Cloud Adoption and Digital Transformation in the Context of Education: A Phenomenological Study

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***Abstract*—The purpose of this Research Full Paper is to systematically collect and evaluate the experiences of learners, instructors, decision-makers and IT employees of educational organizations of the secondary and tertiary sector who have been involved in cloud and ubiquitous technology adoption processes. It contributes to a better understanding of how digital transformation in educational organizations takes place, how ubiquitous access to cloud-based tools can be established within educational structures and what effects the use of cloud and ubiquitous technologies has on pedagogical work. We investigate educational use cases of cloud and ubiquitous technologies as well as their technical and practical requirements and examine adoption strategies pursued by educational organizations, the challenges faced and how to cope with them. In addition, we examine the role cloud and ubiquitous technologies have played in efforts to maintain instruction in times of Covid-19.**

***Index Terms*—Cloud Computing, Ubiquitous Computing, Digital Transformation, Education**

I. Introduction

Cloud computing has been experiencing constant growth since the early 2000s regardless of industry and application area [1], and has opened up many possibilities for the education sector. It provides organizations, instructors and learners with tools to deploy computer system resources on-demand and alleviate the burdens imposed by local infrastructures [2]. Its rising penetration of the markets, popularity in the software industry and maturity level encourage a critical exploration of cloud service integration into educational organizations.

The cloud computing paradigm is based on the idea that, rather than each organization being set up with its own computing devices, computing resources can be pooled and shared via the Internet or other network technologies [3]. Consumers of cloud services are provided with on-demand network access to a shared pool of configurable computer system resources, such as servers, storage, networks and applications, which can be commissioned and decommissioned with minimal effort [4]. The scope of services offered in the cloud almost covers the entire spectrum of information technology [5].

Access to cloud services is highly dependent on how organizations adapt to the demands of a cloud environment; users can only benefit from the variety of cloud services available when having the opportunity and rights to utilize them [6]. Ubiquitous access is closely linked to the concept of ubiquitous computing, which denotes a vision of embedding computers and communication in human surroundings to build an environment where seamless access to computing resources is provided to the user [7]. Cloud computing has greatly supported the development of ubiquitous computing by providing an outsourcing option for demanding computation tasks and centralization of information [8].

The digitization has brought about fundamental changes in the practice of learning globally and transferred education beyond classroom boundaries [9]. Despite the potential that digital technologies offer in a wide variety of areas, the increasingly technical and networked environment also brings challenges with it that are apparent on a variety of levels. In the recent past, the focus of software development has shifted from standalone toward service-oriented architecture in combination with cloud computing [10]. Increased computation power, network speed and data volumes underpin the emergence of digital innovations such as artificial intelligence, virtual and augmented reality, and the Internet of Things. This work contributes to a better understanding of cloud and ubiquitous technology adoption processes in educational organizations by giving insight into the experiences of stakeholders of the secondary and tertiary sector.

II. Theoretical framework

A. 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]. Details of this definition provided by the National Institute of Standards and Technology (NIST) are summarized in Table I.

Three systemic literature reviews gather a range of educational use cases on how to apply cloud-based tools in various educational scenarios [11]–[13]. Many of today’s achievements in education would not have been possible without the recent developments in cloud computing. The technical possibilities opened up have significantly extended, and can further expand the scope of many educational tools and support the creation of virtual learning environments [2].

The need of cloud environments has also been acknowledged at a legislative level in the European Union (EU).

TABLE I
CLOUD COMPUTING CHARACETRISTICS, DEPLOYMENT MODELS AND SERVICE MODELS [4]

Characteristics	Self Service	• Unilateral provision of resources • No need for human interaction
	Broad Network Access	• Services available via the Internet or other computer networks • Access through standard mechanisms and interfaces
	Resource Pooling	• Multiple consumers are served by a service provider based on a multi-tenant model • Resources are dynamically allocated based on consumer demand • Consumers are unaware of the exact location of provided resources, but location can be contractually limited to a region, country, data center, etc.
	Rapid Elasticity	• Quick and in some cases automatic provision of services • Consumers can scale rapidly outward and inward
	Measured Services	• Resource use is metered • Automatic control and optimization features • Transparency for both consumers and service provider
Deployment Models	Public Cloud	• Services can be used by the general public • Physical resources are housed off premises • Owned and managed by a business, academic, or government organization
	Private Cloud	• Operated only for a certain organization • Managed by the organization itself or a third party • Located in the data center of an organization or a foreign institution
	Community Cloud	• The same infrastructure is shared by several institutions with similar interests • Operated by one of these institutions or a third party
	Hybrid Cloud	• Combination of different cloud infrastructure types (public, private or community) • Bound together by connections via standardized interfaces
Service Models	Infrastructure as a Service (IaaS)	• Consumers can rent the most basic resources (e.g. operating systems, runtimes) • Responsibility for virtualization, server, and network lies with the service provider
	Platform as a Service (PaaS)	• Consumers can host own applications via a hosting environment • Control is limited to the deployed applications and a range of configuration options for the hosting environment
	Software as a Service (SaaS)	• Consumers can lease applications hosted on a cloud infrastructure • Applications are accessible through a thin client interface or a program interface • Almost everything is managed by the service provider (e.g. applications, operating systems, runtimes, servers, etc.)

New cloud technologies, services and solutions are constantly emerging, fostering the development of a digital single market in Europe. Currently, however, the market is fragmented and characterized by the lack of a common cloud culture. The Horizon Cloud project ("H-Cloud") funded by the EU aims to address this issue by establishing a sustainable forum for stakeholders to develop a shared vision of the future of cloud computing in Europe [14]. The project contributes to the realization of the potential of cloud computing and supports the development of a digital single market.

Despite increasing activities in research in the last couple of years, cloud computing has only been marginally exploited in the education sector so far [11]. In the light of sweeping data privacy regulations, wide-ranging transformation requirements and other circumstances, a range of challenges associated with the adoption of cloud services are prevalent [15]. Educational organizations are supposed to be flexible and adaptable to new digital education concepts, offer a variety of digital tools, guarantee high availability and robustness and have a powerful IT infrastructure in place, while at the same time being liable for the security and privacy of student data and keeping costs under control. When making cloud adoption decisions, education providers need to consider the interplay of various technical, legal and economic factors [15].

B. Ubiquitous Computing

Ubiquitous computing does not refer to a concrete technology, but to a vision of ubiquitous data processing and use of information systems in an environment where intelligence and computing capabilities are seamlessly embedded into everyday objects and there are neither significant operating requirements nor hardware burdens for the user [7]. The essential characteristics of ubiquitous computing include the decentralization and modularity of hardware components, disappearance of a significant human-computer interface, the adaptivity and smartness of the systems, the self-organization and contextual perception, the broad applicability and the action-relevant linking of local and global information [16]. Ubiquitous computing, which assumes a one-to-many relationship between user and devices, subsumes traditional computing paradigms including desktop and mobile computing [17].

The goal of ubiquitous computing is the assistance of people through embedding computing power in the everyday physical world, in objects of daily use, completely permeating the life of the users [18]. The ubiquity of information technology and computing power evokes a promising vision of improved quality of service and efficacy of processes in any area of human life. Digital assistants become incorporated into the world around us, performing services for users, providing them with proactive support in day-to-day tasks, doing most of the work without human intervention, but individuals can still interact with them; for example, to set them up, give them instructions or access data [19].

Interactions with ubiquitous technologies happen through multiple, dynamic and distributed interfaces [20]. Ubiquitous interactions are intuitive when resembling interaction with the physical world [21]. If information technologies fade into the background, users are able to sense and control what directly interests them. Constantly monitoring the users' environments, ubiquitous systems may act almost invisibly as virtual agents in the background of our field of activity and perform context-aware computing and natural interaction [19]. This kind of ubiquity is also reflected in a large number of similar concepts, such as pervasive computing, ambient intelligence and the Internet of Things.

In multi-agent systems, devices only have partial information, communicate with other related components and act on the information they get from one another [22]. Due to the trend towards mobile devices and the associated limitation of computing power in those devices, the majority of ubiquitous systems is connected to a cloud in the background in order to centralize information in a single point of truth and perform demanding computing tasks for the users [23]. The computing requirements are high, especially in the areas of artificial intelligence, machine learning and data processing.

Under ideal conditions, every device should be able to connect and fully exploit the possibilities of the cloud. In reality, ubiquitous access is constrained by device support restrictions, organizational restrictions as well as lack of access devices. Lack of access devices refers to the unavailability of technologies for each individual. Organizational restrictions refer to constraints stemming from strategic orientation, IT governance and compliance policies, resource scarcity as well as legal provisions [15]. Device support restrictions result from the absence of interfaces and the fact that services are usually designed for specific devices [23].

C. Digital Transformation

Digital transformation is the active change in response to changing framework conditions as a result of digitization [24]. Progress in digital technology is continuously transforming the way in which people live, learn and work. The digital revolution has brought about significant and beneficial changes in many aspects, but there are also downsides and risks involved with the current trends. Three levels of change can be distinguished within digitization processes [25], [26]:

- *Integration* - New technologies are incorporated into proven routines without substantially affecting the underlying practices. One example is sending emails instead of letters.
- *Modification* – Conventional practices are significantly altered or extended by new technologies. News agencies, for example, have tapped into web presentation and social media to better reach their audience.
- *Transformation* – New technologies trigger revolutionary changes disrupting traditional structures. For example, the rise of online shopping has led to massive reductions in offline stores.

Digital transformation is closely related to Educational Technology, which denotes "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" [27]. It encompasses any technological approach that can support learning and teaching processes, including all technological tools and media that assist in the communication of knowledge, its development and exchange [28].

III. State of Research

Cloud computing is a relatively young, but heavily discussed research area. Firstly, enhancements are being achieved in the technical realm concerning the provision of cloud services. Secondly, the adoption of cloud concepts in specific areas like the education sector are discussed. Thirdly, many other disciplines also border on this influential topic, and research is conducted from various standpoints.

Cloud computing is widely recognized as an increasingly powerful, eco-friendly and technically grown technology, which is empowered by virtualization and automation, utility and grid computing, and web services [29, p. 26]. The degree of maturity is already at a high level, and yet further development opportunities are being explored and exploited. Currently heatedly discussed research topics include data security and privacy, mobile computing, handling of big data, optimization of resource utilization, and networking and virtualization techniques [5], [30].

For the adoption of cloud computing, NIST provides a reference architecture that is intended to be applicable to all types of organizations and all industries [31]. However, it is not specific to the framework conditions of the education sector. In education, cloud services are used for both reliable operation of information systems and experimentation in the classroom [12]. Cloud services can simplify access to digital tools, content, applications and mobile learning, enable the flexible creation of learning environments and improve efficiency of computing-intensive exercises [2]. Most of the literature on cloud adoption in education today is limited to individual application scenarios, neglecting overarching organizational conditions [11].

The rapid growth of cloud computing encouraged intense research also in several adjacent fields. Jurists focus on legal issues related to the use of cloud computing in organizations, including data protection, liability, contract design, exit management, and other issues [32], economists deal with financial and managerial issues [10]. Due to the young age of the technology, recently introduced regulations and the resulting lack of empirical data, many aspects have still only been studied sparsely; a lack of precedents and empirical knowledge leads to a higher degree of uncertainty with regard to strategy, security, etc. [33].

Ubiquitous computing was coined by Mark Weiser in the early 1990s to describe a future in which invisible computers, embedded in everyday objects, replace desktop computers [7]. Many visions have emerged and been discussed in the research community since then [19]. In contrast to desktop computing, ubiquitous computing can occur using any device, in any location and in any format [23]. The computer exists in many different forms, including laptops, tablets and terminals in everyday objects. Mobile computing, which refers to the execution of computing tasks without having to be connected to a fixed physical link, has given rise to a new class of context-aware computing [34]. Challenges in ubiquitous computing include the design and implementation of technical facilities, the integration of connected devices in our living spaces as well as the definition of smart environments [8]. As time has progressed, measuring the current state of development and permeation of our world with ubiquitous technologies has come into the spotlight [35].

Digital technologies have not only impacted work and leisure, but have also brought about fundamental changes in the practice of learning globally by making it possible to transfer education beyond classroom boundaries and giving students increased control over their individual training and learning [9]. Digital technology adds value to both the learning process and the organization of educational institutions. There has been a range of research concerned with the digital transformation of education [26], [36], [37]. The abrupt transition from traditional to online instruction caused by the Covid-19 pandemic has had an accelerating impact on the digital transformation of educational institutions worldwide [33].

TABLE II
DRIVING QUESTIONS FOR THE SEMI-STRUCTURED INTERVIEWS

Area	Questions
Cloud Computing	Which services do you know or have you used so far? What strategies exist in your organization? How secure do you think cloud platforms are? What legal and ethical concerns have been raised? What IT governance frameworks are in place? How has the corporate culture adopted cloud computing? What are your experiences with migrating legacy systems? What is the business perspective on cloud computing?
Ubiquitous Computing	What devices do you use regularly, either private or professional? How do you experience the use of technologies in the classroom and online? How do you assess the availability and accessibility of technologies in your institution? What are the application areas for these technologies? What applications do you use with these technologies?
Digital Transformation	To what extent has digitization changed your workplace? How do you assess the progress of digitization in your institution? How has the Covid-19 pandemic impacted teaching and learning? How does your institution promote the use of new technologies in the classroom? What needs to be improved in the curricula?

IV. Methodology

This work seeks to explain how cloud adoption processes in educational organizations take place, how ubiquitous technologies and cloud-based tools are used for educational purposes and in which directions the trend is moving. To this end, we examine educational use cases of cloud and ubiquitous technologies as well as their technical and practical requirements, scrutinize adoption strategies pursued by educational organizations, the challenges faced and how to cope with them. Additionally, this work examines the role cloud and ubiquitous technologies have played in efforts to maintain instruction in times of Covid-19.

Phenomenological research is used to describe the meaning of experiences of a phenomenon for several individuals, which in this case are the experiences with cloud adoption and digital transformation made by relevant stakeholders of educational organizations. The phenomenological researcher reduces the gathered experiences to a central meaning, with the goal of understanding the essence of the experiences.

Hermeneutic interviews were conducted to examine the interpretive meaning of lived experiences [38]. The application of thematic analysis for data interpretation seems convincing with regard to the objective of this research work. Data was evaluated to identify patterns of themes in the interview data. The process of data analysis was aligned with the guidelines of Braun and Clarke [39]:

1) Familiarizing with the data
2) Generating initial codes
3) Searching for themes
4) Reviewing themes
5) Defining and naming themes
6) Producing the report

To use phenomenological interviews effectively, it is essential that the interviewer has identified participants who have both experienced and are able to talk about the particular lived experience under examination [38]. Learners, instructors, decision-makers and IT employees are the four major actors playing key roles in educational digitization processes [2]. Table II lists the driving questions for the interviews. The questionnaire has been aligned with their roles and responsibilities in the overall organizational context. Ten semi-structured interviews, with five individuals from the secondary sector and five individuals from the tertiary sector, were conducted in Austria. Each interview lasted approximately 30 minutes. Figure 1 shows the thematic map that was devised from the collected data.

V. Results

A. IT Management and Operations

For a long time, IT custodians at schools had been required to be generalists and specialists in one person. Their duties included the administration of the IT infrastructure, installation and maintenance of client devices, servers and web services, planning and conception of future development and documentation as well as support and consulting of administration and pedagogical staff regarding the use of hardware and software. They needed profound knowledge and skills in the areas of operating systems, server technology, computer networks, authentication methods, security and monitoring, identification and resolution of hardware failures, data backup as well as IT support and advisory. In a dynamic and growing IT environment, all those tasks could no longer be expected from a teacher who is actually employed as an educator.

With the reorganization of the IT custodianship a couple of years ago, IT management has significantly changed in the

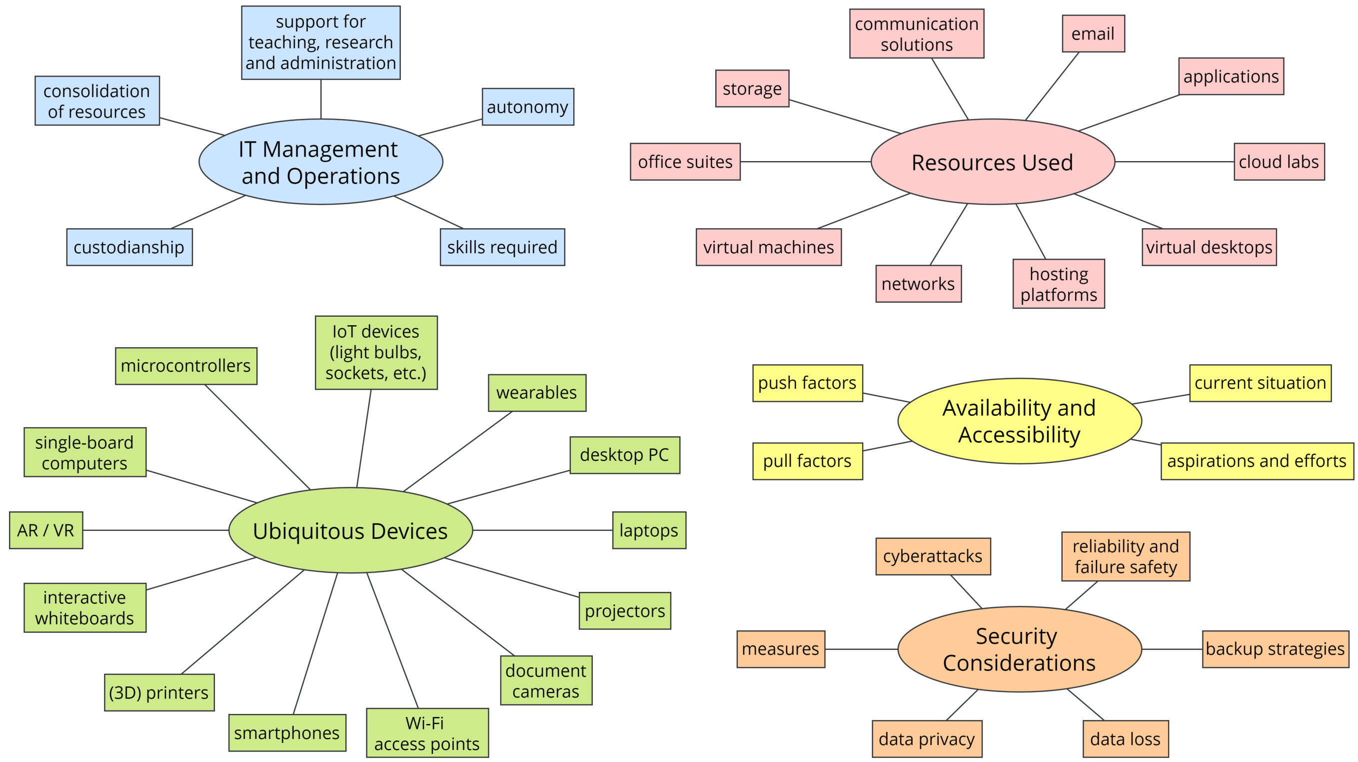

Fig. 1. Thematic map devised from the collected data.

secondary sector. Installation and maintenance of client operating systems, networks and hardware are now performed by an independent system administrator who is responsible for several schools in regional clusters. Pedagogical-organizational activities, such as advice on pedagogical questions regarding the use of digital media in the classroom and organizational support of classes with digital devices, are still carried out by a teacher within the framework of the IT custodianship. External service providers are engaged for more complex services in the areas of network, server and IT security.

While schools used to manage their applications and infrastructure fully independently, efforts are made by the ministry and educational directorates to set up shared infrastructure and services comparable with a community cloud. For the technical support of the digitized learning process, a central platform with single sign-on functionality for all essential applications has been introduced. Its goal is to support employees, teachers as well as pupils and their guardians with consolidated and clear information and easily accessible tools. Various applications, such as learning platforms or the digital class register, have been introduced and can be consumed as a managed SaaS service. The centralization of IT resources is intended to enable better cooperation with the IT departments in the educational directorates, ease the technical burdens on schools and their IT staff and foster more flexible development and implementation of innovations, strategic projects and operational measures as well as more effective use of IT resources.

Tertiary educational institutions such as universities and colleges are typically larger in size and have their own IT departments that provide infrastructure and digital services for teaching, research and administration. The demand for IT services is more complex, as they are usually provided for far more users from various groups, including students, course instructors, researchers, faculty members and administration. The digitization of research and teaching, the modernization of legacy systems and applications, and the exploration and application of new technologies drive the need for secure, stable and scalable IT environments. Particularly, research and teaching projects on future topics such as artificial intelligence and big data require high-performance computing infrastructure.

Organizations of the tertiary sector predominantly rely on the use and further expansion of on-premises infrastructure, although licenses are increasingly issued for cloud applications as well. These include less data-intensive applications such as office suites or video conferencing systems. The protection of IT networks and computer systems as well as the processed data to guarantee information security without violating data protection rights is a central issue. The tertiary sector is increasingly moving more in the direction of private clouds, with public cloud services also being used where appropriate.

In the tertiary sector, educational institutions have greater autonomy regarding the use of IT services, as they are not bound to a superordinate directorate, in contrast to schools. Technology assessment is the responsibility of the tertiary organizations themselves. Thus, there may be partial differences in interpretation between various educational institutions. The introduction of new technologies is usually subject to three central considerations: the added value, the costs and the legal feasibility. All three factors need to be held in reasonable balance.

B. Availability and Accessibility

The delivery of computing services from the cloud offers flexible resources, faster innovation and economies of scale. In many cases, the resources are accessed via the Internet, while the underlying software and hardware are housed in a remote datacenter. Many cloud services publicly available nowadays hold great potential to improve educational services. Many features of today's information technologies can only be used in combination with cloud computing, and also legacy systems are being pushed more and more towards the cloud by the discontinuation of updates and support by providers. Some respondents experience a growing pressure on educational institutions to adopt a concept for dealing with cloud computing.

There is a gradual opening with regard to public cloud services in both the secondary and tertiary sector. In general, SaaS services from the cloud have been adopted and considered on a case-by-case basis. This has primarily concerned communication and learning platforms for which no comparable on-premises alternatives have been available. They are usually licensed in a bundle or provisioned once by the IT department and made available for the entire organization. Individual commission options of other types of cloud services are currently very limited. There is a lack of credit supply that would grant wide access to the many services available on large public cloud platforms. Either the use of free offers or the use at instructors' or learners' own charge with or without reimbursement remain.

Organizations of both the secondary and tertiary sector have recently turned towards hybrid directory and identity management services to leverage local identity provision to manage access to cloud features, which has also been used to setup multi-factor authentication to strengthen security for cloud and on-premises applications, self-service password management, device registration, monitoring and alerting. Single sign-on allows users to log in once (e.g. on a school device) and access services without re-entering login credentials. It has become easier and faster to manage user accounts, create improved application security and implement access to cloud services. As a result, the focus in the secondary sector has shifted from the expansion of on-premises server infrastructure toward the improvement of the Internet connection through fiber optics and Wi-Fi as well as the provision of digital end devices for pupils and teachers while harmonizing IT operations of common applications. Also in the tertiary sector, the expansion of the bandwidth and the provision of digital end devices has been a topical issue.

C. Resources Used

Migrating email servers to the cloud was one of the first points of contact with cloud computing in most organizations. The cloud offers high availability, automatic updates, simple administration and numerous additional protection features against spam, malware and viruses. Especially for small organizations that are severely challenged with the maintenance effort of their own email server, the cloud offers a good alternative. In many cases, a hybrid transformation was carried out first to make the transition as simple as possible without impacting users and without reconfiguring individual devices.

In addition to storing files on end devices with limited capacity, they can also be stored in a cloud in almost unlimited quantities. This not only saves storage space on the device, it is also practical for storing, structuring, sharing, and accessing information from virtually any device via the Internet. Regardless of how many devices are used, the location of the file is centralized in the cloud, and the cloud provider takes care of backups, which minimizes the risk of data loss. Shared cloud storage has been used for creating intranets and document libraries. Daily routine tasks can be managed with workflows, lists and forms. Many more storage options than file shares are offered by cloud providers, but have only been used scarcely so far.

Cloud-based office suites for word processing, spreadsheets, etc. are often provided to educational institutions free of charge. They come with automatic updates, comprehensive web and mobile versions, cloud storage and interfaces to other cloud services, which brings about innovative features for mobility, teamwork, analytics, artificial intelligence, and so on. Overall, respondents felt that collaboration and productivity could be increased, and administration has become simpler. The mobile versions of the tools have been more difficult to use and often have a limited set of features compared to the desktop versions.

IT resources at lower levels of the service model hierarchy such as virtual machines and networks, hosting platforms for websites or virtual desktops have been scarcely used in education so far. For teaching networking technology, the distance to the hardware is expected to be an obstacle. The motivation to learn is likely to be stronger when learning tasks relate to the real-life environment of the students. Although cloud labs have the advantage of creating virtual learning environments quickly using reusable templates and artifacts, the underlying hardware is completely separated and thus probably less conceivable.

The Covid-19 pandemic forced many educational organizations to send their members to home offices and develop strategies for remote teaching and learning. This shift was more pronounced at the tertiary level than at the secondary level. The younger the group of learners, the more emphasis was placed on sustaining classroom instruction. Overall, the use of cloud-based collaboration tools for remote teachers and learners has increased drastically. They provide the ability to participate in online conferencing, chats, screen transfers and data sharing. In many cases, cloud-based collaboration tools have been chosen due to the required scalability and the need for a quick installation.

File sharing and synchronization across devices is a highly regarded feature to make information and knowledge accessible from anywhere at any time. With ubiquitous networks of different devices and increasingly popular cloud solutions, synergy effects can be realized. Cross-device and device-independent teaching and learning is becoming increasingly important with the multitude of devices in use.

D. Ubiquitous Devices

Nowadays, the usual setting in a school is such that there is a desktop PC and a projector in each classroom. Modern projectors can establish connections to almost any digital device via standardized protocols. Additional desktop PCs for learners and teachers are available, for example, in seminar rooms or computer rooms. Many schools have dedicated laptops that are used for written exams. Some first classes have already been equipped with personal notebooks or tablets as part of a digitization initiative.

At the tertiary level, lecture halls and classrooms are similarly equipped. Blackboards and projectors for presentations are part of the basic equipment. Document cameras are partially available. Employees are provided with a PC standard workstation (laptop, monitor, etc.) and a user account for the network that gives them access to personal mailboxes, Internet, Wi-Fi, file and document storage, learning platforms, video conferencing systems and other internal and external applications. Digital devices are only occasionally available to students during courses (e.g. network lab). In most courses, however, a personal device is required. This leads to a diversity of convening devices with different specifications, features, and operating systems, which makes it especially complicated when a course necessitates the use of specific or high-performance hardware or software.

Smartphones are integrated into the classroom in both the secondary and tertiary sector, usually in line with the Bring-Your-Own-Device (BYOD) principle. Nowadays, almost everyone owns a smartphone that can be pulled out quickly and easily. The engagement of the learners was found to increase through learning with their own devices. The lessons become livelier and more vibrant. With the help of digital devices, various formats and sources can be used to work on a topic, such as videos, images, texts, podcasts. However, the learner's attention is diverted away from the teacher and onto the smartphone, and it can hardly be checked whether the learners are using their smartphones to complete tasks. For this reason, the smartphone has a higher standing in the tertiary sector.

Conventional printers are offered to teachers and learners to a sufficient extent in both secondary and tertiary education. Promising experiments with the educational use of 3D printers have also been conducted already. Currently, no more than one 3D printer is typically available per school, as the purchase price is high and the application possibilities are still rather limited. For example, 3D printers have been used in art lessons to print 3D artwork created on the computer. There are also incentives to use 3D printers with dynamic geometry software in the future.

Interactive whiteboards, which allow teachers and learners to interact with the images on the screen directly, are still less widespread. An IT manager's assessment is that schools will never get to the point where conventional blackboards are completely replaced, because a blackboard is very quick and easy to use and also a great backup in case of problems with its digital equivalent. There is also the possibility of cloud-based apps that serve as a digital whiteboard.

By enriching reality with additional information (Augmented Reality; AR) or by creating a completely virtual environment (Virtual Reality; VR), the way has been paved for new forms of teaching and learning. 3D visual impressions and stereoscopic displays can create a high level of sensory perception. Acoustic and haptic feedback provide scope for a lively and dynamic learning experience. With decreasing hardware prices and the development of new applications, VR/AR glasses could also soon find their way into teaching and learning. Currently, the level of use and availability in educational organizations can still be considered very low.

Single-board computers such as the Raspberry Pi and microcontrollers such as the Arduino have a long history of use in Informatics lessons in schools. The Raspberry Pi is a complete system on a single card. It can act as a fully functional computer with processor, graphics card and memory. The Arduino is a simple microcontroller that contains input/output pins, processor and power supply. It does not have an operating system, but can still control small devices and run small projects interpreted by its firmware.

Different types of IoT devices such as light bulbs and sockets have been used in networking classes to create active learning environments that link teaching and learning to practice. The physical presence of these devices provides visualization and vividness. Exploration, drawing connections in a structured way, asking questions, summarizing content and explaining facts to each other are important components of those practical lessons. Cloud-based IoT hubs can be used to process and route messages between devices, show the current status of connected devices and often include services for storage and analysis of information.

A sports teacher reported that wearables such as smartwatches have been used in physical education classes. Since no school equipment was available, the learners used their own devices. With the help of the watches, they can track their run times and measure their heart rate. They learn how to exercise effectively with the help of wearable technology. Additional sensors could be connected (e.g. smart shoes or chest straps) to obtain results that are more accurate. The expectation is that many more health and fitness monitors, wearable cameras and smart clothing will be available in the future. Due to the small size and limited capabilities of a single wearable device, the connection to other devices or a cloud server is essential. Synchronizing and analyzing data on smartphones or other devices is common.

E. Security Considerations

The level of protection against malicious attacks that seek to unlawfully access data, disrupt digital operations or damage information is overall considered to be higher in the cloud compared to local infrastructure. Although large cloud providers are more likely to be attacked as they pool resources from many different organizations and attract a lot of attention and interest from the public, they are expected to meet much higher standards in terms of IT security, data protection and confidentiality.

There is awareness that the risk of breakdowns and data losses also exists in the cloud. Data centers can be affected by minor and major live site incidents, stemming from hardware failures, network and power outages, up to environmental disasters. It is expected that cloud providers have comprehensive solutions in place, such as backups, redundancies, monitoring and more. Some cloud providers let their customers choose from a range of redundancy options that determine the tradeoffs between lower costs and higher availability.

Educational organizations can experience huge complications from having sensitive information exposed. Data breaches, which are incidents that have the potential to disclose sensitive information to an unauthorized party, may be caused by a weakness in technology or user behavior. A data leak can mean exposing highly confidential information such as social security numbers, residential addresses and banking information to foreign parties. This is particularly problematic at the secondary level, where information from minors is processed. To avoid this, IT managers and administrators use methods such as encryption of sensitive data, patching and updating software as soon as options are available and enforcing strong passwords and multi-factor authentication. Educating users on best security practices is an important aspect that should not be neglected.

VI. Discussion

The education sector is undergoing a major transformation as a result of digitization [36]. Digital technologies have given rise to new forms of teaching and learning and have given students greater control over what and how they learn [9]. Covid-19 has further accelerated this trend by provoking the temporary or permanent transition from traditional to online instruction [33]. The provision of IT resources and infrastructure in educational institutions has become increasingly complex over time. While the IT custodianship used to be less of an effort a couple of years ago, there is a lot more attached to it today. The didactical use of digital technologies is widely promoted throughout all educational levels to facilitate personalized learning, improve learners' digital literacy and prepare them for modern occupational fields [40].

The federal act on financing the digitization of school instruction (SchDigiG) is a recent, large-scale initiative in Austria for creating framework conditions to foster IT-based instruction in all types of schools from the 5th grade onward [41]. It provides for the gradual equipment of pupils with a digital device. The devices used in schools should optimally support the pedagogical requirements and have a uniform configuration interface to simplify device management at the school site and increase the security of the IT network [42]. If learners already own a digital device and want to use it at school, this is possible under certain circumstances. A formal process exists for the use of learners' own devices, which aims to check whether the device fulfills the necessary technical specifications to meet the pedagogical, didactic and technical requirements at the respective school location [42].

When creating digital learning environments, it needs to be ensured that teachers and learners have access to the necessary equipment, as a lack of access leads to exclusion and has a negative impact on performance [43], [44]. As for remote learning, it should be considered to provide a pocket Wi-Fi for learners who do not have a network access environment to ensure off-campus network access. Especially in times of cloud computing, a good connection to the Internet is crucial [13].

In education research, cloud computing has been mainly seen as a technology providing new instructional tools that are put to use with the goal of testing how well they work [11]. In this study, the phenomenon has been placed in a wider context to give a better understanding of how organizations are currently positioned and whether they are allowing those changes to take place. This is not only a matter of the IT department or the school custodian, but also a question of the strategic orientation of faculties, departments and directorates.

VII. Conclusion

This phenomenological study gathered the experiences of learners, instructors, decision-makers and IT employees regarding cloud computing and ubiquitous technologies. The focus was on the organizational aspects and framework conditions for the integration of new technologies into teaching and learning. Thematic analysis of the hermeneutic interviews yielded five themes: IT Management and Operations, Availability and Accessibility, Resources Used, Ubiquitous Devices, Security Considerations.

While many resources have already been pooled and centralized by the responsible educational directorates in the secondary sector, there is greater autonomy in the tertiary sector. The trend is heading towards community clouds, with the use of public clouds where needed. In terms of service models, the tendency is more on SaaS and less on PaaS and IaaS. The reason could be a lack of appropriate on-premises alternatives for specific application software.

Together with the increasing amount of computing devices that surround us, a strategic orientation towards cloud computing is becoming increasingly important. Positive initial experiences have already been made with cloud computing. While many services are readily available, access is often still limited and needs to be democratized. Cloud computing offers an efficient, flexible, and scalable model for delivering the infrastructure and resources that are needed to support educational improvements.

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