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THE CONCEPTUAL BASIS OF THE UNIVERSITY CLOUD-BASED LEARNING AND RESEARCH ENVIRONMENT FORMATION AND DEVELOPMENT IN VIEW OF THE OPEN SCIENCE PRIORITIES

Abstract. This article explores the scientific and methodological background of the creation and development of the cloud-based learning and research environment in the context of open science priorities and the European Research Area (ERA) formation. The conceptual and terminology body of the cloud-based environment investigation and the main features of such an environment are delineated. The main methodological principles of the environment design and development, for instance, the principles of open science, open education and also the specific principles inherent to the cloud-based systems are described. The study aim is to analyze the conceptual body, principles, and features of the formation and development of the cloud-based educational and research environment in the context of the open science concept. The objective of the study is to determine the prospects of cloud technologies that are used to support educational and scientific activities and to outline the principles and technologies of open science use and explore their broader application in pedagogical systems of higher educational institutions. The research methods are the analysis of official international documents, publications on the research, observation, comparison, the analysis of the experience of the educational and scientific application of cloud technologies, and experimental studies. The results of the research substantiate cloud technologies in the principles of creation and development of the learning and research environment (LRE) of a higher education institution. The concept of the cloud-based environment is explained; the characteristic features of its functioning are outlined. Additionally, the prospects and estimation of the cloud-based LRE development in the aspect of open science are defined. Conclusions and recommendations encompass the application of cloud-based open science technologies covering European research infrastructures, scientific and educational networks, European open science cloud, and also cloud services for collecting, submitting and processing data as a topical and promising trend for the development and modernization of the learning and research environment of higher education institutions.

Keywords: cloud computing; cloud-based learning environment; cloud services; open science; open data; openness; flexibility.

1. INTRODUCTION

Nowadays, an effective and promising approach to open pedagogical systems design is the use of the cloud computing technologies to provide ICT support for the functioning and development of the computer-based educational and research environment. Innovative technological solutions for learning environment organization and design using cloud computing (CC) and ICT outsourcing show promise and usefulness [1], [2], [3]. The challenges of making the ICT infrastructure of the university environment fit the needs of its users, taking maximum advantage of modern network technologies, and ensuring the best

pedagogical outcomes leads to the search for the most reasonable ways of its modernization [4], [5].

The cloud-based approach is to ensure the processes of open learning giving way for broader access to quality learning resources, supporting the processes of collaborative learning and also making the learning environment available for the user practically from any place and at any time [6].

However, the cloud computing platforms are to support not only open learning but also open science processes. These processes are related to open access to research data, open discussion and analysis of research results and open communication with society [7], [8], [9]. To support these processes, the corporate or hybrid cloud-based university environments are useful as the essential components (accomplishments) for the resources of the various public information networks such as research infrastructures and social networks. Thus, the analysis of the principles and essential features of the structure and design of the university cloud-based learning and research environment becomes additionally valuable because of its support of open science processes.

The inconsistency of the structure and composition of the learning and research with the requirements of constructing pedagogical systems (PS) belongs to the modern challenges of higher education development. An absence of educational practice that includes open science priorities, the insufficient study of theoretical and methodological foundations of the university cloud-based environment development, and its learning resources and tools constrain the university pedagogical systems development and hinder its further quality improvements.

The analysis of the recent research and publications. According to the recent research [3], [10], [11], [4], [12], [13] the problems of cloud technologies that are implemented in higher educational institutions to provide software access, support collaborative learning, research and educational activities, exchange experience and also project development are especially challenging. Currently, the formation of the cloud-based learning and research environment is recognized as a priority by the international scientific and educational community [14] and is intensively developed in various areas of education [6], [15], [5], [12], [16], [17].

Since the annual international seminar that is entitled "Cloud Technologies in Education" was initiated in 2012 in Ukraine [21], specific steps were carried out following this direction, for instance the activities of joint research laboratories of the Institute of Information Technologies and Learning Tools of NAES of Ukraine with Kryvyi Rig National University, Ternopil National Pedagogical University (named after Volodymyr Hnatyuk), I.Franko Zhytomyr State University, I.Franko Drohobych Pedagogical University, National University of Life and Environmental Sciences of Ukraine were developed [11].

Theoretical results and practical orientation of the researches conducted at the Institute of Information Technologies and Learning Tools of the NAES of Ukraine are mainly subordinated to the specified educational paradigm that is aimed at the development of the scientific and methodological foundation of implementing the principles of open education. In particular, V. Bykov's work "The Models of Organizational Systems of Open Education" proposes the models of information educational environment. The aim of the work is to create the methodological basis for further research in this area and the cloud-based environment is a new step in the development of open education systems [1].

In 2015‒2017, the research project "Methodology of the formation of the cloud-based learning and research environment of a pedagogical educational institution" was conducted at the Institute of Information Technologies and Learning Tools of the NAES in Ukraine, State Registration №0115U002231, with the project coordinator M. Shyshkina. In the course of this project the conceptual basis, principles and approaches to the environment formation,

classification of services, design of the general model of its formation and development were considered and implemented [5].

In recent years a series of dissertations on the application of different types of cloud-based services at higher educational institutions have been completed in Ukraine (O. Glazunova (2015), M.Shyshkina (2016), M.Kyslova (2015), M.Popel (2017), O.Merzlikin (2017), T. Voloshyna (2018) and others http://iitlt.gov.ua/eng/atestat/spetsializovana-vchena-rada/avtoreferaty-dysertatsiyi.php).

Along with the development of open education and open science systems, the tools and technologies of learning and research environment formation are improving. In [2] the stages of the evolution of the information and communication networks tools of open LRE, such as service, content, and adaptive information and communication networks tools are revealed [2, p.11].

Due to the introduction of the cloud computing technology (which enforces the emergence of adaptive information and communication networks), new forms of activity arise within LRE that affect the content, methods and organizational forms of open education and science. Tools and services of cloud computing constitute the information and technological platform of the modern educational and research environment and become the network tools for its formation and development.

The unresolved aspects of the problem. The scientific and methodological background of creation and development of the cloud-based LRE needs further research in the context of Open Science Priorities as they are defined within ERA formation. The conceptual and terminology body of the cloud-based environment investigation progresses, and the main features of such an environment are developed continuously. Therefore, the main methodological principles of this environment design and development are to be considered to enforce its wider take-up and implementation. The principles of open education, the specific principles that are inherent to the cloud-based systems, and the principles of open science need to be outlined to prospect their broader application in pedagogical systems of higher educational institutions.

The current issues include existing approaches and models for electronic educational resources delivery within the cloud-based setting [2, 18, 6], the methodology of CC-based learning and research university environment design, the information research and educational networks and research infrastructures use [2, 18], the use of different types of services within the CC-based LRE such as educational robots, systems of language processing, databases and others [19, 20, 17], evaluation of current experience of cloud-based models and components use [3], [11], [21], [4]. The problem of creating corporate educational and research environment of the university that would combine different types of services to support open learning and research activities and collaboration by CC platform arises as essential and prevailing [20], [22], [23]. This brings the problems of the cloud-based open learning and research environment design and development conceptual basis substantiation to the forefront.

The purpose of the article is to outline the conceptual body and principles of the cloud-based learning and research environment formation and development to consider the possible ways of its use and application within the pedagogical systems of higher education given Open Science Priorities.

2. THE RESEARCH METHODS

The research methods in analyzing the current research (including the domestic and foreign experience of the application of cloud-based learning services to define the concept of the investigation and research indicators), official international documents, publications on

the research, observation, comparison, analysis of the experience of educational and scientific application of cloud technologies, examining existing models and approaches, technological solutions and psychological and pedagogical assumptions about better ways of introducing innovative technology consider and elaborate on the general principles of the environment formation and the analysis and estimation of current experimental results.

3. THE RESEARCH RESULTS

The use of ICT affects the content, methods and organizational forms of learning and managing educational and research activities that require new approaches to learning environment arrangement [2], [3]. Therefore, the formation of modern cloud-based systems for supporting learning and research activities should be based on appropriate innovative models and methodology that can ensure a harmonious combination and embedding of various networking tools into the educational environment of a higher education institution [2], [3], [24], [22].

The cloud-based learning and research environment (CBLRE) of a higher education institution is the environment in which the virtualized computer-technological (corporate or hybrid-based) infrastructure is purposefully built for the realization of computer-procedural functions (such as content-technological and information-communication functions) [22].

Essential features of formation and development of the cloud-based learning and research environment of higher educational institutions are such properties as openness and flexibility [22], [24].

The openness of the cloud-based environment relates to its permanent dynamic relationship with the external to this environment socio-economic space, which sets goals and objectives and defines the requirements for the functioning and development of educational systems, provides them with the necessary resources and utilizes end products. If the resources necessary for functioning and development of educational systems are available, the openness is the imperative for the systematic adaptation of the environment structure to the tasks and requirements imposed by the external socio-economic space. The ability of the environment to be adaptive, to provide progressive changes are determined by the flexibility of its structure and configuration [22], [24].

The flexibility of the cloud-based environment as for providing conditions for the development of the target and methodological learning subsystems of a particular pedagogical system means the potential suitability of the environment to changes (in certain predetermined allowable limits) of the composition, structure and parameters of its components, which do not lead to loss of its integrity (the destruction of its system-forming relations, going beyond the intended variability of component parameters), significant changes in its primary target and functional subsystems or loss of safety [22], [24].

The development of the cloud-based environment is an evolutionary change in the structure of the environment and / or its component parameters (for example, the procedural capacity and volumes of storage clusters, the coverage area of access to computer networks through wireless communication channels) that occurs in accordance with the updated goals of the pedagogical system, desirable (planned, predicted, hypothetical) characteristics of its end products at certain stages of development [22], [24].

This is due to such properties of the cloud-oriented environment as the openness and flexibility of its structure and composition so that it can be brought into conformity with the planned development goals and new tasks which have arisen or will arise shortly. These properties potentially enable changes in the tasks of the formation and development of the environment and, as a result, adequate changes in the composition and parameters of its facilities and the modernisation of the methods of its design and use [22], [24].

Flexibility and openness of the environment are achieved through the cloud technologies application. After all, these technologies, as well as the cloud platforms, were basically introduced to build and maintain flexible and open systems. That is why this type of platforms is the most promising for the design of the computer-based infrastructure of the educational institution as a whole, as it will be possible to create the best conditions for the progressive development of this environment [22], [24].

At the same time, the cloud-based environment of an educational institution is a complex system that contains a significant number of subsystems, implements various functions that are formed at the level of the institution, its separate structural subdivisions. In this aspect, the cloud-based approach to the environment creation is to provide the basis for the integration of different types of services to support various kinds of learning and research activities as well as the integration and close relationship between the learning and research on the whole. Special attention is required to the methods of designing and using environment components for different levels of its organization in the implementation of various types of the cloud-based tools. Therefore, a set of techniques may be needed to deploy and use the cloud-based environment or its components.

The cloud-based network instruments of open learning and research are the ICT tools that provide the formation and current maintenance of network electronic information resources and cloud services of the open learning and research environment, the implementation of the technology of design and application of open cloud-based pedagogical systems. The most important network tools for open learning and research systems include cloud-based science and education information networks and infrastructures; cloud-based corporate information systems and services; network electronic educational resources and services for data collecting, processing and presentation; educational and scientific laboratories of remote access; language technologies; educational robots, etc.

3.1. The Open Science Research Priorities

The task of implementation of the most advanced ICT tools including the cloud computing services and technologies is one of the top priorities in the field of ICT for education, development of open science and education space. This is evidenced by a number of government initiatives from different countries and the adoption of international documents such as "Digital Agenda for Europe" (2010), "European Cloud Computing Strategy in Europe" (2012), according to which the cloud computing has been recognized as a priority area [7] that has had a significant impact on the development of the European Research Area and the formation of ideas of open science.

In 2000 a document entitled "Towards a European research area" was developed in Brussels, outlining the main principles of its formation [25]. This document emphasised the need to establish the mechanisms for scientific cooperation between countries in order to coordinate efforts, resources, human capital to improve research efficiency and competitiveness of the economy. The European Research Area (ERA) is understood as "a unified area open to the world, in which scientific knowledge, technology and researchers circulate freely" (the site "European Research Area", http://ec.europa.eu/research/era/index_en.htm).

"The European research area should be an area where the scientific capacity and material resources in the Member States can be put to best use, where national and European policies can be implemented more coherently, and where people and knowledge can circulate more freely; an area attractive both to European researchers and to the best researchers from third countries and built on respect for the common social and ethical values of Europeans and their diversity" [25, p.24].

In 2015, the Roadmap for the formation of ERA (2015-2020) was launched; it was proposed to implement this Roadmap at the national level by different countries [8].

On March 23, 2018 the Roadmap of Ukraine's Integration into the European Research Area, which is based on the implementation of these priorities at the national level, was approved by the Ministry of Education and Science of Ukraine. It provides significant opportunities for Ukrainian scientists and research groups to be engaged in scientific cooperation within the ERA, which requires a broader introduction of the open science ideas into the practice of research.

The main features of the open science paradigm as one of the fundamental concepts in ERA development have been identified in some international instruments.

In particular, in 2013 the European Commission published a conceptual document "Digital Science in HORIZON 2020" outlining the basic principles of the vision of science development issues in the light of the improvement of digital technologies, in particular, the cloud-based, due to the implementation of HORIZON 2020 research program.

"This is a science based on e-infrastructure, mainly for I) developing and disseminating specific ICT tools for solving scientific problems; II) provision of online access to scientific resources, including publications and data; III) the creation and development of platforms and tools that enable large-scale collaboration without the need for physical presence" [7]. The "digital science" policy is aimed at broader and more efficient use of electronic infrastructures in Europe.

In 2015, the conceptual document "Open Science" was developed which identified five of the main Open Science Priorities [9].

1. *Open access*. "Open Access stands for unrestricted online access to research in general" [9, p.2], that is, the concept of "open access" is considered in the light of the Budapest Open Access Initiative [19].
2. *Open data*. In order for data to be considered open, they must meet the following requirements:
   − Availability and accessibility: "The data should be available as a whole and at no more than a reasonable reproduction cost, preferably by downloading the internet. The data must also be available in a convenient and modifiable form, including meta-data" [9, p.3];
   − Reuse and Redistribution: "The data must be provided under terms that allow reuse and redistribution, including intermixing with other datasets" [9, p.3];
   − Universal Participation: "Everyone must be able to use, reuse and redistribute - there should be no discrimination against the fields of endeavor or individuals or groups. For example, "non-commercial" restrictions that prevent "commercial" use or restrictions of use for certain purposes (e.g. only in education) are not allowed" [9, p.4].
3. *Open methods*. "The purpose of Open Methods is to make clear accounts of the methods used freely available through the Internet to enhance the scientific process" [9, p. 4].
4. *Open education*. "Digital resources and the Internet are transforming pedagogy. Open Education not only creates access to education, but it also makes use of open content, such as open educational resources and places emphasis on the learner's network" [9, p. 5].
5. *Open evaluation*. "Traditionally the scientific publishing and funding systems provided essential basic services: access and evaluation. As the number of scientific publications constantly grows, evaluation and impact assessment for selection will only become more important. However, traditional peer review and bibliometrics

based on article citation in its present state can not cope with all dimensions of Open Science regarding validity and transparency" [9, p. 6].

What is the purpose of creating and spreading the Open Science technologies? As indicated on the website of the European Commission (https://ec.europa.eu/digital-single-market/en/open-science), "Open Science aims at transforming science through ICT tools, networks and media, to make research more open, global, collaborative, creative and closer to society". Open science is to make scientific processes more efficient, transparent and effective as it offers new tools for scientific collaboration, conducting experiments and analysis of research results and by making it more easily accessible [7].

In order to implement the Open Science Priorities, in 2016 the European Commission developed a document entitled "The European Cloud Initiative - Building a Competitive Data and Knowledge Economy in Europe" [14].

As it is defined at the website devoted to this initiative, it will provide European science, industry and public authorities with a world-class data infrastructure to store and manage data; it is to provide high-speed connectivity to transport data; and ever more powerful High Performance Computers to process data, making it possible to exploit in full scale the benefits of Big Data. It makes possible to move, share and re-use data seamlessly through global markets and borders, and among different institutions and research disciplines (https://ec.europa.eu/digital-single-market/en/european-cloud-initiative). All this will enable the data obtained in the research to be as open as possible, accessible to those who can use them for research, development, innovation, the creation of new industries, etc. (https://ec.europa.eu/digital-single-market/en/european-cloud-initiative).

The original notion of this initiative is the development of the European Open Science Cloud (EOSC). "A European Open Science Cloud (EOSC) will offer Europe's 1.7 million researchers and 70 million science and technology professionals a virtual environment to store, share and re-use the large volumes of information generated by the big data revolution" [26]. The European Open Science Cloud as a platform for the European Cloud Initiative will combine the power of major pan-European research infrastructures such as EGI, EUDAT CDI, INDIGO-DataCloud and others.

On October 26, 2017, the Declaration of European Open Science Cloud was published in Brussels, in which the main principles of the formation of the cloud [19] were formulated. The basis of these principles is the concept of "Fair, Transparent Data" (FAIR Data), that is, data that can be found, available, compatible, and suitable for reuse (Findable, Accessible, Interoperable and Re-usable).

On March 14, 2018, the European Commission concluded a paper "Implementation Roadmap for the European Science Cloud". The purpose of this document is to identify the main areas of research on research data management so that the "data-driven science" [26] can be fully developed.

The issues of the definition of the principles governing the formation of EOSC; creation of business models of its provision; issues of compatibility and availability of data, their suitability for re-use are considered in this document as the most urgent [15]. Also, the issue of identifying the essential services necessary to collect and organize the processing of FAIR Data and related research products that are to be made available through service platforms is the current one [26, p. 7].

As it is noticed in the Roadmap there is a belief that EOSC should be scalable and at the same time to be adaptive to the emerging needs of the scientific community, and to be able to support a fully-fledged scientific data lifecycle [26, p. 8]. The formation of the Cloud should take place step by step so that it can promptly respond to the changing needs of a scientific community regarding the use of data, as well as to the EU strategies and national strategies as for the processing and use of research data [15].

This document also describes the main kinds of services that should be provided by EOSC, among them there are such as a unique identification and authentication service and an access point and routing system towards the resources of the EOSC; a protected and personalized work environment/space; access to relevant service information and to specific guidelines; services to find, access, re-use and analyze research data generated by others, accessible through appropriate catalogues of datasets and data services; services to make their own data FAIR, to store them and ensure long-term preservation [26, p.14].

The services of these types can now be provided through already existing European infrastructures such as EGI, EUDAT, GEANT and others, also due to existing data repositories. Meanwhile, the services of these providers are available to specific communities of scientists; their supply is limited to the context of use or disciplines, national boundaries. EOSC will make them accessible, regardless of a subject matter or a country [26].

Thus, the cloud services, cloud platforms and more generally the cloud-based university environment become the focus of attention regarding the need to consider and support the open science processes and learning and research communication given Open Science Priorities. The cloud computing efficiency in maintaining these processes appears to be urgent. The cloud platforms are fit most of all for the tasks of integration and aggregation of a considerable number of different services as this is necessary for the realization of open science aims. Among them there is the need of integration into university learning and research environment of a large number of various information and technological support tools, such as the scientific and educational information networks [18], corporate network tools and services for learning and research [24], as well as various language tools to support the multi-language content [17], the use of intelligent educational agents and robots, databases [19], [20] and so on. Thus the cloud-based learning and research environment of an educational institution conceptual basis, principles of design and elaboration as well as content and services modelling and implementation with regard to Open Science Priorities are among the promising issues to be considered and discussed.

3.2. The Principles of Open Science in the Formation of the Cloud-based Learning and Research Environment.

Priorities and characteristics of open science, the main provisions of the EOSC Declaration, and current research results on this topic and other current valuable sources and documents make an essential framework to reveal and explore the principles of open science to be realized within the cloud-based learning and research environment, to prospect their implementation in various pedagogical and scientific and educational systems.

The main Open Science characteristics were described by Open Science Monitor, the website for monitoring open science worldwide that was launched on March 20, 2017, as part of ongoing work for the European Commission (https://www.rand.org/randeurope/about/news/2017/new-website-launched-monitoring-open-science-worldwide-.html). This site was developed by RAND Europe, Deloitte, Digital Science, Altmetric and Figshare to host a monitor to provide stakeholders, including researchers, policymakers, funders, libraries and publishers with access to data and trends on open science (https://www.rand.org/randeurope/about/news/2017/new-website-launched-monitoring-open-science-worldwide-.html).

Due to Open Science Monitor, the main characteristics and indicators of open science were revealed given Open Science Priorities (http://aims.fao.org/activity/blog/open-science-monitor-access-data-and-trends-open-science). There are three main characteristics that were proposed to be monitored by particular sets of indicators, among them, Open access to publications; Open research data; Open scholarly communication.

The whole set of characteristics may be taken as the instrument to reveal the main groups of open science principles to be provided within the cloud-based learning and research environment of a university in the context of the realization of Open Science Priorities.

It seems useful to consider each of these characteristics through the lens of Open Science principles.

Open Access to Publications means open access to publications in the sense of Budapest Open Access initiative [19]. (It covers the first of Open Science Priorities "Open Access"). Now it may be realized through the number of current open science instruments such as the use of open licenses; the use of open data repositories among which there are such as The Open Access Infrastructure for Research in Europe (OpenAIRE), Registry of Open Access Repositories (ROAR), Directory of Open Access Repositories (OpenDOAR); the use of preprints so as to ensure the long-term access to publications; alternative publishing platforms are also among the ways to provide open access to publications. Among the instruments of the open science are also the services of the international infrastructures of scientific information such as Google Scholar, social networks such as Research Gate, Academia.edu, Unpaywall, Sci-Hub and others aiming to make the broader access to scientific knowledge possible.

Open access refers to the possibility to freely access research publications. These are divided into gold and green access. According to the EC, "'Gold open access' means that open access is provided immediately via the publisher when an article is published, i.e. where it is published in open access journals or 'hybrid' journals combining subscription access and open access to individual articles. In gold open access, the payment of publication costs ('article processing charges') is shifted from readers' subscriptions to (generally one-off) payments by the author.[…] 'Green. open access' means that the published article or the final peer-reviewed manuscript is archived by the researcher (or a representative) in an online repository." (Source: H2020 Model Grant Agreement) [27].

Open Access to Data is to provide the data to be available in the open repositories aiming to link the research and data. "Open research data refers to the data underpinning scientific research results that have no restrictions on its access, enabling anyone to access it" [27]. (It covers the second of Open Science Priorities "Open Data" and the third one "Open Methods").

Among the open repositories, there are those registered in the Registry of Research Data Repositories, and also the platforms such as Databib or Zenodo. To provide open data, the identifiers ORCID and DOI are also valuable in terms of protecting the authors' copyright.

"Implementation of the FAIR principles must be pragmatic and technology neutral, encompassing all four dimensions: findability, accessibility, interoperability and reusability. FAIR principles are neither standards nor practices. The disciplinary sectors must develop their specific notions of FAIR data in a coordinated fashion and determine the desired level of FAIR-ness. FAIR principles should apply not only to research data but also to related data algorithms, tools, workflows, protocols, services and other kinds of digital research objects" [19].

In some research, the Open Methods or the Open Methodology are also declared as the open science principles. Open Methodology means to document the use of methods, as well as the whole process, as far as possible and appropriate [29].

Within the FOSTER project, devoted to the open science practices (https://www.fosteropenscience.eu) the stages of the research process were identified, as well as what steps should be taken to ensure openness at each stage (or for each type of activity of a scientist) [30]. Among them there are such stages as Data collection; Data processing; Store data and results; Long-term storage; Publishing and distributing; Reuse. At the final stage, the next steps are revealed: publishing open source metadata; using extensive evaluation; linking

publications, data and methods; using institutional repository capabilities. So the need to relate data, methods and evaluation is emphasized.

Open Scholarly Communication refers to open peer-reviews services, provided by electronic journals, use of altmetric platforms, discussion using the open data and publication, open evaluation of research results. It coincides with the fifth Open Science Priority "Open Evaluation", but is not limited to it. "Communication spans discussion on social media (e.g. Twitter, ResearchGate and Academia.edu), comments on published papers (e.g. PubPeer), discussion of preprints (e.g. bioRxiv), communication while projects are ongoing, and 'live' project or proposal work (e.g. the 'opening science' book (Bartling & Friesike 2014)), or proposals for the open data prize (Martone et al. 2016)" [28].

"Open scientific collaboration refers to the forms of collaboration in the course of the scientific process that do not fit under open data and open publications. It includes different type of outputs such as open code, open hardware, the use of collaborative platforms between scientists and the "citizen-science" phenomenon" [28].

Thus the processes of open communication cover the processes of extensive evaluation and open collaboration meaning that communication is open not only at the discussion and evaluation of results but also at all the stages of the process of research.

On the website of the FOSTER project (launched in 2017 under the HORIZON 2020 program), the definition of open science was formulated through its main principles (https://www.fosteropenscience.eu/ content / what-open-science-introduction). As the authors of the project emphasize, open science is to extend the principles of openness to the whole cycle of research, promoting sharing and collaboration, and ensuring the possibility of joint action with resources at the earliest stages of the study [31]. It states: "Open science is a new approach to organizing a scientific process based on collaborative work and discovering new ways of spreading knowledge that becomes possible through the use of digital technologies and new means of supporting cooperation."

Aiming to create the open learning and research university environment the principle of wide use of the most diverse and powerful ICT-based tools and services to support the processes of educational activity is to be provided. Among a wide range of current ICT-based tools and services arising in this area, there are such as European research infrastructures; scientific and educational networks; cloud services for collecting, submitting and processing data; as well as the services of the European open science cloud. Within the conceptual framework of open science and education, they form the variety of modern cloud-based open science technologies and instruments.

Thus, we may consider the principle of *extensive use of ICT, cloud-based network tools and services* to support the open science processes.

Thus, taking into account the trends in the development of ICTs, in support of scientific research, in particular cloud technologies, it should be noted that the principles of the cloud-based learning and research environment functioning should be accompanied by the principles of open science: the open access to publication; the open data; the open communication; extensive use of cloud-based network tools and services to support scientific collaboration and to organize data sharing in the workflow.

3.3. The Principles of Open Education in the Cloud-based Learning and Research Environment Formation

The aims of education are transformed due to the Open Science Priorities as the open research supposes the full range of learning activities. The learning and research processes are tightly connected so the principles of open science should be implemented into the learning

process as well as the appropriate learning resources are to be incorporated into the open science platforms.

The open education principles coincide with the fourth of the Open Science Priorities emphasizing the important role of this principle within the open science concept. So among the whole set of psychological and pedagogical principles of the cloud-based environment formation, the individual attention should be paid to the principles of open education which are realized in greater extent through the tools of this environment; and the specific principles typical for the cloud-based educational and research systems.

The principles of open education in the learning and research university environment are not limited to the use of the learning resources devoted to open science goals and mastering of the open research skills. The open education principles refer to the broader context of open access to qualitative education, accessibility, flexibility and mobility of learning that may be provided due to the cloud-based approach, and tight relationship between the learning and research processes integrated by uniting framework created in the university.

The present research is based on the following principles of open education [1]:

the principle of *mobility of students and teachers* ensuring mobility of graduates of an education system and teachers on markets (including international) of labor and educational services;

the principle of *equal access to educational systems* ensuring equal access to education for everyone who has the desire and needs to study throughout life and has the opportunity to do so;

the principle of *qualitative education* refers to the provision through open systems of such quality of education that would correspond to the individual educational needs of students and the requirements of society regarding the general and professional educational level of its members;

the principle of *the structure and implementation of educational services formation* is connected to the provision of the market mechanisms for the formation of the qualitative and quantitative structure of training, retraining and advanced training of learners, and the implementation of a range of educational services offered through open education systems.

The cloud-based systems are to support the full range of learning and research processes within the university environment, so the main principles inherent to the cloud-computing approach are advisable to be provided and realised within the environment.

To the *specific principles* (typical for the cloud-based systems) we refer the following [24, 23]:

the principle of *adaptability* concerns the suitability of learning tools and services of the system for the needs of the broadest possible contingent of users, who may have different information and procedural needs associated with different levels of knowledge, individual characteristics, the rate of mastering material, etc.;

the principle of *personalization* of services delivery ensures a person-oriented (personified) approach to learning by adjusting the ICT infrastructure of the environment (including virtual) to individual information and communication, resource, operational and procedural needs of participants of the educational process;

the principle of learning and research environment of *ICT infrastructure management unification* presupposes the uniformity of its structure, aimed at integrated data storage and management of large arrays on the unified basis, which is necessary to ensure systematic, invariant approaches to the organization of access to learning and research resources within this environment;

The principle of full-scale interactivity of learning and research tools of the cloud-based environment relates to the organization of the useful feedback of these tools use and to the support of the interactive mode of cooperation with mobile participants. Through the

feedback the control and evaluation of the learner's actions and the permanent access to the guidance and support materials are provided. It is assumed that the feedback comes up as instant, something that helps in real time, allowing the most comprehensive response to the needs of the learner;

the principle of *flexibility and scalability* of access to resources and tools of the cloud-based environment is aimed at dynamic receiving, deploying and supplying of the cloud services and platforms, as well as promptly releasing the computational resources that are not at need, increasing the effectiveness of the learning process organization, providing the ability to quickly adapt to the changing requirements and arising problems;

The principle of *data and resources consolidation* is implemented by simplifying procedures, deployment and management of data centres infrastructure, enabling more effective association, storage, filing and processing of large data sets and resources collections.

The principle of *standardization and interoperability* of learning data and resources is based on the standardization of tools and procedures of cloud services and resources supply to provide more transparent and understandable ways to design and deploy the components for educational purposes, their presentation and incorporation into the learning environment based on cloud-based models.

The principles of *security and reliability* of learning services supply means that within the cloud-based infrastructure the availability and reliability (continuity) of educational services supply increases to provide more stable performance in the environment, getting the right amounts of necessary resources and data in time to avoid or reduce the threat of data loss, unauthorized access.

The principle of *innovation* is realized with the ability to order and pay for the cloud-based services delivery as soon as they are used, to provide the freedom of choice and experimentation with different types of electronic resources, software, computer platforms and technologies in the learning process, expanding the share of investigative approach in learning, it contributes to the development of skills for collaboration in the learning process, joint research and data analysis processes.

The formation of the cloud-based learning and research environment of a higher education institution should be based on the principles of open education, open science, and specific principles, in particular, adaptability; personification of services delivery; ICT infrastructure unification; full-scale interactivity; flexibility and scalability; data and resources consolidation; standardization and interoperability of learning data and resources; safety and reliability; innovation and others (Table 1).

Taking into account these principles, as well as the features of the structure and the use of the cloud-based information-analytical network tools at the learning and research environment design it will be possible to facilitate the expansion of access to high-quality and large-scale information resources, to a wide range of information services offered by the learning and research information networks, practically unlimited range of users regardless of their age, gender, citizenship, location.

Table 1

The Principles of the Cloud-based Learning and Research Environment Formation Given the Open Science Priorities

Open Education Principles	Open Science Principles	Specific Principles
Mobility of students and teachers; equal access to	Open access to publications Open research data ✓ Fair principles:	Adaptability; personification of services delivery;

educational systems; qualitative education; the structure and implementation of educational services formation	– Findable – Accessible – Interoperable – Reusable ✓ Open research methods Open scholarly communication ✓ Open collaboration ✓ Open evaluation Wide use of cloud-based network tools and servces to support the research	ICT infrastructure unification; full-scale interactivity; flexibility and scalability; data and resources consolidation; standardization and interoperability of learning data and resources; safety and reliability; innovation

3.4. The results of the formation and implementation of cloud-based environment of open education and open research

The cloud-based LRE was implemented at the Institute of Information Technologies and Learning Tools in the course of research projects and pedagogical experiments conducted during 2012-2017. In the scientific and educational process in this period the cloud-based services for open education and open science support have been introduced.

The formation of information resources of the Institute was carried out in the environment of research and educational information networks, while the intensive application of services of electronic libraries, Internet conferences, scientometric and bibliometric cloud services had been introduced in scientific activity since 2011.

During 2012-2014, the Internet-based tools of broadcasting reports and speeches of participants in seminars and conferences, as well as the support of distance participation in the Institute's activities, in particular on the platforms such as Skype, Wiziq and others, have been used to support the scientific activity. Since 2014 the institutional system Edu-conference has been introduced. Using this platform, the submission and review processes of the annual All-Ukrainian Scientific and Practical Conference of Young Scientists "Scientific Youth", reports of the scientific conferences and seminars of the Institute have been supported.

The leading tools for the scientific and educational activities support the electronic journals and libraries that are deployed using the cloud platforms. In particular, the electronic journal "*Information Technologies and Learning Tools*" (https://journal.iitta.gov.ua/index.php/itlt) in 2011 was transferred to the basis of the Open Journal Systems (OJS) publishing system, developed by the Public Knowledge Project (Canada), an open information and technology platform for the deployment of scientific journal systems; since 2012, the journal has been indexed in scientometric databases, such as Google Academy, Index Copernicus, Universal Impact Factor (UIF), since 2015 it has been indexed by the scientometric database Web-of-Science, and numerous abstract databases (including the Directory of Open Access Journals (Sweden), Academic Journals database (Switzerland), National abstract database "Ukraine Science" (Ukraine). Now the journal is a part of Open Data Depositaries such as Doaj and OpenAir.

In 2009-2011, the *electronic library of the Institute of Information Technologies and Tools of NAES of Ukraine* (http://lib.iitta.gov.ua/cgi/irstats.cgi) was created and filled with information resources. In 2012-2014 the services of the electronic library were actively used in the research process (regular downloading of full texts of publications prepared within the framework of research work, monitoring of their implementation with the help of scientific and metric services of the library was conducted). The electronic library is a part of the Doaj Open Data Depositary.

The social networks of scientific and educational purposes that are still of much relevance as for the support of network collaboration were actively used in the process of research. Among them there were such as LinkedIn, Research Guide, Academia.edu and others which were used for discussion and review of publications, exchange of experience in the development of scientific issues, establishing contacts with colleagues, finding useful information.

The tools of open science scientometric platforms have been used to support the research processes. The most popular non-profit one is the Google Scholar Platform (http://scholar.google.com/). Google-profiles were created for all employees of the Institute, which provides instant access to the list of scientific works, links to their full-text versions, index of citation of each employee [18].

Analysis of the quantitative and qualitative indicators of the final research products during this period shows a tendency towards their steady growth [18].

The development of experimental activities of the Institute was carried out through the activity of joint research laboratories, implementation of scientific projects of the national level, conducting of regional and national experiments. In 2012, the annual International Scientific and Methodological Internet Workshop "Cloud Technologies in Education" was launched, http://tmn.ccjournals.eu/index.php/cte/CTE2014/. In 2013 the joint research laboratory with the Kryvy Rih National University http://cc.ktu.edu.ua/ was created on which the information resources of the laboratory were formed; in the same year, a permanent monthly laboratory workshop was launched. In 2014, the scientific-educational cloud of the Department of Cloud-Oriented Education Informatization Systems of the Institute of Information Technologies and Learning Tools of NAES of Ukraine (https://school11-public.sharepoint.com/) was created to organize joint activities and exchange necessary resources.

Since 2012 the joint research laboratories devoted to cloud computing in education have been organized on the basis of Ternopil Volodymyr Hnatiuk National Pedagogical University (2013) [11], Zhytomyr Ivan Franko State University (2016), joint research work was conducted on the basis of Kherson State University (2012-2017) within the framework of joint research laboratory with the focus on issues of educational quality management using ICT [4], in Drogobych State Pedagogical University named after I.Franko (2013-2015) [4], [4], in National University of Life and Environmental Sciences of Ukraine (2013-2016) [23] and others.

In 2015, the research project "Methodology of the formation of the cloud-based learning and research environment of a pedagogical educational institution", (DR No. 0115U002231) coordinated by M. Shyshkina was launched. In the same year, the Kryvy Rih National University was approved as the experimental base for the pedagogical experiment "Formation of the cloud-based learning and research environment of a pedagogical educational institution". In the course of this research work, the general model and the methodological system of certain cloud-based services use were elaborated [23], [22], [5]. There were some cloud-based components created for this purpose. Among them, there was the research-educational cloud of the Institute that was developed by Office 365 service in the Department of Cloud-based Systems of Education Informatization.

In the course of a series of pilot experimental studies (2012-2017) the mentioned cloud-based tools of ICT support of training and research processes were deployed; the cloud-based environment was created, and the methodological system and separate methods of using its components [5] were deployed, a series of training seminars, webinars and sessions were conducted for researchers, educators, teachers on the use of cloud services in scientific and educational activities, intermediate and control testing were conducted.

At the final stage of the experiment (2016-2017), a study of the ICT competence dynamics was conducted for the participants in the cloud-oriented community, which was formed and integrated around joint research laboratories. The experimental group consisted of the participants of the joint research laboratories, the department of cloud-based systems of informatization of education, on the basis of which the experiment was conducted, as well as postgraduates, doctoral students, research staff of the Institute of Information Technologies and Learning Tools of NAES of Ukraine, who participated in educational and scientific activities conducted in the course of the study (in total 60 participants joined this group). The control group consisted of representatives of higher education institutions, on the basis of which the experiment was conducted, who were also interested in the implementation of cloud technologies for education and research, but did not participate in the activities conducted during the experiment (training sessions, seminars, webinars, scientific-practical events), this group included 58 participants.

The analysis of the results of the final stage of the pedagogical experiment was conducted by the learning and research criteria of ICT competence formation which were specially designed and used to measure the achieved levels of its formation. The analysis showed that the distribution of indicators of the formation of ICT competencies as for the use of cloud technologies in experimental and control groups has statistically significant differences by the learning and also the research criteria due to the use of the appropriate methodological system in the training of research and educational personnel, which is confirmed according to Fisher's criterion ($\varphi emp = 2.04 > \varphi 0.05 = 1.64$) [22]. These data indicate that in experimental groups there was a statistically significant increase in the level of ICT competence of scientific and pedagogical personnel on the use of cloud technologies, which indicates the effectiveness of the formation of cloud-based LRE of higher education institutions and the corresponding methodological system [22].

In 2018 the Institute of Information Technologies and Learning Tools of NAES of Ukraine became one of the partners of V4 + Academic Research Consortium that would address regional issues related to EU ICT research priorities: Partner search for Horizon 2020, building up digital platforms of the future, language barriers, technology-enhanced learning, scientific-cultural heritage, know-how to exchange. The focus will be on the networking of the V4 + partners in order to integrate their research expertise, perform partner search and benchmark these issues using the virtual technological platform. So the processes of open learning and research are in the focus of this project. The partners of the project are six scientific and educational institutions from Slovakia, the Czech Republic, Poland, Hungary and Ukraine. The important part of the project is to explore the use of the cloud-based platform to integrate and deploy different types of learning and research services such as educational robots, language technologies and databases [19].

Thus, due to the wider involvement of facilities and services of scientific and educational networks, in particular cloud-oriented, into the process of scientific research it is possible to achieve positive changes in the implementation of research activity, improvement of its qualitative and quantitative indicators, application of new forms and models of its organization, which positively influences the educational results of students and the general development of the education system of Ukraine.

4. CONCLUSIONS AND DISCUSSION

The application of open science technologies covering European research infrastructures, scientific and educational networks, cloud services of collection, presentation and processing of data, as well as services of the European open science cloud is a topical and

promising direction for the development and modernization of the cloud-oriented learning and research environment of higher education institutions.

The integration of resources and services into a single, cloud-oriented educational environment contributes not only to improving the efficiency of access to the necessary tools; it enables the use of advanced training technologies, big data processing tools, and other sources of open education and science. The use of the cloud-based technologies in building an IT-infrastructure ensures LRE performance and efficiency.

The European open science cloud is an illustrative example of how it will be possible to use the services of public scientific and educational networks to support the research and learning activities, while these services are becoming more accessible, scalable and universal thanks to the properties of cloud technologies. At the same time, it is equally important for maintaining scientific collaboration to use also the corporate information and communication platforms and networks. Therefore, the issue of modeling and designing cloud-oriented environments for supporting research and educational cooperation in higher education, taking into account the principles and priorities of open education and open science and providing ever-increasing integration, accessibility, flexibility, openness, scalability of the services involved, their expedient selection and approbation in accordance with the current trends of international cooperation needs further attention and elaboration.

The question of choosing and integrating services, exploring their various components, as well as supporting open education and science systems, combining intelligent technologies and network services presents a prospect for further research that needs careful study.

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КОНЦЕПТУАЛЬНІ ОСНОВИ ФОРМУВАННЯ ТА РОЗВИТКУ ХМАРО ОРІЄНТОВАНОГО НАВЧАЛЬНО-НАУКОВОГО СЕРЕДОВИЩА УНІВЕРСИТЕТУ В КОНТЕКСТІ ПРІОРИТЕТІВ ВІДКРИТОЇ НАУКИ

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Анотація. Розглянуто науково-методологічні засади формування й розвитку хмаро орієнтованого навчально-наукового середовища в контексті пріоритетів відкритої науки та формування Європейського дослідницького простору. Визначено поняттєво-термінологічний апарат дослідження хмаро орієнтованого середовища, виявлено основні особливості такого середовища. Серед засадничих методологічних принципів проектування та розвитку середовища є принципи відкритої освіти, відкритої науки, а також специфічні принципи, властиві хмаро орієнтованим системам. Метою дослідження є: аналіз концептуального апарату, принципів та особливостей формування та розвитку хмаро орієнтованого навчально-наукового середовища в контексті концепції відкритої науки. Завдання дослідження: визначити перспективи використання хмарних технологій для підтримування освітньої та наукової діяльності; окреслити принципи та технології використання концепції відкритої науки та перспективи їх застосування в педагогічних системах вищої освіти. Об'єктом дослідження є: процес формування та розвитку хмаро орієнтованого навчально-наукового середовища. Предметом дослідження є: принципи формування та розвитку хмаро орієнтованого середовища діяльності учасників навчального і наукового процесу університету. Методи дослідження - це аналіз офіційних міжнародних документів, публікацій з дослідження, спостереження, порівняння, аналіз досвіду освітнього та наукового застосування хмарних технологій, аналіз даних педагогічного експерименту. Результати дослідження – обгрунтовано принципи формування та розвитку хмаро орієнтованого навчально-наукового середовища вищого навчального закладу. Визначено поняттєво-термінологічний апарат дослідження; виявлено характерні особливості його функціонування. Проведено аналіз та оцінку перспектив формування і розвитку хмаро орієнтованого навчально-наукового середовища в контексті пріоритетів відкритої науки. Висновки та рекомендації: застосування хмаро орієнтованих технологій відкритої науки, що охоплюють європейські дослідницькі інфраструктури; наукові та освітні мережі; хмаро орієнтовані сервіси збирання, подання та опрацювання даних; а також сервіси Європейської хмари відкритої науки є актуальною і перспективною тенденцією розвитку та модернізації хмаро орієнтованого навчально-наукового середовища вищих навчальних закладів.

Ключові слова: хмарні обчислення; хмаро орієнтоване середовище; хмарні сервіси; відкрита наука; відкриті дані; відкритість; гнучкість.

КОНЦЕПТУАЛЬНЫЕ ОСНОВЫ ФОРМИРОВАНИЯ И РАЗВИТИЯ ОБЛАЧНО ОРИЕНТИРОВАННОЙ НАУЧНО-УЧЕБНОЙ СРЕДЫ УНИВЕРСИТЕТА В КОНТЕКСТЕ ПРИОРИТЕТОВ ОТКРЫТОЙ НАУКИ

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Аннотация. Рассмотрены научно-методологические основы формирования и развития облачно ориентированной учебно-научной среды в контексте приоритетов открытой науки и формирования Европейского исследовательского пространства. Определены понятийно-терминологический аппарат исследования облачно ориентированной среды, выявлены основные особенности такой среды. Среди основных методологических принципов проектирования и развития среды выявлены принципы открытого образования, открытой науки, а также специфические принципы, присущие облачно ориентированным системам. Целью исследования является анализ концептуального аппарата, принципов и особенностей формирования и развития облачно ориентированной учебно-научной среды в контексте концепции открытой науки. Задачи исследования: определить перспективы использования облачных технологий для поддержания образовательной и научной деятельности; определить принципы и технологии использования концепции открытой науки и перспективы их применения в педагогических системах высшего образования. Объектом исследования является: процесс формирования и развития облачно ориентированной учебно-научной среды. Предмет исследования: принципы формирования и развития облачно ориентированной среды деятельности участников учебного и научного процесса университета. Методы исследования: анализ официальных международных документов, публикаций по предмету исследования, наблюдение, сравнение, анализ опыта образовательного и научного применения облачных технологий, анализ данных педагогического эксперимента. Результаты исследования: обоснованы принципы формирования и развития облачно ориентированной учебно-научной среды высшего учебного заведения. Определены понятийно-терминологический аппарат исследования; выявлены характерные особенности функционирования облачно ориентированной среды. Проведены анализ и оценка перспектив формирования и развития облачно ориентированной учебно-научной среды в контексте приоритетов открытой науки. Выводы и рекомендации: применение облачно ориентированных технологий открытой науки, охватывающих европейские исследовательские инфраструктуры; научные и образовательные сети; облачно ориентированные сервисы сбора, представления и обработки данных; а также сервисы Европейского облака открытой науки является актуальной и перспективной тенденцией развития и модернизации облачно ориентированной учебно-научной среды высших учебных заведений.

Ключевые слова: облачные вычисления; облачно ориентированная среда; облачные сервисы; открытая наука; открытые данные; открытость; гибкость.