# The Hybrid Cloud-based Service Model of Learning Resources Access and its Evaluation

Mariya Shyshkina

Institute of Information Technologies and Learning Tools of the National Academy of Pedagogical Sciences of Ukraine, M.Berlinskoho Str., 9, Kyiv, Ukraine
marple@ukr.net

**Abstract.** Nowadays, innovative technological solutions for learning environment organization using cloud computing and ICT outsourcing have shown promise and usefulness. Problems of providing access to electronic educational resources and their configuration within a cloud-based university learning environment have given rise to diverse research trends. This article outlines the conceptual framework of the study by reviewing existing approaches for electronic educational resources access organization within cloud-based settings. The hybrid service model of learning resources access is described and proved. The problems of quality evaluation of learning resources in the cloud-based learning environment are outlined. Indicators of cloud-based learning resources quality evaluation are proposed. An empirical estimation of the proposed approach and current developments of its implementation are provided.

**Keywords:** learning environment, cloud computing, electronic resources, quality, hybrid model, university.
**Key Terms:** ICTInfrastructure, Model, TeachingProcess.

## 1 Introduction

The development of a modern university learning environment is supported by emerging ICT on the basis of advanced network infrastructures, especially within cloud-based settings. Cloud computing (CC) technology is used to enhance multiple access and joint use of educational resources at different levels and domains, combining the corporate resources of the university and other learning resources within a united framework. Progress in the area has provided new insights into the problems of educational electronic resources access and configuration within the learning environment, bringing new models and approaches. The promising trend of research is concerned to the hybrid service models [4, 19, 24]. It has given rise to research of better ways of introducing innovative technology.

A set of different service models may be elaborated and combined to provide access for the cloud-based learning components within the hybrid environment's architecture. Quality evaluation of cloud-based components is a promising way to choose and approve the most appropriate delivery settings.

ICTERI 2016, Kyiv, Ukraine, June 21-24, 2016

*The purpose of the article* is analyse the ways of educational electronic resources delivery within the hybrid cloud-based settings, and to substantiate and validate the quality evaluation indicators and approach to the cloud-based learning components design.

The *research method* involved analysing the current research (including the domestic and foreign experience of the application of cloud-based learning services to reveal the concept of the investigation and research indicators), examining existing models and approaches, estimating the current state of quality research development, considering existing technological solutions and psychological and pedagogical assumptions about better ways of introducing innovative technology, and conducting pedagogical experiments, surveys and expert evaluations.

## 2 Problem Statement

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, have led to the search for the most reasonable ways of e-resources access within the environment framework. The cloud-based learning resources have many progressive features including better adaptability and mobility, as well as full-scale interactivity, free network access, a unified structure among others [4, 21, 23]. So, the modelling and analysis of their design and deployment in view of the current tendencies of modern ICT advance have come to the fore.

Among the priority issues there are those concerning existing approaches and models for electronic educational resources delivery within the hybrid cloud-based setting; the cloud-based learning components quality assessment techniques; quality research indicators substantiation and validation; evaluation of current experience of cloud-based models and components use.

## 3 State of the Art

According to the recent research [4, 9, 15, 20, 21], the problems of implementing cloud technologies in educational institutions so as to provide software access, support collaborative learning, implement scientific and educational activities, support research and project development, exchange experience are especially challenging. The formation of the cloud-based learning environment is recognized as a priority by the international educational community [18], and is now being intensively developed in different areas of education, including mathematics and engineering [2, 8, 28, 30].

The transformation of the modern educational environment of the university by the use of the cloud-based services and cloud computing delivery platforms is an important trend in research. The topics of software virtualization and the forming of a unified ICT infrastructure on the basis of CC have become increasingly popular lines of investigation [8, 20]. The problems with the use of private and public cloud services, their advantages and disadvantages, perspectives on their application, and targets and implementation strategies are within the spectrum of this research [7, 8, 28].

There is a gradual shift towards the outsourcing of ICT services that is likely to provide more flexible, powerful and high-quality educational services and resources [4]. There is a tendency towards the increasing use of the software-as-a-service (SaaS) tool. Along with SaaS the network design and operation, security operations, desktop computing support, datacentre provision and other services are increasingly being outsourced as well. Indeed, the use of the outsourcing mechanism for a non-core activity of any organization, as the recent surveys have observed happening in business, is now being extended into the education sector [9]. So, the study of the best practices in the use of cloud services in an educational environment, the analysis and evaluation of possible ways of development, and service quality estimation in this context have to be considered.

The valuable experience of the Massachusetts institute of technology (MIT) should be noted in concern to the cloud based learning environment formation in particular as for access to mathematical software. The Math software is available in the corporate cloud of the University for the most popular packages such as *Mathematica*, *Mathlab, Maple, R, Maxima* [30]. This software is delivered in the distributed mode on-line through the corporate access point. This is to save on license pay and also on computing facilities. The mathematics applications require powerful processing so it is advisable to use it in the cloud. On the other case the market need in such tools inspires its supply by the SaaS model. This is evidenced by the emergence of the cloud versions for such products as Sage MathCloud, Maple Net, MATLAB web-server, WebMathematica, Calculation Laboratory and others [2, 8]. Really there is a shift toward the cloud-based models as from the side of educational and scientific community, and also from the side of product suppliers. The learning software actually becomes a service in any case, let it be a public or a corporate cloud.

There are many disciplines where it is necessary to outsource the processing capacity: for example, the computer design for handling vast amounts of data for graphics or video applications. This is also a useful tool used to support the collaborative work of developers, as the modern graphical applications appear to be super-powerful and require joint efforts [7]. There is a research trend connected to the virtual computing laboratories (VCL) [16, 29] delivered in the cloud-based paradigm. This trend is inherent in the field of informatics, and learning resources for processing and sharing are needed.

Nowadays there are various universal cloud consumer applications, in particular MicrosoftOffice 365, Google Apps and others which gain an appropriate use in educational process [9, 26]. There is also a wide range of cloud services such as online photo and video editors, web pages processors, services for translation, check spelling, anti plagiarism and many others which are now available [26].

There is a principal transformation of approaches in concern to services supply within the cloud based infrastructure. It is considered to be a new stage of the service oriented models development [10, 27]. There is a branch of research devoted to the service oriented infrastructure in this actual perspective. The issues of service oriented architecture development are described in [10]. The problem of turning software into a service is also posed [27]. For example, more powerful approaches for services integration appear while services compositions are used as building blocks in a process of elaboration of programming code [16]. The CC development brought the term the *service orchestration* into scientific discussion while number of web services can be combined to perform the higher level business process to manage and coordinate execution of the component processes [11]. In this regard the notion of the global software development (GSD) is considered as novel trends overcome geographical limits [11]. There is a significant revise of approaches to ICT services elaboration and this is concerned to its integration and composition.

Another set of problems is concerned with the hybrid service models and infrastructure solutions combining different public and corporate services on the united platform. Due to this approach, access to educational software set on a cloud server or in a public cloud is organized. This trend is now especially promising for the sphere of education [8, 19]. The challenge regarding novel technological solutions and their impact guide the search for the most reasonable method of implementation.

An essential feature of the cloud computing conception is dynamical supply of computing resources, software and hardware its flexible configuration according to user needs. So comparison of different approaches and cloud models of software access is the current subject matter of educational research [7, 8, 26, 28]. Despite of the fact that the sphere of CC is rather emerging there is a need of some comparison of the achieved experience to consider future prospects [28]. Also the problems of software choice in the learning complexes to be implemented in a cloud arise. This leads to the problems of cloud-based learning resources quality evaluation techniques and research indicators substantiation.

In the cloud-based learning environment, new ways of EER quality control arise. There are specific forms of the organization of learning activity related to quality estimation. For example there are e-learning systems based on the modelling and tracking of individual trajectories of each student's progress, knowledge level and further development [31]. This presupposes the adjustment, coordination of training, consideration of pace of training, diagnosis of achieved level of mastery of the material, consideration of a broad range of various facilities for learning to ensure suitability for a larger contingent of users. The vast data collections about the students' rates of learning are situated and processed in the cloud [31]. There are also collaborative forms of learning where the students and teachers take part in the process of resource elaboration and assessment; this is possible in particular by means of the SageMathCloud platform [2].

Thus, in view of the current tendencies, the research questions are: how can we take maximum advantage of modern network technologies and compose the tools and services of the learning environment to achieve better results? What are the best ways to access electronic resources if the environment is designed mainly and essentially on the basis of CC? What are the most reasonable approaches to validate quality evaluation criteria? This brings the problem of the cloud-based learning components modelling, evaluation and design to the forefront.

## 4 Pedagogical Aspects of Electronic Resources Delivery and Quality Research Indicators

Cloud computing technology is now one of the leading trends in the formation of the information society. It constitutes an innovative learning concept and its implementation significantly affects the content and form of different types of activities in the sphere of education [4, 12, 20].

Along with the emergence of cloud computing, the number of objects, developments and domain applications are continually growing, which indicates the rapid spread of the innovation [23]. The concept of *the cloud-based learning environment* is now in line with the wider trend; that is to say, the ICT environment of the university, where some didactic functions as well as some fundamentally important functions of scientific research are supported by the appropriately coordinated and integrated use of cloud services [23]. The *aim* of the cloud-based learning environment formation is to meet the users' educational needs. To do this, the introduction of cloud technology in the learning process should to be holistic and carried out according to the principles of *open education*, including meeting the following needs: the mobility of students and teachers, equal access to educational systems, providing qualitative education, and forming and structuring of educational services [3, 23].

The main elements of the cloud computing conception, including the types, application service models, essential features, ICT architecture and others, are reflected in the structure of the modern educational organizational systems [5]. Therefore, a number of concepts and principles that characterize the development and application of CC-based services are significant in the consideration of the educational environment design.

The concept of *electronic educational (learning) resources* (EER) appears to be the centre of attention. In particular, at the Institute of Information Technologies and Learning Tools of the National Academy of Pedagogical Sciences of Ukraine the conception that provided the definition of electronic educational resources (EER) its classification, and the ways it can be applied has been developed and proposed [5].

According to the definition given in [5, p.3], "The electronic educational resources are a kind of educational tool (for training, etc.) that are electronically placed and served in educational system data storage devices which are a set of electronic information objects (documents, documented information and instructions, information materials, procedural models, etc.)".

The elaboration of the electronic learning resources should be considered as a specific activity, which is linked to the mandatory need to take into consideration the psychological and pedagogical aspects of building an educational system methodology, the design of an open computer-based learning environment, and the involvement of the scientific and pedagogical staff, including the best teachers and educators [4].

*Cloud Service* – is a service that provide "network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand" [12, p.6]. These services are used to supply the electronic educational resources that make up the substance of a cloud-based environment, and to provide the processes of elaboration and use of the educational services.

Electronic resources appear to be both the objects and the tools of activity for a learner; therefore, these resources are used to maintain certain functions that are realized in the learning process. By the *educational service* we mean a service provided at the request (in response to an inquiry etc.) of a user that meets some service function carried out by the organization or institution (service provider, outsourcer) [4].

There are also four *service deployment models* for cloud computing application that reflect the mode of the cloud infrastructure set up in a particular organization: *the corporate cloud* is owned or leased by the organization; *the cloud community* is a shared infrastructure used by a community; *the public cloud* is a mega-scale infrastructure that may be used by any person under some payment terms; *the hybrid cloud* is a composition of one or more models [4, 18].

The *hybrid service model* is to combine various approaches for learning resources access within the cloud-based settings.

The EER of the public cloud can occupy the role of software for general purposes such as office applications, systems support processes for communication and data exchange and others, and also the special software designed for educational use [15, 26]. The number of EERs is increasing and this trend is likely to intensify. By means of CC-based tools, a significant lifting of restrictions on the implementation of access to qualitative leaning resources may be achieved. Now, these questions are not a matter of future perspective, they need practical implementation. For this purpose, the problem of the design and delivery of electronic educational resources in the cloud-based environment in particular within the hybrid service modes is a complex one and not only should technological needs be considered, but also the pedagogical aspects.

Due to the significant educational potential and novel approaches to environmental design, its formation and development, these questions remain the matter of theoretical and experimental studies, the refinement of approaches, and the search for models, methods and techniques, as well as possible ways of implementation [4].

To carry out research and experimental activities and the implementation and dissemination of the results, the Joint research laboratory of the Institute of Information Technologies and Learning Tools of the NAPS of Ukraine and the Kherson State University was created in 2011 with the focus on issues of educational quality management using ICT [32].

As part of the programme of joint research work, the Kherson State University was approved as an experimental base for research on the definition and experimental verification of the didactic requirements and methods of evaluating the quality of electronic learning resources in the educational processes of the pilot schools [32]. The purpose of the experiment carried out was to identify and experimentally verify the requirements and methods of evaluating the quality of the electronic learning resources used in the educational process in secondary schools [32].

The quality evaluation of EER in the cloud-based learning environment is a separate line of work in the Laboratory's research. In this case, there are different approaches and indicators. The access organization has been changed so the models of learning activity have been changed also. There are the following questions: What features and properties have to be checked so as to measure the pedagogical effect of the cloud-based approach? With regard to the pedagogical innovation, what are the factors influencing pedagogical systems, their structure and organization? Is the improvement in learning results achieved due to the cloud-based models? In this context, the quality of EER is a criterion for estimating the level of organization and functioning of the cloud-based learning environment.

With regard to this, the following *hypothesis* is to be posed: the design of the learning environment on the basis of cloud models of access to learning resources contributes to the improvement of the quality of these resources and the improvement of the processes in this environment and their organization and functioning, resulting in an improvement in learning results.

The method of electronic resources quality estimation was developed and used in the Joint laboratory of EER quality control [14, 32]. In this case, the different quality parameters have been detailed and selected [14]. It is important that the psychological and pedagogical parameters are estimated in the experimental learning process, while the other types of parameter such as technological or ergonomic may be estimated out of this process.

The prospective way of the estimation of the quality of learning resources is by means of the cloud-based environment. As the resources are collectively accessed, there is a way to allow experts into the learning process so they may observe and research their functioning. This is a way to make the process of quality estimation easier, more flexible and quicker. The process of estimation becomes anticipatory and timely. The estimation may be obtained just once along with the process of EER elaboration, and it is very important to facilitate the process [25].

There are several groups of quality criteria to be taken into consideration and checked in the process of complex quality assessment of ICT-based learning tools. Generally, there are main groups such as: psychological and pedagogical indicators; and ergonomic and technological indicators [14, 32]. There is no single set of criteria clearly acknowledged to be unambiguous. There is a problem of criteria substantiation as the didactic and methodical, and psychological aspects of educational use of ICT, are hardly regulated and standardized [22]. Still, there are research works devoted to the problems of quality evaluation in this field, where the system of quality criteria has been substantiated and proved experimentally [14].

Another kind of problem is connected to the cloud-based learning tools' quality estimation. Specific kinds of criteria are valuable in this case with regard to innovative features of advanced learning settings. So, for the purpose of this study, the quality criteria were scrutinized to reveal the most significant. There were also two groups of indicators selected: the pedagogical and psychological; and technological. It is not feasible to take into account all possible criteria inherent to cloud-based tools' application. There are a lot of technical and technological aspects to be considered, such as portability, sustainability, security, and others. Not to underestimate the importance of all relevant features, the study is concerned with those quality aspects that are valuable only in the case of educational use of ICT-based tools.

Therefore, among the variety of technological parameters, this study focuses on those that are important for pedagogical study in relation to the introduction of emerging ICT. Technological innovations cause shifts in pedagogical approaches and transformations of target, content, and methodological aspects of educational systems [4]. So, the quality of emerging ICT tools must reflect the prospected shift in learning technologies and improvement of pedagogical outcome.

Among the technological indicators of cloud-based educational resource quality evaluation, are those concerned with *ease of access,* showing if electronic resource access organization is easy and convenient; *the intuitive clarity of the interface*, reflecting if the user interface is clear and easy to learn; *responsiveness*, meaning performance in real time work; *sustainability,* concerning capability of functioning while working with the resource from any computer via a browser; *support of collaborative work,* encompassing facilities to support collaboration in the learning process; *ease of integration,* meaning suitability to be incorporated into a single environment along with other resources; and *usefulness,* covering overall utility (feasibility) of resource use.

The pedagogical and psychological criteria of the cloud-based learning resource quality evaluation should be the same as any other educational electronic resource in many respects. However, this is an important step in the quality evaluation process that cannot be neglected while investigating any tool aimed at learning. The set of psychological and pedagogical indicators for the research are as follows: the *scientific clarity* of the content; *accessibility* of the content, delivered by the resource; *fostering the intellectual development* of a learner while working with the resource; *problem orientation* of content and functioning; *personalization* in the learning process; *adaptability* as suitability for most of the possible user contingent; *methodical usefulness,* meaning the most appropriate support for learning methods; *professional orientation* as providing learners' professional development; and *feedback* connection.

As the criteria set is identified and formed, there is a need to provide validity of every indicator that may be achieved by this research.

## 5 The Hybrid Service Model of Learning Software Access

To research the hybrid service model of learning software access, a joint investigation was undertaken in 2013–2014 at the Institute of Information Technologies and Learning Tools of the NAPS of Ukraine and Drohobych State Pedagogical University named after I.Franko. At the pedagogical university, the experimental base was established where the cloud version of the Maxima system (which is mathematical software), installed on a virtual server running Ubuntu 10.04 (Lucid Lynks), was implemented. In the repository of this operational system is a version of Maxima based on the editor Emacs, which was installed on a student's virtual desktop [24]. In this case, the implementation of software access due to the hybrid cloud deployment in Scenario 3 was organised.

In Fig.3, the configuration of the virtual hybrid cloud used in the pedagogical experiment is shown. The model contains a virtual corporate (private) subnet and a public subnet. The public subnet can be accessed by a user through the remote desktop protocol (RDP). In this case, a user (student) refers to certain electronic resources and a computing capacity set on a virtual machine of the cloud server from any device, anywhere and at any time, using the Internet connection.

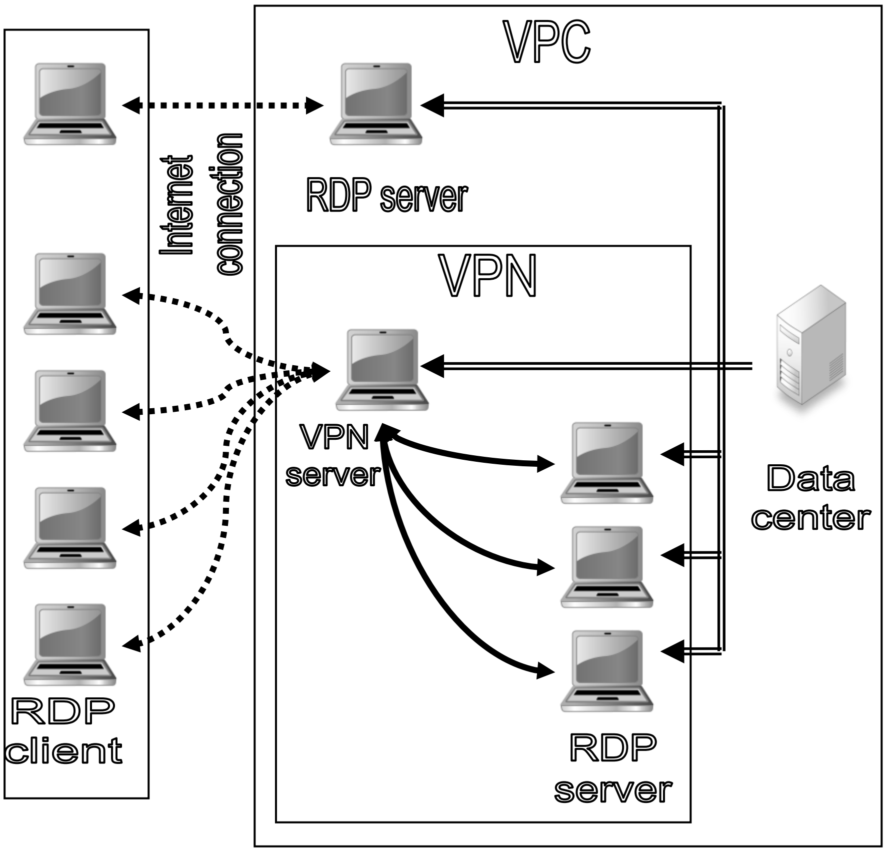


**Fig. 1.** The hybrid service model of the learning resources access.

In this case, a user's computer is the RDP-client, while the virtual machine in the cloud is the RDP-server. In the case of a corporate (private) subnet, a user cannot apply to the RDP-server via desktop because it is not connected to the Internet directly. Computers in the corporate subnet have Internet access via the VPN-connection, i.e. the gateway. Thus, these computers cannot be accessed from any device, but only from the specially configured one (for example, a computer in the educational institution or any other device where the VPN-connection is set up) (Fig.1).

The advantage of the proposed model is that, in a learning process, it is necessary to use both corporate and public learning resources for special purposes. In particular, the corporate cloud contains limited access software; this may be due to the copyright being owned by an author, or the use of licensed software products, personal data and other information of corporate use. In addition, there is a considerable saving of computational resources, as the software used in the distributed mode does not require direct Internet access for each student. At the same time, there is a possibility of placing some public resources on a virtual server so the learner can access them via the Internet and use the server with the powerful processing capabilities in any place and at any time. These resources are in the public cloud and can be supplied as needed.

## 6 Implementation and Evaluation

In the joint research experiment held at Drohobych State Pedagogical University named after I.Franko, 240 students participated. The aim was to test the specially designed learning environment for training the operations research skills on the basis of the Maxima system. During the study, the formation of students' professional competence by means of a special training method was examined. The experiment confirmed the rise of the student competence, which was shown using the $\chi^2$ – Pearson criterion [24]. This result was achieved through a deepening of the research component of training. The experiment was designed using a local version of the Maxima system installed on a student's desktop.

The special aspect of the study was the expansion of these results using the cloud version of the Maxima system that was posted on a virtual desktop. In the first case study (with the local version), this tool was applied only in special training situations. In the second case study (the cloud version), the students' research activity with the system extended beyond the classroom time. This, in turn, was used to improve the learning outcomes.

After that another research was held in Ternopil National Pedagogical University named after V.Gnatyuk (2014-2015). The aim of this experiment was to test the use of the cloud-based component in the learning process. 48 students participated in this experiment. There was the experimental group of 24 students who used the cloud-based component with Maxima system. It showed increase of the students' percentage with the high level of ICT competence from 16% to 75%. It was significantly different from the level of ICT competence of those students who did not used this component (from 14% to 20%), which was justified by the Fisher criterion.

The cloud-based learning component used in the experiment has undergone a quality estimation. The method of learning resources quality estimation developed in the joint laboratory of educational quality management with the use of ICT [14] was used and adapted for this study. The 20 experts were specially selected as having experience in teaching professional disciplines focused on the use of ICT and being involved in the evaluation process. The experts evaluated the electronic resource by two groups of parameters. The first group has contained 7 technological parameters:

ease of access; the clarity of the interface; sustainability; support of collaborative work, ease of integration; mobility; and usefulness. The second group has contained 9 psychological and pedagogical parameters: the scientific clarity; accessibility; fostering the intellectual development; problem orientation; personalization; adaptability; methodical usefulness; professional orientation; and feedback connection.

"Expert evaluation of the EER quality can be considered sufficiently reliable only when a good consistency of expert answers. Therefore, the statistical processing of the results of experts evaluations should include an analysis of consensus of experts. Concordance method is used to assess the degree of consensus of experts on the factors: weights of EER types, parameterization of EER quality indicators, and average factor of EER quality" [14, p.322].

Experts were asked to complete the table 1 for peer review of EER quality parameters validity. The values of the weighting factors were selected from 10 point scale. The results of the survey of experts are presented in Table 1.

**Table 1.** Expert data on validity of EER quality parameters.

| Ex | ERR Quality Parameters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pert | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | #11 | #12 | #13 | #14 | #15 | #16 |
| 1 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 |
| 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 10 | 10 |
| 3 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 |
| 4 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 |
| 5 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 10 |
| 6 | 10 | 9 | 10 | 10 | 9 | 8 | 8 | 8 | 10 | 9 | 10 | 10 | 9 | 8 | 8 | 8 |
| 7 | 10 | 9 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 9 | 8 | 8 | 8 | 8 | 8 | 10 |
| 8 | 9 | 9 | 8 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 8 | 9 | 8 | 9 | 9 | 9 |
| 9 | 10 | 9 | 7 | 8 | 8 | 6 | 8 | 9 | 10 | 9 | 7 | 8 | 8 | 6 | 8 | 9 |
| 10 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 |
| 11 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 |
| 12 | 10 | 10 | 9 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 10 | 10 | 10 | 10 |
| 13 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 |
| 14 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 | 9 | 10 | 10 | 9 | 8 | 6 | 8 | 7 |
| 15 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 10 |
| 16 | 10 | 9 | 10 | 10 | 9 | 8 | 8 | 8 | 10 | 9 | 10 | 10 | 9 | 8 | 8 | 8 |
| 17 | 10 | 9 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 9 | 8 | 8 | 8 | 8 | 8 | 10 |
| 18 | 9 | 9 | 8 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 8 | 9 | 8 | 9 | 9 | 9 |
| 19 | 10 | 9 | 7 | 8 | 8 | 6 | 8 | 9 | 10 | 9 | 7 | 8 | 8 | 6 | 8 | 9 |
| 20 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 | 7 | 6 | 6 | 8 | 8 | 6 | 8 | 9 |

**Table 2.** Expert data on EER quality parameters (ranked)

| Expert | ERR Quality Parameters (ranked) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 2 | 9 | 13 | 14 | 10 | 5 | 1 | 6 | 3 | 11 | 15 | 16 | 12 | 7 | 2 | 8 | 4 |
| 3 | 7 | 1 | 2 | 9 | 10 | 3 | 11 | 15 | 8 | 4 | 5 | 12 | 13 | 6 | 14 | 16 |
| 4 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 5 | 1 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 2 | 4 | 11 | 12 | 13 | 14 | 16 | 16 |
| 6 | 11 | 7 | 12 | 13 | 8 | 1 | 2 | 3 | 14 | 9 | 15 | 16 | 10 | 4 | 5 | 6 |
| 7 | 13 | 11 | 1 | 2 | 3 | 4 | 5 | 14 | 15 | 12 | 6 | 7 | 8 | 9 | 10 | 16 |
| 8 | 5 | 6 | 1 | 7 | 2 | 8 | 9 | 10 | 11 | 12 | 3 | 13 | 4 | 14 | 15 | 16 |
| 9 | 15 | 11 | 4 | 6 | 5 | 2 | 10 | 14 | 16 | 12 | 3 | 7 | 9 | 1 | 8 | 13 |
| 10 | 11 | 10 | 1 | 4 | 12 | 9 | 7 | 6 | 5 | 8 | 3 | 2 | 16 | 14 | 13 | 15 |
| 11 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 12 | 12 | 14 | 13 | 10 | 6 | 2 | 7 | 4 | 11 | 16 | 15 | 9 | 5 | 1 | 8 | 3 |
| 13 | 8 | 1 | 3 | 9 | 10 | 2 | 12 | 15 | 7 | 5 | 4 | 11 | 13 | 6 | 14 | 16 |
| 14 | 8 | 1 | 7 | 2 | 11 | 9 | 3 | 10 | 12 | 4 | 15 | 13 | 14 | 5 | 16 | 6 |
| 15 | 1 | 4 | 11 | 8 | 7 | 10 | 6 | 13 | 2 | 3 | 5 | 9 | 12 | 14 | 15 | 16 |
| 16 | 14 | 8 | 12 | 11 | 7 | 2 | 3 | 1 | 13 | 10 | 15 | 16 | 9 | 4 | 5 | 6 |
| 17 | 14 | 11 | 2 | 1 | 4 | 5 | 3 | 13 | 15 | 12 | 6 | 7 | 9 | 8 | 10 | 16 |
| 18 | 13 | 11 | 3 | 10 | 1 | 12 | 9 | 7 | 6 | 8 | 2 | 5 | 4 | 15 | 14 | 16 |
| 19 | 15 | 11 | 3 | 7 | 5 | 1 | 10 | 12 | 16 | 14 | 4 | 6 | 9 | 2 | 8 | 13 |
| δi | 0,39 | 0,43 | 0,33 | 0,41 | 0,38 | 0,33 | 0,44 | 0,60 | 0,62 | 0,54 | 0,52 | 0,63 | 0,67 | 0,51 | 0,73 | 0,83 |

Concordance coefficient W is calculated according to the formula proposed by Kendall [13]

$$W = \frac{12S}{m^2(n^3-n)} \quad (1)$$

Here $S = \sum_{i=1}^{n} \Delta_i^2 = \sum_{i=1}^{n}\{\sum_{j=1}^{m} x_{ij}\}^2$, (2)

m – number of experts, n – number of objects of examination (the quality parameters, $x_{ij}$ – assessment of the i-object by j-expert. Coefficient of concordance may vary between 0 and 1. If $W = 1$, all experts gave the same assessment for all parameters, if $W = 0$, the evaluations of experts are not consistent.

Using the formula (1) we calculated that coefficient $W$ = 0.189 and it is significantly different from zero, so we can assume that among experts there is objective concordance. Given that the value of $m(n-1)W$ is distributed according to $\chi^2$ with $(n-1)$ freedom degree, then

$$\chi_W^2 = \frac{12S}{m \cdot n \cdot (n+1)} = 52.8. \quad (3)$$

Comparing this value with the tabulated value $\chi_T^2$ for $n-1 = 15$ degree of freedom and significance level $\alpha$ = 0,01, we find $\chi_W^2$ = 52,8 > $\chi_T^2$ = 30,5. Therefore, the hypothesis of concordance of expert evaluations is confirmed according to Pearson.

Thus, the results of pedagogical experiment confirmed the assumption that the method of expert evaluations can be the basis for the cloud-based EER quality evaluating.

The problem was: is it reasonable and feasible to arrange the environment in a proposed way? For this purpose there were two questionnaires proposed to expert concerning two groups of parameters. The 20 experts estimated 16 parameters (there were 7 technological and 9 psychological and pedagogical among them). A four-point scale (0 (no), 1 (low), 2 (good), 3 (excellent)) was used for the questions.

The results of the evaluation of the technological parameters are shown in Fig.2.

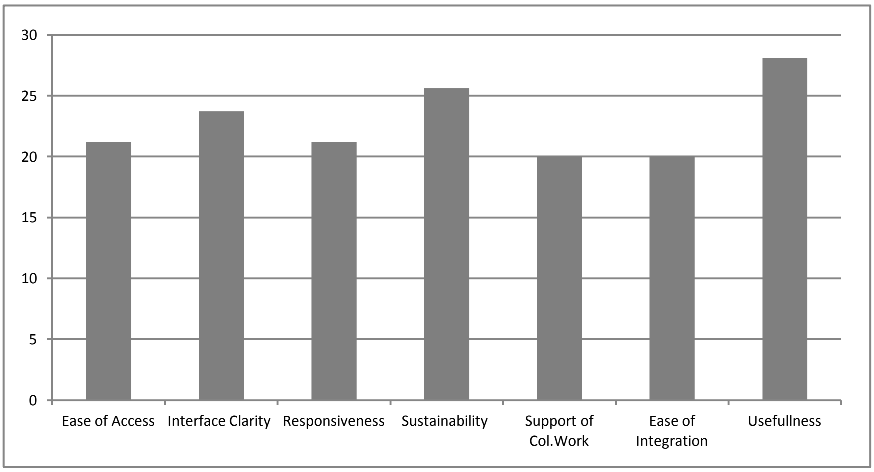


**Fig. 2.** The results of the cloud-based learning resource technological quality parameters evaluation.

The resulting average value was calculated for every parameter: “Ease of access” = 2.1, “Interface clarity” = 2.4, “Responsiveness” = 2.1, “Sustainability” = 2.56, “Support of Collaborative work” = 2.0, “Ease of Integration” = 2.0, “Usefulness” = 2.8, the total value was 2.3.

The results of psychological and pedagogical parameters evaluation are shown at Fig.3.

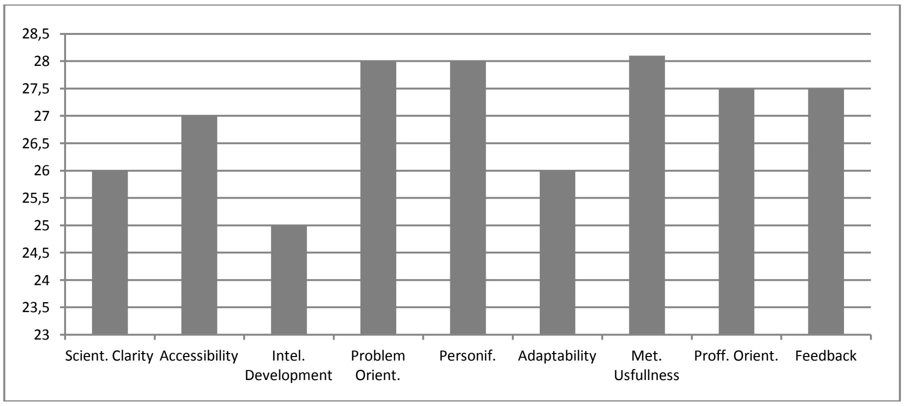


**Fig. 3.** The results of the psychological and pedagogical quality parameters evaluation

The resulting average values for every parameter are: "Scientific clarity" = 2.6, "Accessibility" = 2.7, "Fostering the intellectual development" = 2.5, "Problem orientation" = 2.8, "Personalization" = 2.8, "Adaptability" = 2.6, "Methodical usefulness" = 2.81, "Professional orientation" = 2,75, "Feedback connection" = 2,75. The total value was 2.71.

The value of the weight factor of *i*-type resource indicator may be calculated using the Table 2 by the formula (4) [14].

$$\delta i = \frac{1}{n_i}\sum_{j=1}^{n_i}\frac{k_{ij}}{k_{iM}} \quad (4)$$

$n_i$ – quantity of experts, $k_{ij}$ – ranked *j*-parameter of quality, $k_{iM}$ – the maximum value of *j*-parameter of quality.

Then the average criterion of EER quality may be calculated as follows:

$$\mathrm{K} = \frac{k}{m}\sum_{i=1}^{m}\delta_i\overline{x_i} \quad (5)$$

$m$ – quantity of quality indicators, $\overline{x_i}$ – average value of i-indicator of quality, k – weight coefficient.

The resulted average criterion of EER quality K=2,59. This characterises the resource quality as sufficient for further implementation and use.

The advantage of the approach is the possibility to compare the different ways to implement resources with regard to the learning infrastructure. Future research in this area should consider different types of resources and environments.

## 7 Conclusion

The introduction of innovative technological solutions into the university learning environment contributes to unified learning infrastructure formation and the growth of access to the best examples of electronic resources and services. ICT use is promising regarding learning settings that can advance and develop the tendencies of CC progress. For example, there are tendencies of using the cloud-based models of environment design, applications virtualisation, unifying infrastructure, integrating services, increasing the use of electronic resources, expanding collaborative forms of work, widening the use of the hybrid models of ICT delivery and increasing the quality of electronic resources. The hybrid service model proved to be a reasonable framework to deliver and research the cloud-based learning resources and components of the university educational environment.

## References


1. Amazon Virtual Private Cloud. User Guide, API Version 2013–07–15, (2013)
2. Bard, G.V.: Sage for Undergraduates. AMS, (2015)
3. Bykov, V.: Models of Organizational Systems of Open Education. Atika, Kyiv (2009) (in Ukrainian)
4. Bykov, V.: Cloud Computing Technologies, ICT Outsourcing, and New Functions of ICT Departments of Educational and Research Institutions. Information Technologies in Education, 10, 8–23, (2011) (in Ukrainian)
5. Bykov, V., Lapinskii V.: The Methodological basis for creating and implementation of the electronic learning tools. Computer in school and in family, 2(98), 3–6, 2012.
6. Buyyaa, R., Chee Shin Yeoa, Venugopala, S., Broberga, J., Brandicc, I.: Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Generation Computer Systems, 25(6), 599–616, (2009)
7. Cusumano M.: Cloud computing and SaaS as new computing platforms. Communications of the ACM, 53(4), 27–29 (2010)
8. Doelitzscher, F., Sulistio, A., Reich, Ch., Kuijs, H., Wolf, D.: Private cloud for collaboration and e-Learning services: from IaaS to SaaS. Computing, 91, 23–42, (2011)
9. The Future of Cloud Computing: 4th Annual Survey 2014. The North Bridge Future Of Cloud Computing Survey In Partnership With Gigaom Research, http://bit.ly/2014FutureCloud (2014)
10. Gold, N., Mohan, A., Knight, C., Munro, M.: Understanding service-oriented software, Software, IEEE, 21(2), 71 – 77, (2004)
11. Hashmi1 S.I., Clerc V., Razavian M., and others: Using the Cloud to Facilitate Global Software Development Challenges. 2011 Sixth IEEE International Conference on Global Software Engineering Workshops, (2011)
12. ISO/IEC 17788:2014(E) Information technology – Cloud computing – Overview and vocabulary. First edition 2014–10–15, (2014)
13. Kendall M. Rank Correlation Methods, Charles Griffen & Company, London, (1948)
14. Kravtsov H.M. Methods and Technologies for the Quality Monitoring of Electronic Educational Resources / In: Batsakis, S. et al. (eds.) Proc. 11-th Int. Conf. ICTERI 2015, Lviv, Ukraine, May 14-16, 2015, 311– 325, CEUR-WS.org/ Vol–1356, ISSN 1613–0073, P.311–325, online CEUR–WS.org/Vol–1356/paper_109.pdf, (2015)
15. Lakshminarayanan, R., Kumar, B., Raju, M.: Cloud Computing Benefits for Educational Institutions. In Second International Conference of the Omani Society for Educational Technology, Muscat, Oman: Cornell University Library, http://arxiv.org/ftp/arxiv/papers/1305/1305.2616.pdf (2013)
16. Maamar, Z., et al.: An approach to engineer communities of web services: Concepts, architecture, operation, and deployment. International Journal of E–Business Research (IJEBR), 5(4), 1–21, (2009)

17. Matheson C., Matheson D.: Access and Accessibility in E-Learning. Applied E-Learning and E-Teaching in Higher Education. Ed. by Donnelly R., McSweeney F., Hershey New York, 130–151, (2009)
18. Mell, P., Grance T.: Effectively and Securely Using the Cloud Computing Paradigm. NIST, Information Technology Laboratory, 10–7–2009, (2009)
19. Qing Li, Zeyuan W., Weihua Li, Jun Li, Cheng Wang, Ruiyang Du.: Applications integration in a hybrid cloud computing environment: modelling and platform. Enterprise Information Systems, 7(3), 237–271, (2013)
20. Smith, A., Bhogal J., Mak Sharma: Cloud computing: adoption considerations for business and education. 2014 International Conference on Future Internet of Things and Cloud (FiCloud), (2014)
21. Shyshkina, M.: Innovative Technologies for Development of Learning Research Space of Educational Institution. Information Technologies and Society, 1, http://ifets.ieee.org/russian/depository/v16_i1/pdf/15.pdf (2013) (In Russian)
22. Shyshkina, M.: Advanced Technologies of E-learning in Engineering Education / In: M.Auer, M.Huba (eds.) Proc. of the 14th Int. Conf. ICL2011, ), Piestany, Slovakia, September 21–23 2011, 565–568, (2011)
23. Shyshkina, M.: Emerging Technologies for Training of ICT-Skilled Educational Personnel. Communications in Computer and Information Science, Berlin-Heidelberg, Springer-Verlag, 412, 274–284, (2013)
24. Shyshkina M. U. P. Kohut, I. A. Bezverbnyy. Formation of professional competence of computer science bachelors in the cloud based environment of the pedagogical university. Problems of modern teacher preparation, Uman, FOT Zhovtyy O.O., 9, part 2, 136–146 (2014) (in Ukrainian)
25. Shyshkina, M.P., Spirin, O.M., Zaporozhchenko, Yu.G.: Problems of Informatization of Education in Ukraine in the Context of Development of Research of ICT-Based Tools Quality Estimation. In: J. Information Technologies and Learning Tools, vol. 27, № 1, http://journal.iitta.gov.ua/index.php/itlt/article/view/ 632/483 (2012) (in Ukrainian)
26. Tuncay, E.: Effective use of cloud computing in educational institutions. Procedia – Social and Behavioral Sciences, 2(2), 938–942, (2010)
27. Turner, M., Budgen, D., Brereton, P.: Turning software into a service. Computer, 36 (10), 38–44, (2003)
28. Vaquero L. M.: EduCloud: PaaS versus IaaS cloud usage for a n advanced computer science course, IEEE Transactions on Education, 54(4), 590–598, (2011)
29. Vouk, M.A., Rindos, A., Averitt, S.F., Bass, J. and others: Using VCL technology to implement distributed reconfigurable data centers and computational services for educational institutions. VCL/Reconfigurable. Data Centers & Clouds/NCSU/V19-Draft Feb–2009 1–27, (2009)
30. Wick D.: Free and open-source software applications for mathematics and education. Proceedings of the twenty-first annual international conference on technology in collegiate mathematics, 300–304, (2009)
31. Zhang, J., and others: A Framework of User-Driven Data Analytics in the Cloud for Course Management. Proceedings of the 18th International Conference on Computers in Education, S. L. Wong et al., Eds., Putrajaya, Malaysia, Asia-Pacific Society for Computers in Education, 698–702, (2010)
32. Zaporozhchenko, Yu., Shyshkina M., Kravtsov G.: Prospects of the development of the modern educational institutions' learning and research environment: to the 15th anniversary of the Institute of information technologies and learning tools of NAPS of Ukraine. Informational Technologies in Education, 19, 62–70, (2014).