The Value of Cloud-Based Learning Environments for Digital Education

Patrick Wolfschwenger*, Birgit Albaner†, Oliver Kastner-Hauler‡ and Barbara Sabitzer§
*Department of STEM Education, Johannes Kepler University, Linz, Austria, ORCID 0000-0001-5325-0511
†Department 6 - Media, University of Education Carinthia, Klagenfurt, Austria, ORCID 0000-0001-5592-2932
‡Department 4 - Media, University of Education Lower Austria, Baden, Austria, ORCID 0000-0002-9958-3298
§Department of STEM Education, Johannes Kepler University, Linz, Austria, ORCID 0000-0002-1304-6863

***Abstract*—This work-in-progress paper deals with the adoption of cloud computing in the education sector. In the past few years, the use of cloud-based teaching and learning environments has substantially increased. Many well-known applications have been enhanced with cloud features, but also completely new tools have emerged. This paper investigates the kind of educational tools that can be expected from the ongoing trend and are not feasible with traditional techniques and discusses potential contributions of cloud computing to the development and implementation of current digital education concepts.**

I. Introduction

In the last two decades, cloud computing has emerged as a new paradigm for delivering computer system resources over the network and is nowadays widely accepted as a technically mature and powerful technology. It is based on the idea that, rather than each organization being set up with its own computing devices, computer system resources can be pooled and shared via the Internet or other computer networks. The use of cloud-based applications is rapidly increasing throughout all organizations, regardless of industry and size.

Educational organizations have also made their first movements to the cloud [1]. Advantages of cloud computing can be seen in teaching and learning as well as the management of educational institutions. Particularly, cloud-based learning environments hold great potential for providing support for modern digital education concepts. By now, there is a wealth of literature available on the adoption of cloud computing in education, whereof an overview is provided by three recently published systematic literature reviews (SLR) [1]–[3].

Qasem et al. [3] claim that most of the literature on cloud adoption in education today is limited to individual perspectives. The phenomenon needs to be placed in a wider context to get a glimpse of how cloud-based applications can support educational concepts on an organizational and national level. This literature review has facilitated further investigation into those organizational aspects.

II. Background

In order to distinguish between cloud computing and conventional IT outsourcing and similar technologies, we want to begin with stating the meaning and limits of cloud computing. A widely used definition was issued by the National Institute of Standards and Technology (NIST), which defines cloud computing as "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] In the following, we would like to expand on this definition, which distinguishes five essential characteristics, four deployment models, and three service models [4].

A. Characteristics

On-Demand Self-Service enables consumers to independently and almost automatically obtain and release computer system resources without the need for human interaction with a cloud provider. *Broad Network Access* is the byword for resource use via the Internet or another computer network; standardized interfaces provide access for a large number of client devices such as laptops, tablets, smartphones, etc. *Resource Pooling* means that a cloud provider serves multiple consumers at the same time based on a multi-tenant model. *Rapid Elasticity* allows consumers to quickly scale outward and inward based on demand. *Measured service* signifies that the individual resource consumption is continuously monitored and recorded, for the sake of transparency and in order to enable usage-based billing of the resources used.

B. Deployment Models

Four different deployment models represent the specific types of a cloud environment, mainly distinguished by ownership and size. A *Public Cloud* is intended to provide services to the general public. In a *Private Cloud*, services are only offered to a closed organization and its group of people. A *Community Cloud* provides a platform for members of several organizations and is premised on uniform interests of the organizations. A *Hybrid Cloud* refers to an association of two or more deployment models already listed and described.

C. Service Models

A distinction is made between three fundamentally different service models, based on the resources provided and the degree of abstraction they present to the consumers. *Infrastructure-as-a-Service (IaaS)* describes an IT environment providing computer, storage and network capacities. These resources can be used to install and configure operating systems as well as software. *Platform-as-a-Service (PaaS)* makes it possible to

manage and deploy self-programmed or purchased applications in a hosting environment, while the underlying infrastructure is operated and maintained by the cloud provider. *Software-as-a-Service (SaaS)* relates to any kind of software that is hosted on cloud infrastructure and managed by a cloud provider. The consumer is not responsible for the installation and administration of the software, but only accesses the resources via a client device.

III. Methodology

By conducting a literature review, we would like to lay a foundation for evaluating the relevance of cloud-based learning environments. On the basis of the aforementioned SLRs [1]–[3], we have started our explanatory investigation into the potential impact of cloud-based applications on prospective educational scenarios. We examine the benefits and drawbacks of cloud computing infrastructures and draw a parallel with server-client-like models. The results are discussed in the context of overarching educational concepts. Existing literature has been synthesized to become aware of potentially seminal teaching and learning concepts. We presume that the current trend of virtual teaching and learning will develop further and that the significance of time- and location-independent educational methods will increase. This work should help researchers and practitioners to understand the relevance, potential and challenges of using cloud-based infrastructures in digitization projects and contemporary educational settings.

IV. Results

In educational institutions, stakeholders of cloud computing can be found on all levels. Cloud computing concerns the whole organization, students, teachers as well as the IT staff, management and administration. Strengths and limitations refer to the learning and teaching process alongside the broader areas IT economics, technology management and operation – not evenly spread amongst all stakeholders.

Opportunities for instruction lie in enhanced availability of online applications, support for mobile learning, flexibility and simplicity to create learning environments, and computing-intensive support [1]. IT staff, developers of learning platforms and educational institutions benefit from reduced complexity and cost savings associated with the operation of software and hardware. Drawbacks of using cloud services are mainly seen in the area of security and data privacy.

Students benefit from easier communication and the sharing of resources with access and synchronization amongst all kind of devices and institutional platforms. Stable *Quality of Service (QoS)* being perceived over long periods leads to enhanced availability for learning beyond boundaries (time of day, devices and institutions). Personally tailored learning environments based on SaaS [5], [6] are increasingly available for students without in-depth technical skills allowing them to focus on assignments instead of complex and time-intensive configuration tasks. No extra licenses are needed when applications are accessed on campus, at home or somewhere else. However, students who lack Internet connectivity, access devices or other resources may be left out.

Teachers are able to use new learning scenarios and more collaborative teaching methods. Packaging of pre-configured computing environments with all needed resources increase the use of complex lab environments. Nearly unlimited learning scenarios as discussed in [7] emerge – 24/7 availability with just-in-time launched computing resources using PaaS or IaaS clouds. Learning use cases with need for intensive computing support like heavy simulations, multimedia processing or learning analytics will be realized more broadly, especially in higher education fields.

Cloud computing provides support for time- and location-independent learning activities. Many of today's applications are web-based and accessible via the Internet so that educators and learners can use them without the need to install a specific program or going to a specific place. For example, file storage and document collaboration enable learners to maintain their digital data and collaborate on exercises, group assignments and presentations.

With cloud computing, remarkable success has been achieved in conducting virtual learning labs. Teachers can easily and quickly set up, for example, virtual desktops with pre-established applications that students can use for hands-on assignments on computer networks [8]. When extensive computing resources are required for the duration of a workshop, they can be easily set up and reserved for that time via a cloud computing platform. Cloud services have proven to be a great help, especially with regard to conducting computer-intensive courses.

Even so, cloud-based learning environments cannot fully compensate a lack of expertise in instructional delivery through online methods. The setup and use of standard cloud services is not highly demanding, but the creation or adoption of a scenario that is not pre-fabricated by templates requires highly specialized skills. Teachers need to have an intrinsic motivation to use online learning opportunities. Given sufficient access to devices, teachers' individual attitudes and skills determine the successful integration of digital technologies in the first place [9]. The availability and easy accessibility of public clouds reduces the barriers to digital tools, but cannot fully remove them nor provide a stimulus to use these cloud services.

IT staff of organizations using public or community cloud services faces reduced maintenance and installation costs and efforts [10]. Necessary up- and downscaling of computing resources can be easily managed, which enables application development without scale concerns. Consolidated resource management leads to better utilization and a lower workload.

As cloud service providers are required to maintain and secure their infrastructure with great technical and financial effort, the operation of private or hybrid clouds in educational organizations is rarely found. Introduction, maintenance and further development of cloud environments are complex and demanding tasks. Disadvantages for organizations that do not operate their cloud themselves include dependence on the

provider and the risk of loss of control and data [11].

Educational institutions benefit from pre-configured lab environments and standardized libraries that teachers and courses of several organizations can share among each other. Without investing in and managing overprovisioned infrastructures, highly variable, demanding services can be offered [12]. Hardware investment costs can be spread proportionally and more evenly over time due to small upfront investment costs and payment models reflecting actual use. Through free or pay-per-use applications, purchasing too many or not enough licenses can be avoided. The dynamic cost structure still requires consistent oversight and monitoring.

The ability to handle growing or reducing resources has been one of the key drivers of cloud computing's fast-paced evolution. In a cloud, computer system resources can be scaled upwards and downwards within short periods of time to meet individual demands in a timely and capable manner. Dynamic resource allocation models allow to peg available resources to actual demand and provide an effective solution to benefit from scalability [13]. Thereby, occupation and costs of idle resources can be notably reduced, which makes the operation of hardware and software much more efficient in the cloud. In turn, computing resources can be offered at lower costs for the individual organization [14]. Cloud service providers must be able to handle peak periods without significant performance loss.

With cloud platforms, organizations can significantly reduce their workloads. Cloud providers maintain software and hardware components, make regular updates and take care of system security. The QoS is typically agreed upon in *Service Level Agreements (SLA)*, which are contracts between a cloud provider and a consumer. For example, these SLAs regulate the availability of systems, the speed of data transfer and the response times of interfaces, or the time span within which a provider must react to problems and a cloud system can be switched off for maintenance work [15]. A breach of the agreed terms can result in high monetary losses for the cloud provider and can negatively impact their reputation [16].

Organizations that employ cloud services need to have a comprehensive cloud strategy in place. When employing cloud services, the question of how to handle sensitive, organization-related data also arises. Contracts need to be established ensuring that the cloud service provider as a data processor implements appropriate technical and organizational measures to protect the rights of the data subjects. Even if the processing is shifted to a contract data processor, the organization is still responsible for claims by affected individuals in case of data leakages.

V. Discussion

The demands placed on individuals to function in society have substantially changed over recent years. The digital revolution has transformed many aspects of contemporary life and impacted both work and leisure structures. The Internet has become an established mass medium, the smartphone a ubiquitous presence. Computerization and automation have permanently altered or replaced jobs, but have also created new occupational profiles such as data analysts and software developers [17].

Wide ranges of interactions have been created and complexity and dynamics have increased. It can be assumed that modern work tasks, especially in the field of knowledge and project work, require the simultaneous use of multiple interdependent competencies. In its educational initiative "Innovating to Learn, Learning to Innovate", the OECD therefore calls for targeted educational concepts to promote 21st century skills in schools and universities [18]. It is about a new emphasis on skills such as independent knowledge acquisition, critical thinking, creativity, cooperation and networking. Informal forms of learning, problem-oriented learning and project work come to the forefront [19]. The Internet, or the advance of digitization, has thus led to the development of new formats in teaching. There are many cloud-based alternatives for disseminating learning content: Massive Open Online Courses (MOOC), E-Books, Interactive Teaching Resources etc. They are available everywhere around the clock and are individually tailored to the needs of learners (modularized offer, learning speed, real-time feedback etc.). Even the possibilities of *Formative Assessment* can be efficiently exploited with cloud-based tools. E-learning offers can thus be made available globally. Learning games open up undreamt-of possibilities to make learning more attractive and create long-lasting educational success due to their procedure and process of learning.

For the opening of these new teaching/learning rooms, it is essential to have the necessary skills and to develop new didactics. Underlying digital competences can therefore be described as core competencies of the 21st century [20], [21]. Education programs promoting the development of digital literacy are emerging all around the world and are being integrated into the curriculums on all educational levels, especially K-12. As the digital part in teaching and learning grows, so does the need for reliable, cost-efficient and flexible tools. Cloud computing platforms offer an outstanding opportunity to support and streamline the accessibility of such tools by providing computing as a commodity and can be very helpful for the implementation of modern teaching and learning models that rely on the integration of digital media.

Cloud applications have apparently overtaken single server solutions in many aspects. A large part of SaaS providers seems to perform automatic updates and make new components and functionalities instantly available. Resource supply is almost unlimited, especially in public clouds, and can be aligned with actual demand of the users. Cloud computing eliminates high investment costs for server hardware, as services are charged on a pay-per-use basis. Resource bundling makes it easier for cloud providers to offer professional operation and maintenance of IT resources and support around the clock.

However, cloud computing may also bring new problems and challenges with it, compared to on-premises solutions. Appropriate access devices as well as a fast network connection to

the cloud are important requisites for its use. Whereas the use of public clouds necessitates high speed Internet connection, on-premises solutions only require a connection to the server on the intranet. As cloud providers want to bring their software to as many users as possible in an unchanged or only slightly individualized form, cloud solutions are usually more standardized than their on-premises equivalents. When using cloud services, an organization is usually dependent on the cloud provider in terms of data security and availability. Educational institutions retain control when maintaining servers on their own premises.

A pilot project was launched in Austria in the 2017/18 school year with the goal to introduce a compulsory digital literacy subject in lower secondary schools. A new curriculum has also been applied since the 2018/19 school year. The nationwide implementation is currently in progress. The didactical use of digital technology is strongly supported at a legislative level in Europe [22]. In this context, a cloud computing platform could help to create, manage and deliver services, content, applications, and workflows and alleviate the burdens imposed by infrastructures on institutions' own premises. Cloud-based digital learning infrastructures have been endorsed under Horizon 2020 [23].

E-learning has encouraged the development of new forms of teaching and learning, giving students greater control over what and how they learn, and has also extended education beyond classroom boundaries. A major value of e-learning lies in the ability to train anyone, anywhere and at any time [24]. Combining e-learning with cloud computing helps to overcome networking, processing and storage limitations. It can increase the variety of available digital tools for teaching and learning, enhance the way students work and effectively support collaboration and mobile learning. Cloud-based learning infrastructures that enable educators to create and deliver educational content provide a good basis to exploit personalized and experimental learning opportunities.

Cloud computing platforms provide considerable support for computer-intensive e-learning applications. Computing efforts of video streaming, simulations and virtual worlds are typically high, the amount of processed data is steadily increasing. MOOCs in particular require high amounts of computing resources. The load factor fluctuates strongly, depending on the time of day, season and other circumstances. A cloud can provide the needed computing resources in a scalable and flexible way.

In the digital age, providing highly available and reliable digital services to students is very important. Modern educational methods are closely interwoven with digital technologies like learning management systems. A lack of access to them has a negative impact on student performance. Cloud computing promises a significant increase in the availability of digital tools compared to self-hosted solutions. Most cloud providers ensure a high uptime rate through cloud clusters that combine a number of physical, often geographically distributed, hardware resources [25].

The resources and infrastructures that are needed to run e-learning tools are not available in all educational institutions. High efforts in obtaining the necessary computer system resources is a major obstacle to the adoption of modern teaching and learning approaches and innovation in the education sector. In case resources are only needed for a short period of time, like in computer network, programming and other computing-intensive courses, purchasing and installing the hardware and software components in a traditional sense would require high efforts and costs. Cloud platforms can help education providers to get the required resources easily, quickly, on-demand and exactly for the time they are needed, without worrying about the underlying infrastructure.

The use of cloud-based *Artificial Intelligence (AI)* in conjunction with self-driven online-learning is highly promising for the future of individual learning. An AI learning-buddy will guide the student through learning pathways and help prepare for exams with special regards to low scoring areas from previous exercises.

VI. Conclusion

Cloud computing has massively contributed to the evolution of the many digital learning offerings available today. Learning materials can be made available in online learning platforms, synchronous conference dates can be used for meetings, groups can exchange information in forums and work together on documents and wikis. Learners are encouraged to reflect on their learning progress in learning diaries and write their experiences down in a blog. Even longer absences from the classroom can be easily managed with online learning and conferencing platforms, and it is possible to maintain acceptable teaching conditions and stay in touch with students during longer periods of virtual learning. The focus of in-person meetings is set on presenting results, personal exchange and reflection. This combination of media-supported learning with face-to-face elements links online-interaction with integration into a social group supervised by a teacher and can thus increase motivation and retention.

The influences of cloud computing on the development and dissemination of learning environments raise various questions about the future and lead to a confrontation with numerous challenges. Thoughts need to be given to the central organization of cloud infrastructure, coordination among institutions and resource units, adaptation of IT governance frameworks as well as strategical, security, data protection and other issues within institutions [26].

The conclusion that learning processes and learning pathways are becoming more and more digitalized results in higher demands on learners and educators. ICT-literacy will be highly important when using cloud-based learning and teaching environments in a productive way. Furthermore, intervention, adaption and modification of the steering parts in cloud education need oversight and awareness for the big picture on part of the teachers. Knowledge about and the use of computational thinking skills are essential success factors for both learners and educators.

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