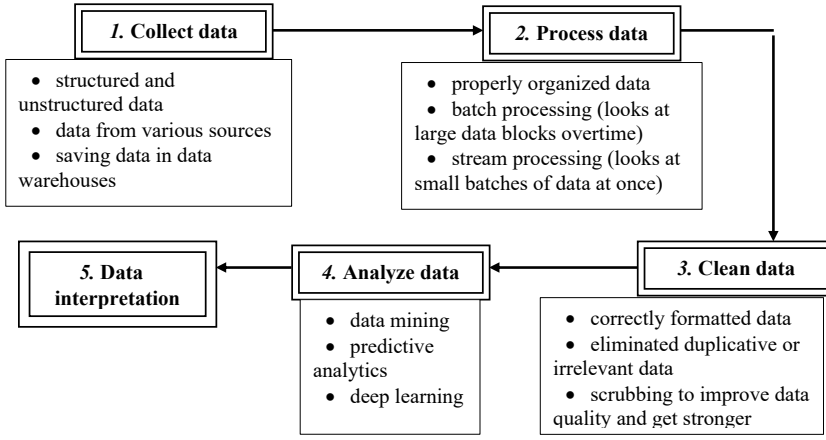

Figure 7. Sequence of functioning of Big Data Analytics [17]

individual educational trajectory of students and the choice of acceptable learning methods, the quality of organizational interaction within the educational institution.

The results of big data analysis can be used by teachers, in particular, to improve the learning environment, educational content, quality of classes, as well as approaches to evaluating student learning outcomes. Analytics can also provide detailed information about test errors, task completion times, etc. In general, an advantage of Big Data Analytics is that the results of its implementation can contribute to optimizing the curriculum [18].

The Big Data Analytics helps identify areas where students need additional support; track the career path of university graduates; improve the quality of blended learning; forecast the future performance indicators of the higher education institution; improve student retention programs based on an analysis of the reasons why they leave their studies; modernize career guidance activities based on assessment of real abilities and talents of applicants [18]. Areas of use of Big Data Analytics by universities are summarized in Fig. 8.

Big Data Analytics can be effectively used to reduce student dropout rates. For instance, Perdue University developed a system Course Signals, which can evaluate the level of training, effort and academic performance

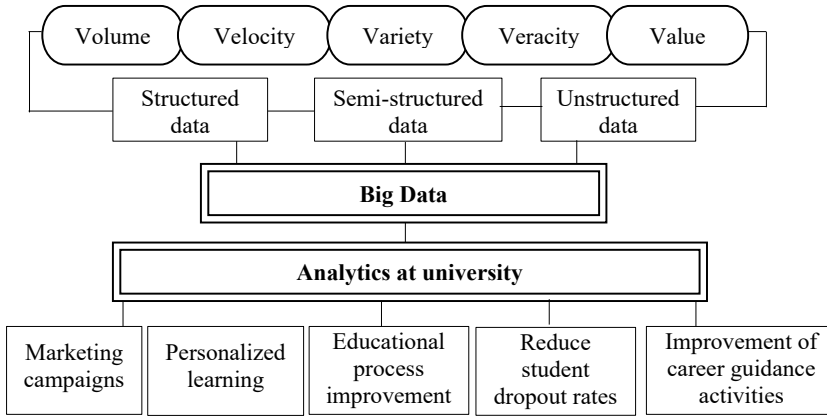

Figure 8. Directions of use of Big Data Analytics at higher education institutions

of students. Based on the results of such an analysis, a risk profile is created for each student. Course Signals informs teachers and students about the need to take relevant measures to avoid the need to expel a student in the future [19].

London South Bank University uses Big Data Analytics, in particular when tracking performance indicators and attending classes by mature, minority and part-time students [19]. Nottingham Trent University has a practice of automatically notifying teachers by e-mail to start a dialogue with students who have not participated in the educational process for two weeks. Big Data Analytics helps teachers identify students with learning problems and choose ways to stimulate them to better results [19].

A combination of Big Data Analytics with Cloud Computing, blockchain and machine learning opens up a number of new opportunities and advantages for innovation-oriented higher education institutions. It should be noted that usually the process of digitization of universities (implementation of digital technologies) requires significant investments. However, these investments will pay off in a few years, as digitalization helps to increase the competitiveness of the university in the global educational services market, attracting the applicants and partners, maintaining the interest of talented students, researchers and teachers.

6. Artificial Intelligence at universities

Currently, higher education institutions pay great attention to Artificial Intelligence, actively studying the possibilities of its use in the educational and research processes. The general characteristics of the Artificial Intelligence are presented in Fig. 9.

Artificial Intelligence can be defined as a system capable of simulating human intelligence and thinking. This digital technology processes and analyzes data using algorithms and computational models capable of recognizing patterns, making predictions, or making decisions [20]. Artificial Intelligence technologies make decisions either on the basis of pre-written clear instructions and a detailed algorithm of actions (Rules based), or on the basis of a set of data, cases for building models (Examples based). The quality of conclusions and the validity of decisions made by Artificial Intelligence directly depends on the volume, completeness and accuracy of information, data and cases that were uploaded to the system and based on which the model was trained.

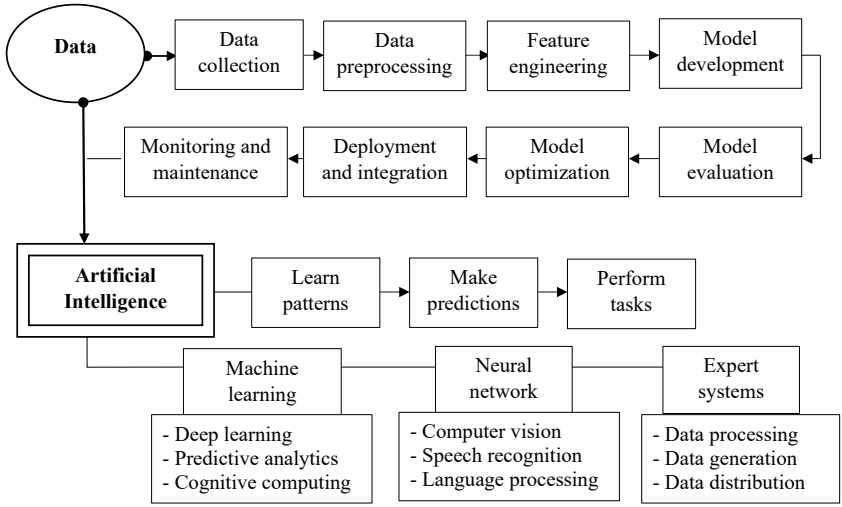

Figure 9. Description of the operation of Artificial Intelligence [20]

The development and operation of Artificial Intelligence systems and technologies begins with the collection of relevant data (structured, semi-structured, and unstructured data from databases, sensors, etc.) necessary for model training. Before entering the model, the data is pre-processed, cleaned and normalized. After feature engineering, the model is developed, and at the next stage, the model is trained on previously prepared data. The developed model, its ability to generalize and efficiency are evaluated according to various indicators. If the evaluation reveals that the model does not meet the desired performance criteria, it can be optimized. When the model satisfies the criteria of scalability, reliability and security, it can be deployed into the production environment. After deployment, the model is monitored, updated and, if necessary, retrained [20]. Training and retraining of the model can be done in different ways: supervised, unsupervised and reinforcement learning.

As highly progressive organizations, higher education institutions are actively mastering Artificial Intelligence and are constantly searching for new ways to use this digital technology to improve the efficiency of their activities. Artificial Intelligence allows universities to improve

administrative processes, including student accounting systems, planning, budgeting, maintenance, etc. AI-based chatbots, which provide round-the-clock support to students (regarding the campus, study problems, financial aid, career opportunities, study features, psychological well-being and many other issues related to the life of students at the university and beyond) have become very popular [21].

For instance, Georgia State University has chatbot Pounce, which can help with answers to questions related to the processes of admission to a higher education institution, registration for educational courses, use of campus resources, the possibility of financial aid, etc. Berkeley Chatbot (University of California) is aimed at working with the requests of students and applicants. Chatbot Genie at Deakin University was created especially for applicants. Staffordshire University uses digital assistant Beacon, which provides students with operational and personalized information. The assistant is focused on supporting the academic and emotional well-being of students. Among the most common requests for this digital assistant are the schedule, important documents, events, communication with employees, extracurricular activities [23].

Artificial Intelligence tools are actively used to provide personalized learning and teaching. For example, to personalize the educational experience of students, virtual tours and virtual teacher assistants are being developed [21].

By systematizing the above, we can determine the key areas of application of Artificial Intelligence by universities – Fig. 10.

Summarizing, we have to state that this digital technology is able to significantly reduce the burden on the staff of higher education institutions, freeing up their time to perform complex tasks, the implementation of important projects, and not to perform monotonous, routine tasks.

7. Internet of Things at universities

Among the innovative digital technologies that have great prospects in implementation at higher education institutions, it is worth highlighting the Internet of Things (IoT). IoT is the combination of Internet-connected devices and the people who use them to share information. In particular, such devices are smart-watches, temperature sensors, motion detectors, GPT receivers, different items in a smart-house, etc. The operation of Internet of Things technologies is described in Fig. 11.

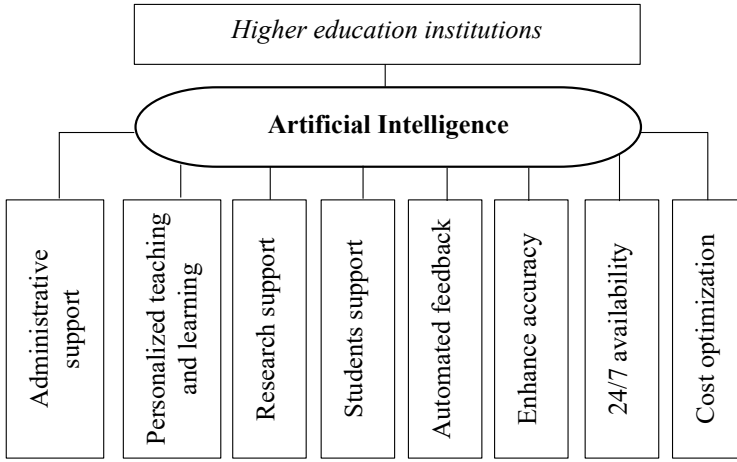

Figure 10. Directions of using Artificial Intelligence by higher education institutions

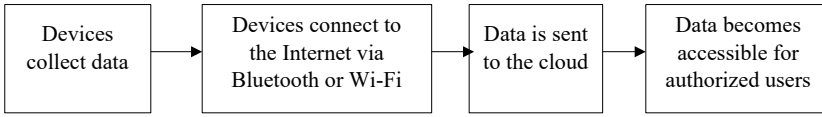

Figure 11. Scheme of IoT operation [24]

The world's leading higher education institutions are actively mastering Internet of Things, implementing it on campus (Fig. 12). IoT-sensors are used to reduce CO_2 emissions, manage sewage systems, and optimize energy use. Stanford University and the University of California reduce operating costs on their campuses through the use of smart lighting, intelligent heating, ventilation, and air conditioning systems [25].

The University of Notre Dame implemented a building management system on campus. The EcoStruxure Building Operation system allows the University to manage energy use, energy efficiency of buildings, solve maintenance problems, control the use of hot and cold water. Also, this system is capable of timely identifying and correcting problems with the comfort of campus residents [26]. Arizona State University and University

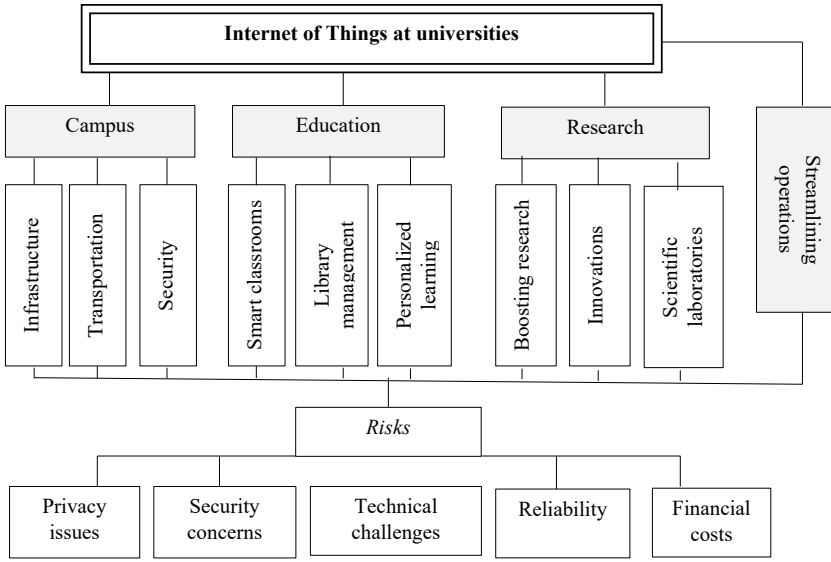

Figure 12. Directions for using the Internet of Things in universities

of Michigan actively use IoT-technologies to optimize transportation within their campuses (route tracking, smart parking systems, real-time bus schedules) [25].

Purdue University and University of Washington apply the capabilities of the Internet of Things to improve security on campuses, which is provided by video surveillance systems, response to emergency situations, etc. [25]. IoT is able to qualitatively monitor the security situation, collect and analyze relevant data and generate appropriate notifications for security services, residents and guests of the campus.

Quite often, IoT is expensive for higher education institutions. Despite this, the world's leading universities use this digital technology in the educational process. As an example, smart classes equipped with Internet-connected devices and interactive displays. IoT makes the educational process more interesting for students, increases the level of their involvement in education; for teachers, IoT is an opportunity to obtain additional valuable information about students, their requests and academic performance [25].

The Internet of Things can be very useful in universities research, as it allows simplifying research processes and inter-institutional interaction of scientists. Massachusetts Institute of Technology has research laboratories equipped with sensors to collect data necessary for conducting experiments (for example, changing environmental conditions) [25]. Therefore, IoT can make data collection for scientific experiments easier, more detailed and accurate, freeing researchers from performing technical operations and giving them the opportunity to focus more deeply on the meaningful side of research, on inventions and innovative solutions.

Despite its obvious advantages, IoT technologies have some risks (Fig. 11). They are mainly related to the probability of information leakage, confidentiality and reliability of the technology. Network failures or device malfunctions can lead to security issues. Regular maintenance, updating and support of the infrastructure requires significant investment; the application of IoT in old buildings often requires significant investments in their modernization. It is worth noting that the implementation, use and ongoing maintenance of IoT technologies usually means significant financial costs for universities [25].

However, despite the costs, cyber risks and other threats, the digitization at universities is an objective process. The competitiveness of modern higher education institutions is now determined by their ability to quickly, qualitatively and safely digitize their activities, that is, to implement and use the latest digital technologies in education, teaching and research.

8. Conclusions

Summarizing the results of the conducted research, we can state the inevitability of the digitization processes of higher education institutions. It is digital technologies that have become the most effective tool for supporting the universities during the COVID-19 pandemic and the full-scale Russian-Ukrainian war. The world's leading educational institutions realized the relevance of digitalization in time and began to actively implement innovative digital technologies in their activities. As the study of foreign experience showed, the most widespread in the university environment are now acquired blockchain, cloud computing, Big Data Analytics, Artificial Intelligence, Internet of Things. In particular, the key areas of implementation of API at higher education institutions are

the integration of information systems (electronic journal, educational platform, financial system) into a single ecosystem; automation of routine processes (registration of students for courses, schedule of training classes, etc.). Blockchain can be effectively used for verification and preservation of educational documents (certificates, diplomas, certificates), for registration and protection of copyrights for inventions. Use of cloud computing at higher education institutions will make it possible to form a flexible infrastructure for storing and processing large volumes of data without the need to invest in own equipment; improve distance learning; ensure students' access to educational materials from anywhere in the world; improve the work of teachers and students on joint projects. Big Data Analytics helps universities qualitatively and quickly analyze the academic performance of students, identify factors affecting learning outcomes, as well as improve marketing activities (study the requests of applicants and the needs of the labor market based on the processing of large amounts of structured and unstructured information that is quickly updated). Today, universities pay a great attention to Artificial Intelligence and the Internet of Things. Artificial Intelligence can be useful for higher education institutions to personalize learning, develop adaptive curricula for students, automate routine administrative tasks, support students, and maintain research. The Internet of Things is used by the world's leading universities to manage campus infrastructure (lighting, heating, security systems, etc.), to monitor the use of resources (energy, water, other utilities), as well as to improve research processes (collection of data from various sensors in real time for scientific experiments).

The change in digital technologies is happening quite rapidly, which in turn leads to the discovery of new opportunities and ways to use them in the activities of higher education institutions. Accordingly, universities should constantly monitor changes and innovations in the field of digital technologies, as well as be flexible and ready to adapt to such changes. For sure, digital technologies cannot completely and qualitatively change the communication between teachers and students, but they can significantly improve the educational process, make it interactive and more interesting for students, automate routine operations, allow teachers and scientists to focus more on generating ideas and implementing innovations.

Summing up, it is worth noting that the digitalization of higher education institutions is an objective process of integrating digital solutions into the educational process, which contributes to the realization of a number of advantages: ensuring a positive learning experience; stimulating the implementation of innovations in practice; obtaining competitive advantages in the educational services market; ability to safely continue the educational process in conditions of a pandemic, war or other circumstances that limit learning in the physical environment; personalization of the educational process; improving communication and ensuring quality feedback between students and teachers; increasing the level of inclusiveness of higher education; increasing transparency and openness of universities [1]. The set of outlined advantages allows higher education institutions to increase their competitiveness, ensure continuity of the educational process, create the appropriate quality of educational services, as well as maintain stability in periods of uncertainty, armed conflicts, wars, epidemics.

Digitization leads to significant changes in the interactions between key stakeholders of higher education institutions, stimulating the development of digital relationships between students, teachers, researchers and employees. Modern students want to implement the learning process based on a flexible, personalized and operational learning experience [4], which makes them more involved in the process of acquiring knowledge. Modern digital technologies help university teachers to become more flexible and mobile in organizing the educational process. In particular, the teacher can use asynchronous (online learning using recorded meetings), synchronous (online learning in real time) and bichronic (a combination of synchronous and asynchronous learning) teaching methods [5].

Digital technologies also facilitate the dissemination of knowledge through research. Scientists got the opportunity to implement the principle of open data, where data can be shared and used by all interested researchers, thereby supporting the process of openness and honesty of science. In addition, Directory of Open Access Journals (DOAJ) contributes to the fact that everyone can access research results, thereby minimizing price barriers and increasing the impact of research on the academic community and society. As a result, there is a need to adapt to new technologies in order to fully use their potential to simplify the educational process. For example, teachers need to review their experience and pay more

attention to the management of digital resources, and students need to acquire skills for working in conditions of varying degrees of digitization. It is also important to support students in the use of digital solutions and to provide them with the necessary technologies to effectively perform their tasks.

Recognizing the perspective and importance of introducing innovative digital technologies into the activities of modern higher education institutions, within the framework of the conducted research, we identified the main barriers of the digitization processes at universities. The vast majority of digital initiatives are implemented in economically developed countries, while developing countries are just beginning the journey to mastering and making digital decisions and face a lack of material, labor and knowledge resources. As a result, there is a widening of the digital divide between countries, their higher education systems and universities.

The lack of support from the management of higher education institution can be a significant obstacle to the use of digital technologies. The digitization process needs the support of digital leaders, who can act as the top management of the institution, as well as created departments, whose main duties are to promote the dissemination of best practices in the digital transformation of educational processes. Changing this situation requires a paradigm shift in management thinking, where digital technologies should be seen as a source of opportunities rather than threats to the traditional education system.

An important barrier is the problem of data security, which can threaten the continuity of the educational process. Among the world practices of higher education institutions, it is worth highlighting the spread of initiatives related to combining the efforts of all subjects of the educational process in ensuring data security, as well as the use of special procedures for data storage, use and management.

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