

# Cloud computing – a necessary reality in modern education

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**Abstract-** Education in the Information Society is always connected and follows the development of information and communication technologies. The deployment of modern information technologies in educational institutions requires appropriate infrastructure and its effective management. Many schools and universities cannot afford the large investment costs of new technologies, which complicates their application in education. Cloud computing is a contemporary effective solution that allows educational institutions to respond quickly and adequately to new challenges and implement innovative approaches in training.

The main objective of the current work is to analyze and summarize the advantages of the cloud computing model for educational institutions, and to reveal its potential for providing infrastructure, platform and applications, which can create innovative learning environment.

**Index Terms-** Deployment models, Cloud computing model, Infrastructure as a Service, Platform as a Service, Service models, Software as a Service

## I. INTRODUCTION

Modern education is invariably linked to the widespread use of information and communication technologies (ICT). ICT enable the implementation of contemporary forms of education based on new pedagogical paradigms where the learner is a central figure, and actively participates in the learning process, interacting and collaborating with all participants. Implementing ICT in education leads to training consistent with the needs and characteristics of the new generation of learners, called "digital natives". They have new requirements for the educational process and the learning environment. In order to meet the changing requirements and expectations, educational institutions need to offer modern forms and methods of training and educational services that are available through a variety of devices. More and more activities (learning and administrative) are affected by ICT because the new technological inventions are more flexible and can expand and open the educational space to a wider audience.

A serious problem for most educational institutions is how to follow and apply the latest innovations in ICT. The deployment of modern ICT requires appropriate infrastructure and its effective management. Many schools and universities cannot afford the large investment costs in new technologies and do not have enough qualified IT staff – factors that complicate the application of modern ICT in education.

Similar to business companies that are quickly embracing cloud services as an approach for effective implementation of their activities, educational institutions are also looking for different ways for effective and profitable use of modern ICT, without increasing their costs. Cloud services are a contemporary and effective solution that allows educational institutions to respond quickly and adequately to the new challenges and implement innovative approaches in training.

For many schools and universities the Cloud computing model offers economically efficient solution to the problem of how to provide resources and services (computing power, storage and applications) to the rapidly growing number of learners without making significant capital investments in hardware and software and their maintenance [1]. On the other hand, the continuous access to information and the possibility of sharing resources are among the most important advantages of cloud computing which make it very important and necessary for modern education.

## II. CLOUD COMPUTING

Cloud computing is not just a new technological phenomenon. It is the result of the evolution of different existing technologies: Internet, virtualization, grid computing, and web services [2]. Cloud computing corresponds with the new stage in community development, the emphasis is on the communication and interaction between people and the new way the content and knowledge are generated [3].

There are many definitions of cloud computing, but the most popular is the definition of the National Institute of Standards and Technology (NIST) as it reflects all essential aspects of cloud computing.

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [4].

The essential characteristics of cloud computing are [4-6]:

- **On-demand self-service.** Users can unilaterally request and receive computing resources when they need them without human interaction with service providers. Cloud computing creates the illusion of infinite computing resources available on demand and thus eliminates the need to make preliminary plans for their long-term delivery.
- **Permanent and broad network access.** Computing resources and services are available anytime from anywhere in the world over the network through standard mechanisms.

Access mechanisms allow the use of heterogeneous platforms and devices, which facilitates users' access to services.

- **Resources pooling and sharing.** The provider's computing resources are pooled to serve multiple users. They are not set aside and fixed between users in advance. They are dynamically assigned according to their needs.
- **Rapid elasticity.** Depending on their current needs, users can dynamically change (increase or decrease) the leased resources. The possibility of scaling the rented infrastructure allows users to react promptly to dynamically changing needs. Users can start with a small amount of resources and increase them only when their needs grow.
- **Varying according to consumption price (pay-per-use).** Payment for cloud services is determined by actual resources consumption: the price depends on the level of users' activity. Users are charged only for the actual consumption of computing resources for the period of time they are used. Users use and pay for resources when they need them and can quickly and easily release them when they are no longer needed.

### III. CLOUD COMPUTING IN EDUCATION

Changes in education inevitably follow transformations in society. Traditional forms of education are inadequate and difficult to apply in training of digital generation learners. Ideas for active learning and social interaction suggest new forms of education that are implemented through new technologies.

Traditional forms of e-learning require significant investments, as well as on-going costs of maintenance and upgrade of hardware and software. There could be problems at times of peak consumption due to limitations of the hardware computing power. The application of traditional IT techniques for solving existing problems is not appropriate and has a high cost for educational organizations. There is a need for a new way of implementing e-learning software solutions, new alternative technologies and tools that allow achieving a high level of efficiency and compliance with modern trends in education and science and at the same time lower costs for acquiring and maintaining of IT tools.

Following the global trends in ICT development, one of which is cloud computing, is an effective way to solve existing problems and achieve objectives at a minimum cost.

Cloud computing is mainly associated with business, but recently it has become a factor in education. More and more cloud service providers adapt or add new functionalities to their applications to serve the needs of participants in the learning process and meet their expectations.

There are various reasons for the growing penetration of cloud computing in education:

- A large number of learners (globally) who need access to education at any time and from anywhere. The idea of lifelong learning involves continuous access to a huge amount of electronic educational resources. Different educational paradigms, requiring interaction and collaboration as an essential element of the learning process, require new tools for their effective realization.
- The attitudes and expectations of society, teachers and learners from the educational institutions are related to the

availability of modern learning environment where the learning process can take place. Users possess a variety of devices and they want to use them to access information (including learning materials) at any time and place and to be connected with the rest of the world. The traditional IT infrastructure cannot serve the ever growing number of personal devices (tablets, smartphones, PCs and laptops) and provide tools for effective interaction of all participants in the training process [7].

- There is a need for implementing tools and applications and delivering web-based services to learners and teachers at an accelerated pace, which is often without a proportional increase in the budget for IT resources and staff [7]. The training in certain subjects includes the use of simulations or modeling as basic tools and forms for acquiring knowledge and skills. Powerful computers and software packages are needed for their successful implementation, frequently with no free alternative, which requires considerable investment costs.

Cloud services are the basis for new strategies that educational institutions should be developing in order to offer new business models that will allow them to deal with insufficient funds for building and managing IT infrastructure necessary for the development of modern forms of education (such as distance and e-learning) [8]. Cloud computing supports the creation of a suitable environment for socially oriented education based on collaboration and interaction between all participants in the learning process.

#### A. Advantages of cloud computing for education

The benefits of the cloud computing model in education are both for teachers and learners as well as educational institutions.

The study of Forrester Research [9] shows that the main reason for moving to the cloud is cost savings. Working in the cloud, organizations realize the true potential of cloud computing to transform their activities. As a result, reducing costs is no longer one of the primary reasons organizations continue to use cloud services.

The advantages of cloud services for education can be viewed from different aspects [3, 6-7, 10-12]. The main advantages are: economic benefits, efficiency and flexibility, accessibility, and innovation.

- **Economic benefits.**

The use of applications and services from an external provider is a cost-effective and efficient solution for educational institutions, which allows a high degree of financial flexibility. The advantages of the cloud computing model compared to the traditional approach are:

*Reducing and reallocating expenses.* A key element of cloud computing is its potential to reduce costs and investments for building and maintaining IT infrastructure and administrative costs for IT staff. Cost savings result from the sharing of hardware and software among many users. Cloud computing provides flexibility and eliminates the need for significant capital investment to purchase hardware and software.

Educational organizations do not need to buy expensive hardware which may not be fully utilized. They can hire the necessary resources from the provider that owns them, and pay only for actual resources consumption for the period of their usage. The cost of rented resources is lower, because IT equipment is shared among multiple users. Software products are

offered in the form of services, and special software installed on client devices is not required, users need a web browser to access services. The applications are not installed and configured on the client devices, there is no need to support and update software, which leads to reduced costs for licenses and maintenance.

Capital expenditures are replaced with operating expenditures, which for organizations means not only a change in their budgets, but also in their overall attitude and perception of IT infrastructure: awareness of the advantage of using IT resources instead of their possession [13]. On the other hand, there is a minimal administration of the IT infrastructure: reducing the cost of technical support of the equipment and software applications. The maintenance of the rented resources is the responsibility of the service provider, which frees the educational institutions from the need to hire IT experts or train their own staff how to maintain and manage the equipment and applications, which also reduces costs.

*Payment for actual consumption and free services.* Many of the cloud services for education are free. At the same time, even if payment for applications or services is required, it is based on actual consumption. This approach can help avoid unnecessary expenses and the insufficient use of licensed software. Payment only for the period of actual use allows teachers to experiment with different software products and systems in order to select those that are appropriate to achieve specific educational goals. Learners can also use various software applications without the need to purchase and install them on their local computers.

*Utilization of old equipment.* It is well known that hardware ages rapidly, forcing organizations to purchase new servers and equipment in order to meet the increasing system requirements of software products. Cloud computing provides opportunities for extending the life of old computers. The use of cloud services does not require powerful computers, a web browser is sufficient to use most of the services. The old computers can be turned to workstations and can be used for a long period of time. For educational institutions the ability to extend the life of obsolete equipment and ensure its effective use in the learning process is a way of saving money and providing the necessary technical tools.

Finally, cloud computing offers a faster return of investment and the ability to deal with rapidly changing software and hardware needs at a lower cost.

- **Efficiency and flexibility.**

Cloud computing creates a virtual world where resources seem limitless, which provides each organization the flexibility and freedom to choose a development policy. Educational organizations can effectively implement their strategy, without the need to consider physical provision (hardware and software), since they have the ability to rent IT resources while securing their maintenance and management.

*Fast acquisition, provision and introduction of new IT solutions.* Cloud computing ensures the use of modern ICT and the ability to follow the rapid development of technologies, which cannot be achieved if the organizations use locally developed IT infrastructure. The cloud computing model allows immediate use of services and applications in the real learning process [14]. Cloud computing offers fast acquisition, provision and introduction of new IT platforms, services and applications [7]. In traditional model contract and delivery of new hardware,

installing and configuring software takes considerable time, which extends the time for implementation of new IT solutions. Cloud service providers have the necessary equipment, software, staff and experience in implementing various cloud solutions in client organizations, which allows for rapid implementation and it also reflects the economic side of the issue: faster return of investment costs. The result is a more efficient response to changing conditions and requirements.

*A complete and effective use of IT equipment.* Cloud computing allows a high degree of efficiency in training in certain subjects which require significant computing power to carry out practical exercises. There are opportunities to work with specialized complex software applications that require intensive computing resources (such as mathematical, statistical tools, CAD systems, etc.). Educational organizations can improve their IT infrastructure by renting powerful cloud computing resources as well as ensure better use of available tools.

*Focusing on specific activities.* Cloud services are provided by specializing in particular area vendors, which guarantees the quality of both the services and their maintenance and management. Clients can implement the best available practices. Using cloud services, educational institutions can focus on activities and processes related to learning and research. They do not need to spend resources (money, time, and people) for maintenance and management of the tools that support their main mission. Such an approach results in higher productivity and efficiency.

*Stimulating and supporting research activities.* Cloud computing supports research activities in educational institutions by providing necessary resources for data processing and analysis. A specific feature of research projects is that computing power is needed for a certain period of time (duration of the projects) and after their completion, computing resources become unusable. Using cloud computing institutions can build multiple virtual parallel computing environments, based on virtualization, that provide the necessary resources for data processing [15]. Opportunities for elastic scaling of rented facilities allow hiring of computing resources and storage without additional investment costs, paying only for actual consumption. The release of rented resources when there is no demand for them is quick and easy. Cloud services not only support research activities but also encourage them by providing the necessary environment and tools.

*Sharing learning resources and activities and collaboration between all participants in the learning process.* Cloud computing supports sharing of learning resources and collaboration and interaction between learners and teachers, which is a prerequisite for achieving higher efficiency in the educational process. Learning content, created by cloud based tools and services, is the product of the collaboration and can be easily shared and disseminated to multiple users. Sharing learning resources allows their improvement and enrichment, avoiding duplication of content and the need for each teacher to develop his own. Cloud computing creates conditions for an environment where the idea of social constructivism can be achieved.

- **Accessibility.**

Cloud computing allows easy and unrestricted access for teachers and learners to services and resources at any time and place through a variety of devices.

A comprehensive accessibility by different devices enables implementation of mobile learning which is characterized not only by the use of mobile devices, but above all by ensuring mobility of participants in the learning process.

Access to applications at any time and place is an important factor for the implementation of the idea of continuing education and lifelong learning. Learners can use their own devices for training, without requiring prior configuration or installation of specific software. Since most students, especially those in higher education, rely on mobile technologies for their daily activities, the use of mobile devices for educational purposes is completely natural. The capability to use applications offline and synchronize data between local devices and the cloud allow effective work at any time and place.

- **Innovation.**

In education, technologies should provide opportunities to create innovative learning environment where various pedagogical paradigms, methods and approaches can be realized. Higher education is a field where technologies should support the implementation of innovative ideas and approaches in learning and research activities. Through cloud services educational institutions have the privilege to experiment with new applications, services and tools with minimal financial and time commitment and engagement with vendors, paying only for actual consumption [7]. This approach enables them to choose the most appropriate solutions for learning and research activities in order to be effective and efficient.

In conclusion, cloud services enable the creation of a flexible learning environment with a variety of opportunities, resources and tools that match learners' needs, learning goals and expected results. It allows the implementation of different teaching approaches and scenarios consistent with the leading paradigms of Social constructivism and collaborative learning.

### *B. Risks of cloud computing model in education*

Risks and concerns associated with the use of cloud services by educational organizations are: security and data protection, loss of control over data and applications, unwanted ads, and inability to migrate to other providers [6, 10, 16].

- **Security and data protection.**

Outsourcing data in remote locations is a serious risk and challenge for any organization. One possible solution to the problem of data security is the deployment in a private cloud which is more secure compared to the public clouds. The private cloud is a more expensive alternative (from a financial point of view), which makes this solution less preferred by many educational institutions with limited budgets. In order to improve security, some cloud vendors warrant data storage only in certain countries with strict laws on data protection.

Data separation and deployment in several clouds, supported by different vendors, may provide a higher level of security and avoid vendor and data lock-in. The main drawback of this solution is that the transfer of data between clouds is not always possible and can put data at risk. Another possible decision is critical data and applications do not deploy in the cloud and

continue to be stored on local servers which are under the control of the organization.

Unauthorized data access is another major problem of cloud computing. One of the most common solutions for data protection is data encryption before deployment in the cloud. Direct contacts and collaboration with the service provider, without the use of intermediaries, is another approach that guarantees data protection, since the presence of multiple intermediaries increases the risks to data security and protection.

- **Loss of control over data and applications.**

The cloud computing model suggests data and applications are physically stored on the service providers' servers. The result is the transfer of the liability for maintenance and management of infrastructure, applications and data to the vendors. At the same time, data storage on remote servers automatically transfers control of the data in the hands of the providers. The consequence is a significantly reduced degree of users control over their data. Users will have no knowledge of when, where and why their data is processed and there is a substantial risk of data extraction and analysis for unclear purposes [17].

- **Unwanted ads.**

A possible risk of cloud computing solutions is the accumulation of personal information of users which vendors can misuse for their own benefits. A common shortcoming is the "overloading" of users with unwanted advertisements (spam). This problem is predictable and can be prevented as part of the contract for cloud computing services: the majority of providers eliminate unwanted ads as part of their services for educational institutions.

- **Inability to migrate to other providers.**

Although most providers claim they ensure and facilitate migration to other vendors (due to compatibility of products and services), the transfer of content from one system to another is associated with expenses and it is not always possible. The main risk of cloud computing is the commitment and dependence on a specific provider and the inability to migrate to others. The dependence on a particular provider is directly related to the availability of the offered services. If the provider stops providing services for various reasons, users will have no access to data and applications, and therefore will not be able to carry out their activities [17]. It is particularly important for education institutions to have opportunities for experimenting and working with a variety of tools and services in order to select those that are most appropriate to the learners' needs and for achieving specific educational objectives. Often teachers have to replace existing tools with new ones in response to changes in participants' needs and learning environment. One possible solution to the problem of dependence is the institution of open standards and adherence to them by vendors.

Absolute security and data protection does not exist. Organizations have to overcome their fears, because they exist in any decision that includes the use of ICT and the Internet. A careful selection of cloud providers and selective data deployment in the cloud, especially in public clouds, is needed in order to minimize the risks [18]. It is very important to determine the interaction between the cloud service providers and the consumers, which is usually achieved by a Service Level Agreement (SLA). The Service Level Agreement is a contract between the service provider and the user, which defines the requirements of consumers and the responsibilities of the vendor.

SLA regulates the conditions of provision and use of cloud services, which reduces the risks for users and defines their relationship with the providers.

A step-by-step transition to cloud computing helps educational organizations overcome some risks. Initially they can outsource only data and applications that are not crucial to their activities. This is a way to check the reliability of the provider and how offered services meet the needs of the educational organization and participants in the learning process. The opportunity for flexible hiring and expanding rented resources allows gradual transition from traditional to cloud solutions.

On the other hand, cloud computing already has a relatively long history: there are established service providers, and good practices and models for transition to the cloud, which helps minimize the risks and creates conditions for efficient and safe activities in the cloud.

Some of the risks of data migration in the cloud can be viewed from a different perspective and become benefits for users [12, 19-20]:

- **Preventing data loss.**

Data and applications storage in the cloud, instead of on personal devices, makes them safer in cases of hardware problems with local user devices. Users do not need to backup data or transfer it from one device to another, since the cloud is a centralized data repository which is accessible from various locations through a variety of devices.

- **Higher level of data security.**

In comparison to the traditional approach of using hardware and software, where users (individuals or organizations) have to find their own ways and tools to protect data, cloud service providers possess advanced hardware and software means for ensuring a high level of protection of users' data and applications. The location of stored data is not evident to the end-users and therefore theft or unauthorized access is difficult. Despite concerns and contrary to expectations, the cloud infrastructure is characterized by high level of protection and security. The data in the cloud is often better protected than if it is stored on companies' local servers and maintained by their internal IT department. Providers of cloud services ensure the confidentiality of data by encryption, strict control to prevent unauthorized access, scheduling backup, etc. [21].

- **Increased reliability of services.**

Providers of cloud services specialize in providing certain services or applications and this specialization allows them to manage effectively the process of maintenance, backup and restoration of data in case of any failures or disasters.

#### IV. CLOUD COMPUTING SERVICE MODELS IN EDUCATION

Educational institutions can benefit from both different deployment models (public, private, hybrid or community cloud) as well as different service models (Infrastructure as a Service, Platform as a Service and Software as a Service).

The public cloud is a cost-effective solution for educational institutions to use quality services with guaranteed support. The private cloud offers utilization of available technical resources and developed network infrastructure, higher level of data

security and provides only specific services needed by the organization. The community cloud, used by several educational institutions, offers qualitatively and quantitatively comparable information services to consumers [22].

Cloud computing offers an infrastructure, platform and educational services and applications to educational institutions [23].

**Infrastructure as a Service (IaaS)** is a model of providing computer infrastructure. IaaS allows users to rent computing resources according to their needs, avoiding the necessity to buy hardware components. Payment is based on consumption and there is an opportunity for elastic scaling of rented resources. Users are able to run different software packages (including operating systems). The provider manages and controls the cloud infrastructure, while the user has control over the applications [4].

The opportunity to rent computing resources that can be elastically scaled in case of changing needs is essential for educational organizations. They can benefit from rented computing resources to provide the educational process in IT disciplines that require the availability of appropriate infrastructure. Data processing in various research projects also requires powerful computing resources. Cloud computing can facilitate the process of creating IT laboratories for data processing and analysis. After the completion of the project work or semester, the rented facilities can be released quickly and easily.

IaaS model is particularly suitable for educational institutions that have limited budgets for building and maintaining IT infrastructure and insufficient qualified staff for its management. By Infrastructure as a service, even small schools and universities can be competitive in terms of quality of educational services.

**Platform as a Service (PaaS)** is a model to provide a platform and environment for the development and implementation of web and mobile applications. The main advantage of the model is that the components of the environment are pre-configured and maintained by the service provider. The developers can focus on the process of creating of services and applications without obligations to manage the environment.

PaaS model is particularly suitable for educational institutions that offer training in IT disciplines. PaaS provides opportunities for creating and providing a development environment where learners can develop, test and deliver various applications and services. Platform as a Service allows teachers to focus on the learning process instead of on maintenance and management of the environment.

**Software as a Service (SaaS)** is a model where software applications, provided by vendors, are used as services. This model significantly changes the way applications are used: users do not have to purchase a license to use the software; they do not need to install it on local computers and maintain it which saves time, effort and money.

SaaS model is extremely beneficial for educational institutions, since it enables them to work with a variety of software products, experiment with new applications without additional purchase costs, paying only for actual use. The applications are available and accessible from different user devices via web browser at any time and place. Teachers and learners always have the latest

version of the software, there is no need to maintain, control and manage the applications, since it is the responsibility of the service provider. This allows educational institutions to save money for hiring qualified IT staff to manage and maintain applications.

Educational institutions are initially attracted to the SaaS model, since it offers opportunities to use a variety of applications and tools for collaboration, communication and data storage. In most cases, SaaS services are free for schools and universities or are offered at a lower price. Many educational institutions start with cloud office suites and cloud based data storages. Some of the applications offer integration between both types of services.

## V. CONCLUSION

Cloud computing supports the implementation of various forms of electronic, distance and blended learning. It is extremely popular due to the penetration of ICT in education and has significant advantages over traditional forms of education.

One of the main reasons for the transition to a cloud computing model is that the traditional forms of e-learning require significant investments for establishing an adequate IT infrastructure, maintenance and upgrade costs, and funds for highly qualified IT staff to operate and manage it. The increased costs combined with reduced financial resources urge educational institutions to seek solutions to overcome existing constraints and to provide conditions for effective learning process, consistent with the new educational trends and paradigms.

Cloud computing has essential economic advantages but it also ensures comprehensive access to modern ICT for a wide audience at any time and place, from different devices, which is a prerequisite for the realization of lifelong learning. Available IT equipment can be fully and effectively used and at the same time there are opportunities for renting and using powerful computing resources as needed. Using cloud services, educational institutions can focus on their primary activities: teaching and research, and perform them in the most efficient manner.

Cloud computing is extremely important and necessary for modern education. It offers an infrastructure, platform and educational services and applications, which create affordable and innovative learning environment. Participants in the learning process have continuous access to diverse, high-quality educational resources and activities, they can interact and work together, which improves the quality of education.

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Other educational organizations build their e-learning environment (Learning Management System, Learning Content Management System or Virtual Learning Environment) based on cloud computing, achieving a high quality of services and reducing the cost of management and maintenance of the systems. More cloud service providers offer applications specifically designed for educational purposes and in accordance with modern trends and paradigms in education, taking into account the active role of students and cooperation in the learning process.

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