# The areas of educational studies of the cloud-based learning systems

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**Abstract.** The article analyzes the current stage of educational studies of the cloud-based learning systems. The relationship between the notions of the cloud-based learning system and the cloud-based learning environment are investigated. It was found that the researchers paid most attention to the design of a cloud-based learning environment. However, in the process of a cloud-based environment design, the researchers consider a cloud-based system as a component within the cloud-based learning environment of as a stage in the process of design. It is shown that in the research literature there is no single interpretation of the concept of a cloud-based system for educational purposes. Still the number of basic approaches to the interpretation of the concept under investigation are revealed. The first approach is based on the understanding of the system, as a set of cloud services or cloud-based technologies. The second approach is to consider a separate cloud service as a cloud-based learning system. In this case, the cloud service tools should include such components that cover the content, the tools, the forms and the methods of learning. The structure of the cloud-based learning system within the interpretation of the latest works of Ukrainian researchers is considered.

**Keywords:** cloud-based training system, cloud services, cloud-based learning environment, structure of cloud-based training support system.

## 1　　Introduction

### 1.1　　The problem statement

The use of the cloud technologies and services in the educational process is a rather promising direction of modern educational research. At the same time, the cloud services have taken their place both in the educational process of secondary and also higher educational institutions (HEI). This is evidenced by numerous dissertations defended during the latest years devoted to the given topic: Georgii A. Aleksanian "Formation of independent activities of students of secondary vocational education in teaching mathematics using cloud technologies" (2014) [1], Liudmila S. Galkina "The methodology for the development of ICT competence of future economists and managers using cloud technologies in teaching the disciplines of the information cycle"

(2017) [5], Serhii P. Kasian "Workflow Management institutions of postgraduate education based on cloud technology" (2016) [8], Maksym V. Khomutenko "A methodology of teaching senior students atomic and nuclear physics in a cloud oriented learning environment" (2018) [9], Olha V. Korotun "Use a cloud oriented environment to training future teachers of Information Science to master database" (2018) [14], Svitlana H. Lytvynova "Theoretical and methodological bases of designing cloud-oriented learning environment educational institution" (2016) [16], Oksana M. Markova "Cloud technologies as a learning tool of the foundations of mathematical informatics for students of technical universities" [18], Oleksandr V. Merzlykin "Cloud technologies as tools of high school students' research competencies forming in profile physics learning" (2017) [19], Serhii V. Palii "Cloud mechanisms of formation of information-organizational environment of pre-university training of students" (2014) [20], Maiia V. Popel "The cloud service SageMathCloud as a tool of mathematics teacher professional competencies formation" (2017) [23], Susana N. Seytveliyeva "Methods of teaching cloud future software engineers" (2017) [29], Viktoriia G. Shevchenko "Cloud technologies as a tools of forming ICT competence of future informatics teachers" (2016) [30], Mariya P. Shyshkina "Theoretical and methodological principles of formation and development of the cloud-based educational and research environment of higher educational institution" (2016) [31], Nataliia V. Skrynnik "Techniques of teaching Ukrainian literature in the 5th-6th classes using cloud technologies" (2017) [33], Mariia V. Stupina "Formation of students' competence in the field of using tools for developing information systems using cloud technologies (by example the training of future bachelors-developers of information systems)" (2018) [34], Tetiana J. Vdovychyn "The use of network technologies of open systems in the training of future bachelors of computer science" (2017) [39], Tetiana V. Voloshyna "The use of a hybrid cloud-based learning environment for forming the self-education competence of future IT specialists" (2018) [40] etc.

In addition, a number of planed research works were devoted to this topic: "Methodology of the cloud-based learning and research environment formation in the pedagogical educational institution" (SR No. 0115U002231, 2015-2017), "Adaptive cloud-based system of secondary schools teachers training and professional development" (SR No. 0118U003161, 2018-2020), "The development of information and communication competence of teachers in a cloud-based learning environment" (SR No. 0117U000198, 2017-2019) etc. The interest of researchers for the cloud-based environments, cloud-based systems does not decrease despite the fundamental works made in this direction. Although such concepts for pedagogical science as "cloud technologies", "cloud services", "cloud-based systems", "cloud-based environments" are not new, but in research literature there is a certain mix of these concepts. In addition, the relationship between such concepts as "cloud-based systems" and "cloud-based environments" is not completely determined.

### 1.2    Literature review

Cloud computing provides rather new educational tools. They bring new digital resources, digital content, such as cloud-based teaching materials, multimedia learning content, virtual labs and administrative tools for educational institutions. They bring changes, progress and opportunities for HEI. By using cloud computing, the workload of IT staff is shrinking so that they can focus on strategies for more efficient use of IT infrastructure. Using cloud computing, students and teachers gain access to resources and collaborate with HEI, they can communicate and exchange resources and ideas with other students and teachers from various HEIs at any time and anywhere. Different educational institutions do not have the same software and hardware resources due to certain limitations such as financial and material and technical. The learners and staff can access these resources in the cloud by paying a nominal fee for cloud services. A HEI can access cloud resources according to the users needs, such as software, servers, computing machines, network devices, virtual labs, journals, textbooks, multimedia content, and other tools that are useful for their research and training. Thus, cloud computing is useful for HEI for conducting their research work and improving student learning as well as teaching and assessment practices of teachers [32].

Tetiana A. Vakaliuk in [38] gives the following interpretation of the "cloud-based learning support system" concept: "Under the cloud-based learning support system, we will understand a system in which the implementation of the didactic goals involves the use of cloud services and technologies, and ensures group collaboration of teachers and students, development, management, and distribution of educational materials with the provision of cloud-based technologies to the participants of the learning process" [38, p. 7]. The author defined in detail each component of the proposed model and their connections.

Maryna V. Rassovytska and Andrii M. Striuk do not give a clear definition of the concept of "system of cloud-based tools of learning". However, the meaning of the term is given, rather descriptive. In the study [24], it is noted that those types of cloud-based learning tools defined by the authors constitute this system.

Although Svitlana H. Lytvynova does not specifically refers to the concept of a cloud-baseed system, the concept of a cloud-based learning environment is revealed through a system of cloud services: the cloud-based learning environment is an artificially constructed system that provides cloud-based learning with educational services mobility, group collaboration of teachers and students for effective, safe achievement of didactic goals [16].

Oleksandr M. Kryvonos and Olha V. Korotun clarify the notion of the cloud-based system of distance learning: "a cloud-based distance learning system is a cloud-based service for the organization of an educational process that allows the creation, management and dissemination of educational materials in electronic form, monitor and evaluate learning outcomes, and formulate accounting records" [15, p. 134–135].

In this case, Olha V. Korotun, emphasizes that such cloud-based system of distance learning should be as much easy to use and administrate as possible [13]. Problems that may occur during its use, as a rule, do not concern the user, they are taken by the company's developer. At the same time, the cloud-based system as well as any cloud

services does not require additional installation on the device of third-party software, configuration and, moreover, powerful hardware. According to a Korotun's study it can be argued that such cloud-based systems, which represent software as a service, acquire the most popularity in Ukrainian HEIs in the educational process [12].

In further research, Korotun gives somewhat modified author's definition: "the cloud-based distance learning system is a distance learning system deployed within the cloud for organizing an educational process that allows the creation, management and dissemination of educational materials in electronic form, organisation of communication and collaborative work between learners, monitor and evaluate learning outcomes, and formulate accounting training documentation" [14].

Giving the analysis of recent studies of Tetiana A. Vakaliuk, Svitlana H. Lytvynova, Mariya P. Shyshkina and others, the design of the cloud-based learning environments their structure and composition are quite thoroughly considered. However, the cloud-based educational system represent a separate component of this environment structure (Tetiana A. Vakaliuk), or certain cloud-based services (Oleksandr M. Kryvonos and Olha V. Korotun) serve as the basis for further construction of the cloud oriented environment (Maryna V. Rassovytska and Andrii M. Striuk). Therefore, in order to outline different approaches to the definition of the concept of "cloud-based system for educational purposes" and its structure, it should be considered how Ukrainian and foreign scientists understand the notion of "cloud-based learning environments" and how these concepts relate.

### 1.3    The aim of the research

To outline the content of the concept "cloud-based system for educational purposes" and to define the main directions of pedagogical studies of cloud-based systems for educational purposes.

## 2    Research results

### 2.1    The different approaches to the notion of the cloud-based system for educational purposes

According to the Paul Pocatilu, Felician Alecu, Marius Vetrici [21] at the advanced level the development of the cloud-based learning systems is consistent with the same scheme as any other software development project. For designing of the cloud-based e-learning system, you can use the same methods of development as for any software products. This is a source management software, build scenarios to create a deployment package, and automated regression testing.

AlAlaa N. Tashkandi and Ibrahim M. Al-Jabri argue that the gradual introduction of cloud services is also recommended, starting from the traditional cloud computing systems. E-mail, e-learning systems, learning management systems are the starting point for the implementation of the cloud. Cloud services providers targeting the higher education segment should invest in priority systems. Systems related to training,

backup and file storage, as well as university or institute websites are systems that must first be realised by means of cloud computing [36].

According to Ibrahim Arpaci the cloud computing services such as Google Drive, Dropbox, SkyDrive and iCloud can be easily integrated into educational systems. These services can provide students with the ability to save files, share files, view and access files synchronized between different devices. Cloud services can also provide easier and quicker access to data, allow students to store and share documents, offer a more flexible environment, providing widespread access to materials and facilitating student-teacher interaction. Therefore, these services can support the practice of managing educational materials, including the creation or search of data, storage, transmission and use of data [2].

Daniel Pop [22] examining machine learning explodes cloud technologies and gives examples of their combination. The cloud computing paradigm and cloud providers have proven to be valuable alternative to accelerate the work of the machine learning platforms. Thus, some popular statistical tools such as R, Octave, Python are also integrated into a cloud. There are two main areas for integrating them with cloud providers: creating a cluster in the cloud and downloading it using static tools, or increasing the statistical environments with plug-ins that allow users to create Hadoop clusters in the cloud and run tasks on them. Environments such as R, Octave, Mapple, and similar to the low-level infrastructure for data analysis, can be applied to large datasets when used by cloud-based suppliers. Machine learning makes it easy to get training materials from huge data sets for customers who do not have a statistical background, automatically deducing from models of "knowledge models" [10; 27; 28]. Similar projects can either be PaaS / SaaS platforms, or products that can be deployed in private environments [17; 22].

Gustavo Gutiérrez-Carreón, Thanasis Daradoumis and Josep Jorba propose the semantic mechanism for integrating the API of the Cloud-service with the educational system. Researchers focus on issues related to the ease of use and the cognitive loads theory – CLT, which should be considered holistically. This subsection is followed in order to determine whether the proposed solution for integrating cloud education services can benefit both systems and learning. On the one hand, the basic assertion of CLT is that any curriculum design should take into account the limits of working memory in order to prevent the overload of the working memory and, consequently, the deterioration of the training process. On the other hand, the degree to which a user can complete a task with an effective tool is determined; Moreover, the level of ease of use of a tool or program can be determined only in the context of specific users and specific tasks that need to be performed. Gutiérrez-Carreón, Daradoumis and Jorba presents the study of learning management system using the semantic description of services and outlines the results of its implementation [6].

Manuel Sanchez, Jose Aguilar, Jorge Cordero and Priscila Valdiviezo-Diaz exploring cloud-based learning, note that this is an educational model that uses all the digital resources available on the Internet to improve the learning process. In this type of training, a set of tools and services in the cloud that promote the student's learning process, without the need for students and teachers to be physically present in one audience is provided. The combination of cloud learning with Ambient Intelligence can

provide great benefits to the learning process, since it will not only rely on cloud learning services but the environment will be able to determine when it is appropriate to use these services, as well as with which devices or objects, available in the environment to be integrated. Thus, they propose a new concept called Ambient Intelligence for cloud learning (AmICL), which is defined as: "An AmICLis an Intelligent Learning Environment that combines educational services available in the cloud with objects (which can be intelligent or not) in the educational ambiance, in order to adapt the learning process to the student's learning style" [26, p. 40].

## 2.2    The relationship of the notions of the cloud-based learning system and cloud-based learning environment

In the process of analysis of domestic works of scientists and then at the stage of designing a cloud-based learning environment, Tetiana A. Vakaliuk revealed that one of its components is the cloud-based system of education support (CBSES). Therefore, Tetiana A. Vakaliuk considers it necessary first to create a model of a cloud-based system for supporting the education of bachelors of computer science, since this system is necessary for the design of a cloud-based learning environment. Moreover, in other Vakaliuk's works [38] considers the cloud-based system of education support as one of the main components of the cloud-based learning environment.

The types of cloud-based teaching aids, which reveal in their work Maryna V. Rassovytska and Andrii M. Striuk [24] within the process of its systematic use, can be considered as components of the cloud-based environment. Also, researchers are guiding the use of cloud-based learning tools and illustrating the practical implementation of individual components as components of the system of cloud-based learning tools.

Although Oleksandr M. Kryvonos and Olha V. Korotun otherwise understand the meaning of the concept of "cloud-based system for educational purpose", in the Korotun's study [13] it is indicated that using Canvas an open learning environment may be created, as well as open and also closed electronic courses. In this case, the researcher considers Canvas as a cloud-based system of distance learning, including a learning management system.

The ultimate goal of the research team of Jeremy Fischer, Steven Tuecke, Ian Foster and Craig A. Stewart was to create virtual machines as a desktop environment that any researcher can use to facilitate the research work. Jetstream also included cloud services OpenStack and Jetstream to support multiple formats of virtual machines that can convert them to other supported formats, giving the ability to transfer images to any number of platforms that can read certain formats [4].

Toru Kobayashi, Kenichi Arai, Hiroyuki Sato, Shigeaki Tanimoto and Atsushi Kanai focused their studies on a cloud-based education, and cloud-based tools that can be used to help students understand complex technical terms using social media. Thus, a group of scientists linked their research with e-learning services, using cloud computing and e-learning support systems. Many cloud-based services are offered. Most of these systems involve the exchange of educational materials. The use of e-learning systems enables the delivery and exchange of materials managed by means of a cloud in a

common, consistent format. This system also provides students with individual learning content by analyzing their preferences, learning styles and patterns of content usage. In addition, there is a security system for managing data access and cloud encryption. NEC also provides "Smart Education" cloud systems for solving problems arising in the implementation of e-learning; training support, teacher support, school support and PC/tablet management. These systems are related to the system of general educational support for the exchange of educational material or the management of the learning process and the learning environment. On the other hand, the approach merely focuses on the adaptation of the original e-learning material to the e-learning environment. The study was focused on a program aimed at improving the e-learning system. As the e-learning standart SCORM was used, which advocated a reference model of the object Sharable Content Object [11].

Wei Huang, Li Jin and Imtiaz Sandia propose the use of intelligent agents for visualization to manage resources, hardware, platforms, education programs and cloud-based services to coordinate learning activities. The modern concept of the agent itself is associated with distributed artificial intelligence; it can be defined as an autonomous computer system that is capable of flexible interaction with other agents to perform autonomous actions. Agents are based on the concept of distributed artificial intelligence (DAI) in conjunction with distributed computing. They are able to use flexible and manageable strategies to solve many challenging tasks, fully utilizing the benefits of diverse perspectives, distributed problem solving methods, and the benefits of complex interaction schemes. These software tools demonstrate that utilizing intelligent agents can solve methodological problems in an open cloud-based environment. An agent paradigm is well suited to provide flexibility and reduce the complexity of the organization and management of the training system [7].

## 2.3    The structure of the cloud-based learning system

Tetiana A. Vakaliuk in the model of the cloud-based system of supporting the education of bachelors of informatics outlines the following subjects of interaction: administrator, teacher and student. In this case, the researcher combines the traditional system of education and the cloud-based one, therefore, the existing purpose, the content of training, means, methods and forms are presented. However, it should be noted that due to the use of cloud services and cloud technologies, the means, methods and forms of training are expanding, becoming cloud-based. That is, traditional means, methods and forms of training are used along with the cloud-based (those based on the cloud services and cloud technologies). A certain adaptation of the traditional education system to the use of cloud learning technologies is demonstrated due to the introduction of cloud-based learning systems. Among the forms of educational activity of students within the cloud-based learning environment are indicated: practical training, training sessions, control activities, independent work and research work [6]. Particular attention is paid to the scholar's form of organization of educational activities, as a lecture, since this form serves as the basis for conducting training sessions in a cloud-based learning support system. In this case, a detailed analysis of the types of lectures was performed and those that are considered as cloud-based are outlined.

Since cloud-based learning system is intended for the organization of independent work of students, therefore it contains the tools for collecting, checking and evaluating of laboratory, practical or individual works performed by students. A separate component is the tool for protecting laboratory works supported by cloud technologies in online mode [6]. The tasks for independent work are formed by the teacher in advance, not automatically, and the period for which students must complete the task is indicated. In this process, each student can contact the teacher for advice, which can take the form of correspondence (student-teacher) or collective discussion between the teacher and all students of the group.

One of the types of independent work is the group online projects that are intended for a certain period of implementation. The completed project is sent by the students to the teacher for verification. Tasks, their implementation, division into groups, verification and evaluation by the project teacher is carried out only with the use of tools of the cloud-based system.

The organization of the control of learning activities can be implemented using test tasks. In particular, an intermediate control on the learner activity may be online testing. In this case, the student is not limited spatially (because online testing may be passed out off the class) and the score is displayed automatically [37]. As for modular tests, tests and exams, using the cloud-based system toolkit, it is best to check the theoretical part of the study material. To do this, the teacher should prepare practical tasks, tests, surveys. Checking the tasks performed, in this situation can be done both in face-to-face form and with the use of cloud services, online. The consultations before the exam may be also conducted online or in a joint discussion with a group of students. A similar form of work is possible in consultation with a scientific adviser in the process of writing articles, course papers or diploma papers by students.

Maryna V. Rassovytska and Andrii M. Striuk consider the system of cloud-based tools of training consisting of the following tools [24]:

— management training;
— communications;
— joint activity;
— provision of training materials;
— knowledge control.

While selecting cloud-based tools, the specifics of their use and educational purpose were taken into account. In addition, researchers pointed out the most important types of cloud services and tools and noted that these types form a system of cloud-based learning tools. A separate issue is the study of cloud services such as Google and Microsoft, a detailed analysis of their advantages and disadvantages in the learning process.

Although, Tetiana V. Voloshyna does not provide a clear definition of the cloud-based learning support system, but it is noticed that it may include tools for modeling and monitoring student achievement and academic achievement. The progress of the development of educational achievements is preserved in similar cloud-based systems for the further planning of the educational process, its pace. By analyzing significant data sets in which student learning achievements are accumulated, the teacher will be

able to individualize the educational process according to the level of preparation of each individual student of the group [40].

As Olha V. Korotun considers the cloud-based system of distance learning as a cloud service, the object of its research is the cloud-based training management system Canvas [13], which belongs to the category of cloud-based services: SaaS. This cloud-based system is designed for both tertiary and higher education. Using the Canvas tool, the teacher will be able to organize: distance and group work of students (including the project), assessment of their academic achievements and monitoring, training sessions (in the form of lectures, consultations and discussions). Interesting is the integration of Canvas with the following services: Facebook, Twitter, Skype, LinkedIn.

Olha V. Korotun believes that the new forms of organization of the educational process, in particular, mixed learning [14], become simpler thanks to the cloud-based educational system. She emphasizes that cloud-based systems of distance learning appeared within the trend of cloud computing development. At the same time, investigating the structure of such cloud-based systems, the researcher believes that their implementation will be appropriate first of all in small educational institutions. However, if the cloud-based system is not part of the cloud-based environment of a university, then its implementation should be gradual (within the department, faculty, individual student groups) [14].

The researcher carried out a significant analysis of the foreign experience of implementation of cloud-based systems of distance learning, the feasibility of their use, in particular in the educational process of the HEI of Ukraine. Interesting is the composition of a cloud-based system defined in the work [14]:

— a toolkit for authentication;
— a toolkit for access rights hierarchy for individual users and system users;
— a toolkit for managing and debugging an electronic course, including as separate actions of its configuration, setting parameters, etc .;
— a toolkit for managing user accounts;
— a toolkit for the organization of the educational process of a group of students (and individual students);
— a toolkit for organizing and maintaining communication between users of the system;
— a toolkit for analyzing the dynamics of academic achievements as a separate student and user group;
— a toolkit for planning and adjusting the dynamics of the educational process;
— a toolkit for combining with other cloud systems, services, perhaps with social networks;
— tools for organizing collective and individual work of students for the use of various forms of organization of educational activities.

Mattias Bitar argued that IaaS resources could be used to provide an appropriate amount of memory, bandwidth and other tools that were explored in separate versions of e-learning. The researcher also proposed an architecture and cloud-based e-learning model with components that are related with infrastructure, resources, software, service, and applications. Each component has certain benefits that can be changed for

various educational purposes. Software features may vary to meet user requirements [3].

An e-learning based on the cloud is explored by Ghazal Riahi, who proposed a general architecture model for the cloud-based e-learning system. The proposed model has five components, infrastructure, software level, resource management level, service level and, finally, the application layer. Each component has specific characteristics that can be used for personalized e-learning. Hardware and infrastructure levels consist of resources such as physical memory, RAM, storage and central processing. The software component consists of an operating system and software that can have different performance and interface, and also provide developers with tools for further refinement of the software product. The existing level of resource management at the request of self-service and distribution of software through the free communication of hardware and software resources. Resource management can also be used to provide users with the required amount of resources. The existing service level that includes IaaS, PaaS and SaaS, where the service provides a different level of service provider responsibility. The provider can differentiate the software product, depending on what functions the user requires. The latest component is the application layer, which in fact serves as a custom application in e-learning. The key differences between e-learning components and clouds are at the application level. The features of this component are content production, content delivery, education goals, management components, and ratings [25].

By examining the possibilities for improving the delivery of MOOC resources and experience and the potential benefits of cloud computing, Geng Sun, Tingru Cui, Jianming Yong, Jun Shen and Shiping Chen attempted to develop a cloud-based system that creates virtual learning environments for so that both students and teachers work through mobile devices. This system consists of several programs like SaaS and three functional web services. All services and applications in the virtual learning environments will work together and will be deployed through the cloud infrastructure to provide powerful computing capabilities for storage space with a versatile and intuitive interface [35].

## 3    Conclusions and prospects for further research

The proposed research shows that there are different approaches to the interpretation of the concept of "cloud-based system for educational purpose". Depending on the author's understanding of this notion, the structure of the cloud-based system is defined. Some researchers understand the system of certain cloud services under this notion. Another approach is that a separate cloud service acts as a cloud-based system. Also the cloud-based system may be considered as a computer program for training purposes, which is deployed on the cloud. However, all scientists in their studies have come to the conclusion that the cloud-based system is part of the cloud-based learning environment. That is, the concept of cloud-based environment is much wider. However, the way of the cloud-based system design within this environment and combination of its components in each study is described in accordance to the structure of the cloud-

based learning environment. Therefore, it was necessary to investigate not only the content of the concept of "cloud-based system for educational purpose", but also the structure of a similar system. It has been found that in certain studies, the cloud-based system is taken as a separate component. In the studies of other scholars, it is believed that the structure of the cloud-based system is closely intertwined with other components of the cloud-based environment.

The main areas of pedagogical research of cloud-based educational systems are:

— the design of cloud-based training systems, and the methods for developing existing software products that can be applied;
— introduction of cloud services is recommended to begin with the cloud-based learning system;
— cloud services can be easily integrated into the education systems of HEI and secondary education;
— cloud computing has proven to be a valuable alternative to accelerating the work of the machine learning platforms;
— the semantic mechanism of integration of cloud services with the educational system is investigated;
— existing studies of intellectual learning environments combine educational services available in the cloud with the objects of the educational environment;
— researchers propose using intelligent agent technologies to manage resources, hardware, platforms, education programs and cloud-based services.

Further research will focus on the evolution of the formation and development of cloud-based systems and the identification of trends in the development and use of cloud-based systems in the training of teachers in European countries.

## References

1. Aleksanian, G.A.: Formirovanie samostoiatelnoi deiatelnosti studentov SPO v obuchenii matematike s ispolzovaniem oblachnykh tekhnologii (Formation of independent activities of students of secondary vocational education in teaching mathematics using cloud technologies). Dissertation, Armavir State Pedagogical University (2014)
2. Arpaci, I.: Antecedents and consequences of cloud computing adoption in education to achieve knowledge management. Computers in Human Behavior **70**, 382–390 (2017). doi:10.1016/j.chb.2017.01.024
3. Bitar, M.: An analysis of cloud based e-learning providers' versioning strategy. Dissertation, Blekinge Institute of Technology (2017)
4. Fischer, J., Tuecke, S., Foster, I., Stewart, C.A.: Jetstream: A Distributed Cloud Infrastructure for Underresourced higher education communities. In: SCREAM '15 Proceedings of the 1st Workshop on The Science of Cyberinfrastructure: Research, Experience, Applications and Models, Portland, Oregon, USA – June 16, 2015, pp. 53–61. ACM, New York (2015). doi:10.1145/2753524.2753530
5. Galkina, L.S.: Metodika razvitiia IKT-kompetentnosti budushchikh ekonomistov i menedzherov sredstvami oblachnykh tekhnologii pri obuchenii distciplinam informatcionnogo tcikla (The methodology for the development of ICT competence of

future economists and managers using cloud technologies in teaching the disciplines of the information cycle). Dissertation, Perm State University (2017)

6.  Gutiérrez-Carreón, G., Daradoumis, T., Jorba, J.: Integrating Learning Services in the Cloud: An Approach that Benefits Both Systems and Learning. Journal of Educational Technology & Society, **18**(1), 145–157 (2015)
7.  Huang, W., Jin, L. Sandia, I.: Using Agent Solutions and Visualization Techniques to Manage Cloud-based Education System. In: International Conference on Engineering, Technology and Applied Science (ICETA2016), Tai Pei, Tai Wan 20–22 Apr 2016, International Business Academic Consortium. WestminsterResearch. https://westminsterresearch.westminster.ac.uk/download/4e28ebe530f0e91acd90292bd00 0cbec0926b0def48beca232b64f4c4e2063c7/1779663/ICETA%202016.pdf (2016)
8.  Kasian, S.P.: Upravlinnia dokumentoobihom u zakladakh pisliadyplomnoi pedahohichnoi osvity na osnovi khmarnykh tekhnolohii (Workflow Management institutions of postgraduate education based on cloud technology). Dissertation, University management education (2016)
9.  Khomutenko, M.V.: Metodyka navchannia atomnoi i yadernoi fizyky starshoklasnykiv u khmaro zoriientovanomu navchalnomu seredovyshchi (A methodology of teaching senior students atomic and nuclear physics in a cloud oriented learning environment). Dissertation, Volodymyr Vynnychenko Central Ukrainian State Pedagogical University (2018)
10. Kiv, A., Semerikov, S., Soloviev, V., Kibalnyk, L., Danylchuk, H., Matviychuk, A.: Experimental Economics and Machine Learning for Prediction of Emergent Economy Dynamics. In: Kiv, A., Semerikov, S., Soloviev, V., Kibalnyk, L., Danylchuk, H., Matviychuk, A. (eds.) Experimental Economics and Machine Learning for Prediction of Emergent Economy Dynamics, Proceedings of the Selected Papers of the 8th International Conference on Monitoring, Modeling & Management of Emergent Economy (M3E2 2019), Odessa, Ukraine, May 22-24, 2019. CEUR Workshop Proceedings **2422**, 1–4. http://ceur-ws.org/Vol-2422/paper00.pdf (2019). Accessed 1 Aug 2019
11. Kobayashi, T., Arai, K., Sato, H., Tanimoto, S., Kanai, A.: An application framework for smart education system based on mobile and cloud systems. IEICE Transactions on Information and Systems **E100.D**(10), 2399–2410 (2017). doi:10.1587/transinf.2016OFP0001
12. Korotun, O.V.: Clouds oriented learning management system CANVAS. Pedagogical sciences: theory, history, innovative technologies 55(1), 230–239 (2016)
13. Korotun, O.V.: Learning management system Canvas as a component cloud oriented learning environment. Science and Education a New Dimension. Pedagogy and Psychology, IV(45)(93), 30–33 (2016)
14. Korotun, O.V.: Vykorystannia khmaro oriientovanoho seredovyshcha u navchanni baz danykh maibutnikh uchyteliv informatyky (Use a cloud oriented environment to training future teachers of Information Science to master database). Dissertation, Zhytomyr Ivan Franko State University (2018)
15. Kryvonos, O.M., Korotun, O.V.: Steps of the Design of Cloud Oriented Learning Environment in the Study of Databases for Future Teachers of Informatics. Information Technologies and Learning Tools 63(1), 130–145. doi:10.33407/itlt.v63i1.1866
16. Lytvynova, S.H.: Teoretyko-metodychni osnovy proektuvannia khmaro-oriientovanoho navchalnoho seredovyshcha zahalnoosvitnoho navchalnoho zakladu (Theoretical and methodological bases of designing cloud-oriented learning environment educational institution). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2016)

17. Markova, O.M., Semerikov, S.O., Striuk, A.M., Shalatska, H.M., Nechypurenko, P.P., Tron, V.V.: Implementation of cloud service models in training of future information technology specialists. In: CEUR Workshop Proceedings (CEUR-WS.org) (2019, in press)

18. Markova, O.M.: Khmarni tekhnolohii yak zasib navchannia osnov matematychnoi informatyky studentiv tekhnichnykh universytetiv (Cloud technologies as a learning tool of the foundations of mathematical informatics for students of technical universities). Dissertation, Kryvyi Rih State Pedagogical University (2018)

19. Merzlykin, O.V.: Khmarni tekhnolohii yak zasib formuvannia doslidnytskykh kompetentnostei starshoklasnykiv u protsesi profilnoho navchannia fizyky (Cloud technologies as tools of high school students' research competencies forming in profile physics learning). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2017)

20. Palii, S.V.: Khmarni mekhanizmy formuvannia informatsiino-orhanizatsiinoho seredovyshcha dovuzivskoi pidhotovky studentiv (Cloud mechanisms of formation of information-organizational environment of pre-university training of students). Dissertation, Kyiv National University of Building and Architecture (2014)

21. Pocatilu, P., Alecu, F., Vetrici, M.: Measuring the Efficiency of Cloud Computing for E-learning Systems. WSEAS Transactions on Computers **9**(1), 42–51 (2010)

22. Pop, D.: Machine learning and cloud computing: survey of distributed and SaaS solutions. arXiv:1603.08767 [cs.DC]. https://arxiv.org/pdf/1603.08767 (2016). Accessed 21 Mar 2018

23. Popel, M.V.: Khmarnyi servis SageMathCloud yak zasib formuvannia profesiinykh kompetentnostei vchytelia matematyky (The cloud service SageMathCloud as a tool of mathematics teacher professional competencies formation). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2017)

24. Rassovytska, M.V., Striuk, A.M.: The system of cloud-oriented tools of learning computer science disciplines of engineering specialties students. In: Semerikov, S.O., Shyshkina, M.P. (eds.) Proceedings of the 5th Workshop on Cloud Technologies in Education (CTE 2017), Kryvyi Rih, Ukraine, April 28, 2017. CEUR Workshop Proceedings. 2168, 20–26. http://ceur-ws.org/Vol-2168/paper4.pdf (2018). Accessed 21 Nov 2018

25. Riahi, G.: E-learning Systems Based on Cloud Computing: A Review. Procedia Computer Science **62**, 352–359 (2015). doi:10.1016/j.procs.2015.08.415

26. Sánchez, M., Aguilar, J., Cordero, J., Valdiviezo, P.: A smart learning environment based on cloud learning. International Journal of Advanced Information Science and Technology **39**(39), 39–52 (2015)

27. Semerikov, S.O., Teplytskyi, I.O.: Metodyka uvedennia osnov Machine learning u shkilnomu kursi informatyky (Methods of introducing the basics of Machine learning in the school course of informatics). In: Problems of informatization of the educational process in institutions of general secondary and higher education, Ukrainian scientific and practical conference, Kyiv, October 09, 2018, pp. 18–20. Vyd-vo NPU imeni M. P. Drahomanova, Kyiv (2018)

28. Semerikov, S.O.: Zastosuvannia metodiv mashynnoho navchannia u navchanni modeliuvannia maibutnikh uchyteliv khimii (The use of machine learning methods in teaching modeling future chemistry teachers). In: Starova, T.V. (ed.) Technologies of teaching chemistry at school and university, Ukrainian Scientific and Practical Internet Conference, Kryvyi Rih, November 2018, pp. 10–19. KDPU, Kryvyi Rih (2018)

29. Seytveliyeva, S.N.: Metodyka navchannia khmarnykh tekhnolohii maibutnikh inzheneriv-prohramistiv (Methods of teaching cloud future software engineers). Dissertation, Crimean Engineering and Pedagogical University (2017)

30. Shevchenko, V.G.: Oblachnye tekhnologii kak sredstvo formirovaniia IKT-kompetentnosti budushchikh uchitelei informatiki (Cloud technologies as a tools of forming ICT competence of future informatics teachers). Dissertation, Moscow Region State University (2016)

31. Shyshkina, M.P.: Teoretyko-metodychni zasady formuvannia i rozvytku khmaro oriientovanoho osvitno-naukovoho seredovyshcha vyshchoho navchalnoho zakladu (Theoretical and methodological principles of formation and development of the cloud-based educational and research environment of higher educational institution). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2016)

32. Singh, U., Baheti, P.K.: Role and Service of Cloud Computing for Higher Education System. International Research Journal of Engineering and Technology **4**(11), 708–711. https://www.irjet.net/archives/V4/i11/IRJET-V4I11125.pdf (2017). Accessed 21 Mar 2018

33. Skrynnik, N.V.: Metodyka navchannia ukrainskoi literatury uchniv 5-6 klasiv z vykorystanniam khmarnykh tekhnolohii (Techniques of teaching Ukrainian literature in the 5th-6th classes using cloud technologies). Dissertation, National Pedagogical Dragomanov University (2017)

34. Stupina, M.V.: Formirovanie kompetentnosti studentov v oblasti ispolzovaniia instrumentalnykh sredstv razrabotki informatcionnykh sistem s primeneniem oblachnykh tekhnologii (na primere podgotovki budushchikh bakalavrov-razrabotchikov informatcionnykh sistem) (Formation of students' competence in the field of using tools for developing information systems using cloud technologies (by example the training of future bachelors-developers of information systems)). Dissertation, Institut upravleniia obrazovaniem Rossiiskoi akademii obrazovaniia (2018)

35. Sun, G., Cui, T., Yong, J., Shen, J., Chen, S.: MLaaS: a cloud-based system for delivering adaptive micro learning in mobile MOOC learning. IEEE Transactions on Services Computing **11**(2), 292–305 (2018). doi:10.1109/TSC.2015.2473854

36. Tashkandi, A.N, Al-Jabri, I.M.: Cloud computing adoption by higher education institutions in Saudi Arabia: an exploratory study. Cluster Computing **18**(4), 1527–1537 (2015). doi:10.1007/s10586-015-0490-4

37. Vakaliuk, T.A.: Cloud Oriented Model for Support of Bachelor of Informatics Training. Information Technologies and Learning Tools **56**(6), 64–76 (2016). doi:10.33407/itlt.v56i6.1415

38. Vakaliuk, T.A.: Cloud technology in education: Textbook for students of Physics and Mathematics. ZhSU Publishing House, Zhytomyr (2016)

39. Vdovychyn, T.J.: Vykorystannia merezhnykh tekhnolohii vidkrytykh system u navchanni maibutnikh bakalavriv informatyky (The use of network technologies of open systems in the training of future bachelors of computer science). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2017)

40. Voloshyna, T.V.: Vykorystannia hibrydnoho khmaro oriientovanoho navchalnoho seredovyshcha dlia formuvannia samoosvitnoi kompetentnosti maibutnikh fakhivtsiv z informatsiinykh tekhnolohii (The use of a hybrid cloud-based learning environment for forming the self-education competence of future IT specialists). Dissertation, Institute of Information Technologies and Learning Tools of NAES of Ukraine (2018)