A Snapshot of Essential IT-Related Challenges of Universities: A Literature Analysis

What drives IT in higher education today and tomorrow?

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Abstract: Universities have rarely been challenged to radically evolve and transform as they have been in the Covid-19 pandemic. The conduct of teaching and research, as well as the environment of staff and administration, have had to digitalize and transform under time pressure. This development has placed and continues to place high demands on IT and its infrastructure. In addition, new challenges have emerged, such as technology-based future skills, cybersecurity, and the need for an agile university-wide IT governance. Mastering these requires IT to address the present and the future already today. Therefore, in this article, we conducted a literature analysis to identify and examine current and future challenges for IT and its infrastructure in universities. We identified twelve overarching challenges, which we describe individually. This paper provides starting points for further IT-related research and essential viewing angles for IT governance in universities for practitioners.

Keywords: Digitalization, Challenges, Universities, IT Governance, Digital Infrastructure, Digital Education, Higher Education

1 Introduction

The IT and digital infrastructure of universities[3] are a cornerstone of operations for their stakeholders, as Gilch et al. illustrate in their digital model university [GJW21]. Among numerous factors, this includes the management of students and employees and goes beyond the provision of IT services such as learning management systems (e.g., Moodle), video conferencing systems (e.g., Zoom) to specific solutions for the implementation of new (digital) teaching concepts. What it would look like without IT and its infrastructure has been shown by the case of the University of Giessen, which we will briefly discuss later [Ma20]. Without information and communication technologies, everyday university life, especially during Covid-19, would be inconceivable [AHL20]. The IT manages and controls the digital infrastructure and has an increasingly prominent and crucial role in meeting stakeholders' current and future needs in higher education environments [WM17].

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[3] We use the term “university” in this paper for all types of higher education institutions.

doi:10.18420/inf2022_117

One of the growing needs is the agile deployment and use of appropriately configured and secure software for the diverse IT technologies of the future, which are playing a role in more and more disciplines [KM21]. Therefore, the topic of digital and data literacy and its interdisciplinary teaching is a requirement arising from global development [Ri15], [RS20]. Using data as a risk-mitigating element for forecasting and decision support or as the base for reasoning to explain phenomena plays a fundamental role in all disciplines [RS20]. Over the past two years, the Covid-19 pandemic has led as an accelerator for the digitalization of teaching concepts, operational work, and communication in universities. Thus, as one example, Massive Open Online Courses (MOOCs) or distinct divisions of teaching into synchronous (live) and asynchronous parts can be found more and more frequently [KL19]. In the asynchronous part, the lecturers prerecord the classical course content via videos so that they can be accessed by the students on-demand. The synchronous parts are used instead for exercises and direct exchange in the form of discussions about the content. These teaching concepts need to be enabled by universities' IT and bring their own challenges for the provided platforms, tools, and data management [AHL20]. In addition, the flexible integration of new software in compliance with general and university-specific data protection regulations is becoming increasingly important to enable contemporary teaching with modern applications. IT can also provide beneficial services for the researchers themselves and research data management (RDM) [Au19].

Universities as expert organizations have a unique structure compared to other types of organizations, be they private entities or public authorities [RBS15]. This comes through autonomously acting faculties with experts in different disciplines and domains operating in the sphere of action, centralized by a governing body of the university, the presidium. Since these are traditionally grown organizations, IT is characterized by its demand-oriented development process. Complicating matters are inertia and multi-layered bureaucratic processes embedded in the IT governance of universities that constrain agile ways of working. Flexibility, however, is necessary to teach students in current technologies and the latest software and hardware for high-quality academic education. For countering and mastering current challenges, for example, frameworks such as COBIT [Ge20] are applied in universities, data and digital strategies are developed, and C-level positions such as Chief Information Officer (CIO) and Chief Digital Officer (CDO) are filled to spearhead IT governance and digital development [Ho15].

This paper captures current and future challenges for higher education IT based on the literature analyzed. The literature analysis was conducted using the five phases defined by Fettke [Fe06] (1) problem formulation, (2) literature search, (3) literature review, (4) analysis and interpretation, and (5) presentation. The *(1) problem formulation* is described via the following research question (RQ): *What are the current and future challenges facing university IT and its digital infrastructure?*

The *(2) literature search* was primarily executed using Google Scholar as a literature search engine with the inclusion of various databases with the search term (("IT Challenges" OR "Challenges") AND ("Universities" OR "Higher Education")). The search was limited to results with a maximum age of 10 years, i.e., 2012, assuming that

older literature no longer represents the current state of challenges and problems. After several phases of analysis with the exclusion of duplicates, the utilization of the titles, the abstracts, and finally, a full-text analysis, as well as a forward and backward search as recommended by Webster and Watson [WW02], 27 paper relevant to the problem formulation remained. The *(3) literature evaluation* is performed in section 2 (Current and Future IT Challenges of Universities), and the *(4) analysis and interpretation* are performed in section 3 (Discussion and Limitations), which also contains the limitations of this paper. Section 4 (Conclusion) provides the conclusion. This article, in its entirety, represents *(5) presentation* according to Fettke's five phases [Fe06].

2 Current and Future IT Challenges of Universities

All challenges identified are shown in Tab. 1. In this chapter, we will describe each challenge with its specifics. We want to note that many of the challenges are related. However, these cross-connections have not been formulated in detail, as the respective infrastructures of the universities are different, and the relationships are therefore not universally valid.

#	Challenge	Literature Findings
Ch1	Cybersecurity	[Bo17], [Cu19], [Ma20], [UW21]
Ch2	(Interdisciplinary) future skills	[Ha21], [He21], [GJW21], [KLS17], [KM21]
Ch3	Complexity of infrastructure	[Bo17], [FF18], [He22], [Ho15], [Ro21]
Ch4	Mobilization	[AHL20], [Bo17], [GJW21], [KM21], [vv18]
Ch5	Scalability	[GJW21], [Qa19], [WM17]
Ch6	(IT) staffing & shortage of skills	[GJW21], [PW17]
Ch7	Data-driven culture	[Da15], [TZS22]
Ch8	Data & IT governance	[AHL20], [Bo17], [Da15], [Ge20]
Ch9	Agility for change & innovation	[KM21], [PK16], [He21], [MS21], [MS22]
Ch10	Outdated infrastructure	[Ch18], [PS20], [WM17], [ZM21]
Ch11	New learning models	[Gi17], [GJW21], [He21], [Jo20], [KLS17], [KM21], [UC22]
Ch12	(Top) management commitment	[Ge20], [GJW21], [Ho15], [WM17]

Tab. 1: IT Challenges that universities (will) face

Like every organization, universities must protect the data of their users. Given the amount of sensitive data such as student and employee payment information, personnel data, research data not yet intended for publication, teaching documents, and many others [UW21], the issue of **cybersecurity (Ch1)** is particularly relevant [Bo17]. To protect personal data, the European Union has had, among other things, the General Data Protection Regulation (GDPR) since 2018 [Eu18]. However, compliance with these regulations is a challenge in their implementation to create a resilient digital infrastructure. A complex tension exists between compliance with data protection and using modern software, where data is often exchanged, for example, via data notes in foreign countries. In addition, human factors can also be a safety threat [Cu19]. Cases like those in Germany at the University of Giessen in 2019/2020 must be avoided [Ma20]. A successful hacker attack forced the university to take most of its digital services offline for about a month. The effects were far-reaching: Seminars and exams were canceled, for some students, this involuntarily prolonged their studies, and due to the lack of digital interfaces, alternative analog processes had to be used to improvise [Ma20]. This incident clearly shows an inseparable dependency on the digital infrastructure for the orderly flow of university processes and that this must be protected as a result. In the future, this dependency will be even more pronounced than now, as the digitization of processes and data will continue to increase, and the Covid-19 pandemic has further accelerated the process [UW21].

There is a steadily growing need for cross-cutting competencies such as **digital, data, and other skills (Ch2)** that will greatly benefit business and civil society in the future [Ha21]. In exercising their educational mission to prepare and train academics and young scientists, universities must respond to these requirements [He21], [KM21]. The embedding of content becomes challenging if it is taught as interdisciplinary skills across all faculties, such as digital and data literacy [GJW21]. The addressees are primarily students but also lecturers who integrate such competencies sustainably into their courses [KLS17]. An agile centralized or decentralized IT organization with comprehensively defined responsibilities is conducive to the digital infrastructure of such efforts. Particularly in the case of decentralized, faculty-centric IT units, the question often arises in the context of collaborations as to which team provides the services and is responsible for them.

The development of digital innovations is advancing every day, and so is the number of tools, services, processes, and interfaces increasing the **complexity of the surrounding infrastructure (Ch3)** [Bo17]. For example, the pandemic has driven the proliferation of various video conferencing systems, remote work environments, and digital learning tools. Emerging demands from new or further diversifying disciplines also add to the complexity. Efficiently and effectively managing these numerous and diverse IT infrastructure components requires careful planning and coordination through IT governance since the available resources are usually very limited [He22], [Ho15]. An aggravating circumstance is the IT that has traditionally grown up at universities. Thus, the IT and its digital infrastructure are not holistically designed from the ground up to function in a resource-efficient manner but have evolved incrementally through management direction, regulations, or individual needs without structured coordination of

the big picture and its individual components. Thus, in three university digital ecosystems, we observed numerous obsolete, unused, redundant, forgotten, and inefficient software that complicates their IT environment.

A phenomenon worth mentioning that arises in many kinds of organizations but particularly in higher education environments is the formation of silos [Ro21]. In these, processes, content, technologies, tools and data may be hoarded and only used for the organizationally specific goals, for example, of a faculty or department, fostering tribalism [FF18]. For instance, the same problem in dealing with students or in the context of digitalization can occur in several organizational areas, and each of the areas plans, develops, and integrates its own solution and doesn't share its knowledge, while one approach would have sufficed [FF18]. It would be desirable to develop and implement joint solutions that are inclusive and, above all, holistically viewed in a more resource-efficient manner. This is a major challenge for universities and their (IT) architecture management.

Another aspect that became necessary during the Covid 19 pandemic and will take on an essential role in the post-Covid 19 era is the **mobilization of the digital infrastructure and its services (Ch4)** [Bo17]. Meanwhile, events on campus are once again taking place more frequently and regularly. Nevertheless, the development shows that fully digital or hybrid forms of teaching have become established and remain firmly anchored in the repertoire of universities [GJW21]. This results in integrating various services for digital education in the IT infrastructures. In addition to video conferencing systems, these include (collaborative) tools such as online whiteboards, design and programming environments, and computing capacities. Students want digital access to education, but they also want to carry out administrative activities with their university in the digital space in order to save the time that would have been needed to travel to campus [AHL20]. Employees are becoming accustomed to home office as a working model and wonder whether the daily trip to the university is even necessary when they can do most activities at home without restrictions [KM21]. In this context, new-work initiatives are an issue [vv18]. These include, for example, room booking systems that allow on-site workplaces to be shared by several employees [vv18]. Such new services must, in turn, be integrated into the IT infrastructure, and the interacting individuals must become accustomed to the new forms and environments of work over time. In the competitive job market, the mobility characteristic is proving to be an attractive feature. We see the development that the digital and physical campuses will coexist in the future and can be used individually by each student as they see fit. However, universities are places where students come together, engage in academic discourse, and acquire essential competencies, which include social skills. The purely digital role should be reserved for distance universities designed for that purpose. Further cultural reflection on how much digital is too much is an ongoing interdisciplinary issue.

IT structures are typically subject to the issue of **scalability (Ch5)**, especially if the growth is planned and it is possible to be unexpectedly rapid. Ensuring scalability primarily depends on how many resources are available in the (technical) infrastructure [GJW21].

However, this is also related to the effective and efficient use of available resources. For example, designing a process well can mean massive differences in scalability as the activity runs faster, freeing up resources for other activities [WM17]. The scarcity of financial resources and associated cost pressures present universities with a non-trivial task in this regard. One approach that is becoming increasingly popular is the outsourcing of individual or multiple services to external cloud systems [Qa19]. This transfers some of the responsibility to a service provider. Once again, this must be planned in detail, be feasible with the available financial resources, and be permissible from a regulatory point of view. Scaling also affects education itself, such as the delivery of exercises in large courses that require IT support to be feasible. We expect the number of university students and employees to grow steadily in the coming years, making scaling education as well as IT and its digital infrastructures an ongoing and important topic.

The **demand for (skilled) IT staff (Ch6)** on the job market is already very high, as evidenced by many unfilled positions and a rising salary level to address the low supply of (sufficiently trained and experienced) workers [PW17]. Demand is even expected to increase as digitalization continues. Since the private and public sectors, including universities, operate in the same job market, they compete for the supply of IT professionals [GJW21]. In Germany, university jobs are generally subject to collective bargaining agreements, which is not necessarily negative. However, salaries and other incentives often cannot compete with those in the private sector [GJW21]. In addition to recruiting new professionals, it is also a matter of training existing ones to meet current and future skill needs and perform their jobs [GJW21]. The IT sector is fast-moving, and new software products and technologies are added in ever shorter cycles, whose integration and application must be learned and trained. If there is too little personnel capacity or knowledge in the organization, external consulting or IT service providers are often the only alternatives. Overall, it will not be any easier for universities to acquire or train the IT professionals they need in the future.

A growing number of organizations are **adopting a data-driven culture (Ch7)** to improve their performance and decision quality [TZS22]. They all generate verifiable data in various forms and types that have great potential to understand an organization, forecast the future, measure what processes and actions are effective, or whether a product is successful. Because data is ubiquitous in digital environments, a tremendous number of applications exist to analyze them. Universities generate vast amounts of data in each of their pillars, be it education, research, administration, or transfer [Da15]. However, the data is rarely analyzed. Therefore, investment in adequate business intelligence tools, AI, and the teaching of appropriate data literacy is necessary [Da15], [TZS22]. A data-driven culture is not primarily about using data as the sole basis for decisions but about backing them up with information to argue for a direction. This is compounded by the complex challenge of creating employee awareness of data, how to interpret it, and how to deal with it.

Creating a data-driven culture requires a clear framework in the form of **data and IT governance (Ch8)**, which includes processes, guidelines, and standards to define the

organizational goals and support their implementation. Various frameworks such as COBIT and ITIL exist for this purpose, but applying them to the university context is not an easy endeavor [Ge20]. Creating and actively using data is a general challenge in the coming years. It is becoming particularly crucial because, for example, IT risks and data security issues are interwoven with it [Ge20]. In addition, there are the questions of (legally) correct and sustainable data storage, data management, and a uniform specification of integration processes of new data into the existing data ecosystem [Bo17], [AHL20]. Pre-definition for integrating new data is important to ensure that computer-aided analysis and evaluation are possible. Besides the potential applications for improving the university for students and employees, data can also serve as a foundation for argumentation and communication to discuss and support hypotheses, theories, and evaluations in research [Da15]. In the case of scientific data, the FAIR Guiding Principles were established in 2016 [Wi16]. FAIR stands for: Findable, accessible, interoperable, and reusable digital assets. Creating data governance and strategy and gaining its acceptance across the university is a complex, multi-year endeavor. It requires the presence of appropriate professionals and the will of all to realize it successfully. It becomes particularly complicated when there are separate IT units, for example, in the faculties, which act autonomously.

The topics of **agility for change and innovation (Ch9)** must be addressed in universities at all levels in order to be able to demonstrate sufficient flexibility, efficiency, and speed of adoption in the future [He21], [KM21], [PK16]. The entire organizational (IT) architecture must be coordinated for this, which makes this challenge particularly large and complex [MS21]. For expert organizations with autonomously acting working groups, achieving or initiating change is a multi-faceted task. Based on our observations, some IT architectures hinder agility due to an unfavorable mix of multi-tier centralization and decentralization. An example of this would be the following three-layer structure example from practice:

1. Centralized organization of the critical IT infrastructure by a central computer center,
2. Decentralized (agile) units per faculty with smaller teams to serve their individual needs in the faculties, and
3. Decentralized temporary project teams (mostly financed by third-party funds) that fulfill the respective project requirements.

In the case of internal faculty projects, the communication chain with this structure is not optimal, but it is manageable, and responsibilities are regulated. Recently, however, multi-faculty projects such as the teaching of cross-cutting competencies have become increasingly common [MS22]. In this context, there may be difficulties in transferring tasks, as the second level sees itself as responsible only for its faculty. In addition, coordination and documentation among these units are fundamental to governing which services are provided at which level by which unit. The project teams on the third level are usually only temporary for about three years and act autonomously. However, they must communicate with the first and second levels and build on their services to avoid

wasting resources and operate sustainably.

The practical example is one variant of many possible and exemplifies how many parameters and organizational intersections play a role and influence agility, change, and thus innovation [MS21]. Especially due to the silo situation in expert organizations, the democratization of information also takes on an essential function in universities for agility and internal as well as external collaboration. Weaknesses of the described three-layer structure can be lengthy processes, unclear responsibilities, inefficient coordination and use of resources, and slow change overall. As is common in large, established organizations, the first steps of change should be taken on a smaller scale in individual areas rather than initiating an entire transformation at once, if possible. The goal must be to allocate the available, limited resources to the internal and external needs and impulses in the best possible way and to adapt to the operational environment in a minimum of time [MS21].

Another challenge currently and in the future is handling the **outdated systems and software in the IT infrastructure (Ch10)** of universities, especially in developing countries [PS20], [ZM21]. Often, these are deeply anchored in one or more faculties, for example, when it comes to content, campus, and learning management systems. Lecturers have become accustomed to these programs and adapted their teaching scenarios to them. However, the handling is often uncomfortable, the user interface is no longer up-to-date and presentable, and functions such as data analysis and visualization are missing. In addition, such systems often have high maintenance requirements and are vulnerable to cyber-attacks [Ch18]. Other components to consider are old systems that are no longer used and are placed as corpses in the digital infrastructure. Depending on the complexity and rootedness of the systems, adaptations here are less or very costly. The larger the user base, the more likely the university's management, at the top of the hierarchy, will have to be involved in initiating and implementing a change to update the infrastructure, assuming the necessary resources are available [WM17].

One major transformation was the development of **new learning models (Ch11)** needed in the Covid-19 pandemic in an all-around digital learning environment. This change has required a lot from students and lecturers, depending on their existing digital skills [Gi17]. Technical and didactic elements together play here an essential role in ensuring the experience as well as the learning success of and interaction with students [Gi17]. New tools were needed for the IT infrastructure to execute distance learning, which we have already mentioned with video conferencing systems and collaborative learning environments [KLS17]. However, we see this development as far from complete, as such models are just becoming established and entrenched in a post-Corona era [GJW21], [He21], [KM21]. But it's not just distance learning that's changing; on-campus education also shows new facets. Dualization into asynchronous prerecorded teaching videos mixed with synchronous physical teaching units in which (extending) exercises and discussions to the asynchronous parts take place, show up frequently. New tools are becoming more prevalent such as Jupyter Notebooks as an interactive, collaborative environment used for individual exercises or entire courses, as Berkeley University has demonstrated for several

years with its Data 8 cross-sectional introductory data science course [UC22]. In the case of Jupyter Notebooks, common elements such as text, images, and videos can be interactively combined with mathematics, statistics, or programming in the notebook [Jo20]. The computations are usually done on the university's servers to keep the use of the software as low-threshold as possible [Jo20]. The learning models and environments as well as tools mentioned are only an exemplary glimpse of the future developments that must be provided and supported on the part of IT structures and thus one of the current and future challenges for university IT.

A characteristic accompanying almost all significant (successful) changes is the **commitment of (top) management (Ch12)**. Problems arise if there is no designated C-management position for digitalization issues, such as a CDO or CIO, who can drive forward the university's digital development with the appropriate experience, qualification, responsibility, and resource capacity [Ge20], [GJW21], [Ho15]. Such management positions can be justified by the far-reaching and all-pervading digitalization, for which a superordinate control authority is beneficial. In some cases, the overall tasks a CDO or CIO should do in full time are integrated as an additional function, e.g., into the repertoire of the rector, who, on the one hand, usually does not have enough time for it and, on the other hand, often does not have the appropriate qualification background for this functional area [WM17]. Another aspect of the CDO and CIO positions is to regulate clear responsibilities and grant them the necessary hierarchical authority so that binding goals and tasks, as well as resources, can be delegated [Ge20], [Ho15]. Many of the challenges described cannot be mastered without a (top) management commitment and impetus, especially when a large number of stakeholders need to be motivated.

3 Discussion and Limitations

Within a funded project that aims to foster digital and data literacy as cross-cutting competencies across the university among students and lecturers, we confirmingly encountered, to varying degrees, all twelve challenges identified from the literature. In that project, we use employee-driven digital innovations as a basis, i.e., innovations in the form of new and expanded digital or data literacy-promoting teaching concepts and courses designed, developed, and provided by the internal university teaching employees [LLN21], [Op22]. Internally, a funding pot is made available for this purpose as crowdfunding for innovative teaching endeavors [Jo17]. The special note in this project results from the collaboration of all faculties and the integration of new competencies, related technologies, and IT services. For example, in the project, the question of which of the IT teams is responsible frequently arose when tasks or problems affected multiple faculties. We have also encountered the situation where one of the faculties has a working digital solution to a challenge but does not want to share it with other organizational units to save internal resources. Therefore, the other faculties must develop their own solutions unless a management directive triggers the sharing of the solution. This case represents the epitome of a silo solution, where the various stakeholders pursue the goals of their

organizational unit or department but not those of the university as a whole. The illustration of our experience is intended to be an exemplary view of several aspects that should be considered when designing an IT governance and organizational structure.

The status quo of universities for the years ahead is currently just emerging, so more IT-related challenges may arise. However, we are confident that the twelve mentioned in this paper will occupy IT at universities in the coming years and, in some cases, in the next decade. More than ever, a look should be taken at the structures of benchmark companies on the topics of agility, IT governance, and adaptation of innovations, among others. We need to start shaping the university a decade from now. Every concept and implementation step already contributes to this and anticipating the future. Although a decade is long, the upcoming (far-reaching) changes need that time, especially in universities.

This work is not without limitations. Due to the limitation of the literature to Google Scholar and the databases linked therein, we do not claim complete coverage of all relevant literature. Furthermore, interesting literature may not have been found due to the definition of the overall simple search term without additional synonyms. Moreover, our observations and experiences, as well as most of the literature examined, refer to the German area. Altogether, universities represent individual organizations that are structured and function differently in detail, so the challenges described may vary in size, small or large, depending on the initial situation. They also differ further in terms of the type of university. Nevertheless, a consideration of each type would have gone beyond the scope of this article. However, despite the limitations, the results of our analysis should answer the RQ defined at the beginning about current and future challenges in university IT and provide promising starting points for research and perspectives for practice.

4 Conclusion

This paper presents and describes twelve current and future challenges for IT in universities and their digital infrastructure identified from the literature. After a long period of suffering for society in health and social aspects due to the Covid-19 pandemic, universities are slowly resuming their regular operations. However, these are not returning as we knew them before the pandemic [KM21]. New digital ways of teaching, virtual environments for students and employees in the form of new work initiatives, and many other aspects remain in place with varying intensity depending on the university [KM21]. If we reflect on this time, we can undoubtedly find positive elements in the accelerated digital development of universities, but numerous processes and tools had to be integrated into the digital infrastructures under great time pressure, so planning has been noticeably neglected in many places. Each of the challenges outlined in this paper offers starting points for further research and an impetus for active discourse at the scientific and practitioner levels about how these obstacles can be overcome in the coming years. An exciting addition to our work would be to conduct a qualitative analysis in the form of interviews to expand the challenges or find new ones that have yet to be considered.

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