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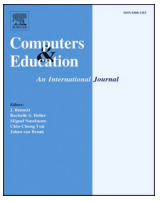

From dual digitalization to digital learning space: Exploring the digital transformation of higher education

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A B S T R A C T

Inspired by the fast digitalization during the Covid-19 crisis, we investigate a key aspect of digital transformation of higher education – the emergence of a digital learning space.

In developing our analysis, we focus on two streams of digitalization in higher education; digitalization of education and digitalization of subjects. We call this dual digitalization, which has been an obstacle for digital transformation of the sector, and made it challenging to develop a shared digital space.

Our research question is, how can we develop a shared digital learning space in higher education?

We conducted our study at the University of Oslo, where we analyzed three phases of digitalization. We identified three underlying forces of the digital learning space. First, the alignment of digital education and digital subjects provided a technical foundation. Second, the digital learning space was enacted and harnessed by redefinition of roles between students and teachers, allowing for new and deeper learning forms. And third, the digital learning space enables universities to transcend the physical and institutional borders, and engage in interactions with the broader society.

1. Introduction

When the Norwegian government, at the outbreak of the Covid-19 pandemic, closed down the country on March 12th' 2020, the University of Oslo spent only one week to transition into digital education. This was done by competent top management and a well-run IT department, who provided the necessary resources and communicated efficiently with 5000 staff and 28.000 students. It was also done by academic staff who, impressively, switched to video lectures at short notice, and it was done by students who accepted the new situation, trying to make the best of it. Many universities around the world succeeded, more or less, in the same way (Crawford et al., 2020; Dick et al., 2020). How was this possible? And what are the implications for the digital transformation of higher education?

One answer to the first question is that universities were pioneers in using digital technologies, and have spent many years establishing digital solutions. Administrative systems, such as student registers, exam systems, HR, and financials, were implemented in the 1980s and 90s and owned by the university administration. Educational solutions, such as Learning Management Systems (LMS), MOOCs, course websites, and library systems, were gradually implemented after 2000. And the digitalization of subjects has been developed locally by academics as part of the scientific development in their fields and disciplines (Crawford et al., 2020). When the Covid-19 crisis arrived, most universities had operating digital solutions to handle the crisis. Research has also shown a high degree of online learning readiness among students during the crisis (Tang et al., 2021).

The second question is harder to assess. Although most universities had working solutions, the digitalization of higher education had been incremental and failed to achieve a digital transformation (Henderson et al., 2017; Jackson, 2019). One key reason was that

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digitalization of the core university tasks has followed two separate tracks, which we suggest to call *dual digitalization*[1]:

- *Educational solutions*, such as Learning Management Systems (LMS), MOOCs, course websites, and library systems, were gradually implemented after 2000 and standardized and run by the IT department.
- *Digital subjects* were mainly developed locally by academics as part of the scientific development in their fields and disciplines. In particular, research solutions were very decentralized, usually down to research groups or even individual researchers.

The fact that these processes were separate and unintegrated had at least two negative effects. First, students and teachers experienced the solutions as two different contexts; the educational solutions dealt mainly with communications from the university departments and teachers to the students, while the digitalization of subjects focused on learning in new ways, and even redefining the domains. Since the solutions were separate and often fragmented, students and teachers experienced this as various digital tools, not a shared digital learning space (Delere et al., 2021). The second problem is that this separation constituted a hindrance to innovation of new learning forms because it was echoing the traditional pattern; first a lecture, then you go and read the book. Overall, the two separate processes have stimulated incremental improvement but failed to create disruptive changes (Jackson, 2019).

What happened in 2020? In a short period, millions of students were transferred from campus to digital classrooms, using tools such as Teams and Zoom (Crawford et al., 2020). Trying to absorb the shock, students, academic staff, and administration embarked on a fast experimentation and learning process on how to teach, learn and administer digital education (Crawford et al., 2020). The jury is still out regarding the long-term effects, but many researchers assume they will be far-reaching, and amounts to a digital transformation of higher education (Dick et al., 2020; Ludvigsen & Dæhlen, 2020).

Digital transformation of higher education has been discussed in the past decade, and the vision deals with many aspects, such as managerial strategy (Jackson, 2019), asynchronous collaboration (Hazemi et al., 2012), and the use of communication tools (Bond et al., 2018). A key approach is a rethinking of the learning process, enabled by technology, i.e., the development of a *digital learning space* (Ellis & Goodyear, 2016; Gafurov et al., 2020; Jackson, 2019). The digital learning space is a complex phenomenon, which we know too little about, both empirically and theoretically. This study aims to investigate the underlying forces and mechanisms that enable the digital learning space.

Our research question is, *how can we develop a shared digital learning space in higher education?*

The research question is motivated by the assumption that a digital learning space is not a technical artifact, but a space where the learning activity is physically, socially, and epistemically situated (Goodyear et al., 2021), i.e., being enacted by students and teachers. We proceed by reviewing the research on digitalization of higher education, in particular, the two processes of digital education and digital subjects, and summarise the discussion in a framework for the digital learning space. Our analytical lens is to regard dual digitalization as the emergence of a digital infrastructure (Hanseth & Lyytinen, 2010), i.e., a growing network of technology and users. Then we present our method in section 3, a qualitative study with in-depth interviews. Our findings are structured in three phases of digitalization, which we discuss in section 5, followed by conclusions.

2. Related research

The digital learning space can be conceptualized from several perspectives; technically (Gafurov et al., 2020), pedagogically (Ellis & Goodyear, 2016), and organisationally (Jackson, 2019). Our starting point is that universities should regard it, not as something completely new and different that can be bought or copied, but as solutions building on the existing structures and practices. We start our review with a brief overview of the digitalization of higher education, then we review the dual digitalization, and use it to assess the challenges of establishing the digital learning space.

2.1. Digitalization in higher education

Higher education is a central venue for the creation of new knowledge economies for the 21st century (Sam & Van Der Sijde, 2014), and digital technologies are key means for realizing this potential (Selwyn, 2016). At the same time, there is ongoing commercialization of the sector, particularly in the English-speaking countries, where strategies from private sector industries are seen as beneficial also for higher education (Commission (EC) E (2012); Pucciarelli & Kaplan, 2016). Some researchers have argued that universities have fallen behind other sectors in digitalization (Rodríguez-Abitia & Bribiesca-Correa, 2021).

Historically, universities were characterized by decentralized organizations to address local and regional as well as professional needs in the researchers' national and international networks. There is, therefore, an inherent tension between the governments' ambitions to use centralized approaches dominated by strategic thinking (Pucciarelli & Kaplan, 2016), and the various professional specialties' need for self-management and control (Clark, 1986), dominated by local knowledge optimization. Digitalization of higher education is, therefore, both top-down and bottom-up. While the strategic level has focused on centralization of IT and governance to enable more effective processes, academic staff are more interested in how digitalization can support education and research.

[1] We use this term in a practical sense, to characterise two parallel developments of digitalization.

2.2. Dual digitalization

We propose that these two different, and partly conflicting, streams of digitalization have significantly influenced the digital transformation of higher education, and illustrate the two approaches of dual digitalization in Table 1.

The conflicting forces are shown in Table 1; the technologies in use were different and mostly unintegrated. In addition, the discourses were separate; digital education was conducted within the strategic management of higher education, while the digital subject's discourse was conducted locally and bottom-up, by academics in different fields.

The digital education stream is process-oriented and deals with the digital classrooms and LMS, the provision of digital materials, such as PowerPoints, video presentations, and the communication of learning outcomes, assignments, and exams. Massive Open Online Courses (MOOCs) had a breakthrough in 2012 (Kaplan & Haenlein, 2016; Siemens et al., 2015), and was an established communication technology for online learning (Siemens et al., 2015), also in Scandinavia when the corona crisis emerged.

The digital subjects stream is knowledge-oriented and deals with digitized domain knowledge. In computer science this is programming, in medicine it can be e-learning resources, in economics it can be transactional data for learning econometrics. Digital representation of knowledge changes many disciplines and enables new learning forms through two key affordances; visualization of information, data, and ideas, and interactivity as a means for providing learning with tools for manipulation and exploration of information (Churchill, 2017). At a deeper level, digitalization of the subjects redefines the disciplines. Within biology, this could be transforming the field from focusing on natural objects to an orientation towards digital representation of natural objects and phenomena (Kulathinal et al., 2020). Within law, this applies to the transition from books to digital sources (Øvrelid, Grøttum, & Westbye, 2020). In medicine, it is about how human biology is represented digitally (Elenko et al., 2015), and in the humanities, digital corpuses that enable trawling in extensive amounts of data can be developed (Tangherlini & Leonard, 2013).

Progress towards a digital learning space in higher education has been slow (Jackson, 2019; Rodríguez-Abitia & Bribiesca-Correa, 2021). Based on the review above we propose that a key reason is that dual digitalization, i.e., the unintegrated development of digital education and digital subjects, has been a barrier. However, the lock-downs caused by the Covid-19 pandemic gave higher education institutions a disruptive shock and required them to establish communication technologies, pedagogical innovations, and organizational rethinking for establishing the digital learning space.

2.3. Digital learning space

A university is traditionally a *place.* While all people relate to place, space is a much more abstract concept, including discursive, cognitive, existential, and material spaces (Ellis & Goodyear, 2016). Since the advent of the Internet, people have become familiar with the digital space, i.e., dealing with virtual objects through devices, such as PCs, mobile phones, and gaming. A digital learning space harnesses these services, but is much more goal-directed:

Technically, it is a geographically non-located environment, offering integrated affordances for learning and communication, through digital devices (Bomsdorf, 2005). The affordances are produced by a large technical digital infrastructure (Hanseth & Lyytinen, 2010). Online interactive tools enable synchronous meetings (Lowenthal et al., 2020), teaching (Martin & Tapp, 2019), collaborative learning (Collazos et al., 2021), and course organization (Wilcox et al., 2016). To work seamlessly, these solutions require technical integrations, often implemented with APIs, i.e., mechanisms that secure and resource these interactions (Ghazawneh & Henfridsson, 2013).

Pedagogically, it is a sub-space of what we understand as *the learning space*, i.e., students learn in physical, hybrid, and digital spaces, which often interact (Ellis & Goodyear, 2016). It is not a set of tools, but rather an integrated environment for deep personalized learning and problem-based learning (McLeod & Graber, 2018). The systematic use of data for exploration, learning, and reflection is a key part (Williamson et al., 2020). Other researchers have pointed out that it enables new learning methods (Aagaard & Lund, 2019; Henderson et al., 2017), as well as learning analytics (Viberg et al., 2018). The digital learning space supports collaborative learning by providing mechanisms for complex peer inteactions (Soller, 2001), and supports situational awareness by visualising participants and actions (Collazos et al., 2021).

Organisationally, it transcends the physical and institutional borders of the university. While universities have always interacted with other parts of society, the campus is also a container, sometimes perceived as an ivory tower, often located outside the city. The digital learning space opens up new possibilities, such as closer co-operation with businesses, government, and other communities (Jackson, 2019).

These somewhat idealized perspectives constitute a vision; they do not describe the realities today. However, it is clear that the Covid-19 crisis accelerated the development of the digital learning space. What we know less about, is the underlying forces that can make this happen.

Table 1
Dual digitalization.

	Digital Education	Digital Subjects
Key terms	Teaching, logistics, management	Representation, learning
Technologies	Zoom, LMS, Social Media	Various software, learning analytics
Governance	Top-down	Bottom-up
Discourse	Strategic Management	Pedagogy, autonomy

3. Method

Our research approach was a qualitative study. Building on a sociotechnical approach, we frame our object of study as a *digital infrastructure.* A digital infrastructure is a network of interacting users, technology, and organizations, which is not designed from scratch (Hanseth & Lyytinen, 2010) but evolves through innovation, adoption, and scaling (Henfridsson & Bygstad, 2013). This implies that the evolution of digital infrastructures is a combination of bottom-up and top-down management. A key aspect of digital infrastructures is the interplay of affordances at the user level, and the interconnected technologies with representations of the domain (Bygstad et al., 2016).

The digital infrastructure of the University of Oslo has evolved for several decades, by adding user groups, technologies, and services. Affordances are mostly enacted in the web interfaces of LMS and other applications, but also increasingly in mobile apps. The technical foundation is a layered structure of national, university, and school solutions. To study the development over time, we selected key informants from faculties such as Law, Social sciences, Natural sciences, Medicine, Humanities and Educational sciences. In addition we interviewed managers and experts from the IT department. The informants were selected for being profiled actors within digitalization.

3.1. Data collection

The informants were selected from various faculties and units, to ensure sufficient breadth. Each informant was selected for particular expertise and experience in digitalization. The interviews were semi-structured, lasting 1–2 h, and focused on the areas of expertise of the informants.

In addition to the interviews, we collected available archival materials, such as plans and reports, architectural documents, and web pages.

3.2. Data analysis

Data analysis was conducted in three steps (Pettigrew, 1985). See Table 3. First, we conducted a chronological analysis of the digitalization initiatives at each faculty, focusing on events, and then a comparative analysis, focusing on similarities and differences. The result of this was a chronology (Fig. 1), covering the evolution of the two digitalization streams, the alignment during the Covid-19 crisis, and the institutionalization of changes.

Second, a thematic analysis of interviews was conducted, identifying key topics and trends. This was an iterative process, where we systematically analyzed events in the two digitalization processes; digital teaching and digital subjects. Following our research question, we aimed at identifying the underlying forces for the emergence of the digital learning space. To that end, we analyzed the events (i) from a technical view, documenting how the various digital resources together created the needed affordances, (ii) from a pedagogical view, to study the experimentation of new learning forms, and (iii) from an organizational view, to map interactions between actors and institutions.

Finally, we conducted a comprehensive analysis, aiming at developing *converging lines of inquiry* in a complex case (Yin, 2017), we built, iteratively, on our preliminary findings in step 2. Here we combined the insights from the events analysis and the interviews to identify the underlying forces of the digital learning space. In particular, we focused on understanding the interplay of technical, pedagogical, and organizational elements.

4. Findings – three phases of digital innovation in higher education

Based on the chronological analysis we structure findings in three phases, illustrated in (Fig. 1).

4.1. Phase 1: Two separate processes (unintegrated digital resources)

The education stream started in the 1990s with university and course web pages, which gradually were standardized. Around 2005 the first LMS was introduced, but only partly adopted, and never liked much by the students. A new LMS, Canvas, was introduced ten

Table 2
Informants.

Digital practice area	Informants	Education topics	Digital subjects issues
Law	Professor Librarian	From manual to digital sources of law for teaching	Lovdata
Social sciences	Study leader	Use of Zoom and Canvas during the Covid-19 crisis	Statistics in political science
Natural sciences	Professor	The gradual emergence of the digital classroom	Computational modeling
Medicine	E-learning expert	e-learning systems for teaching	e-learning portal
Humanities	Professor	Digital solutions for teaching and research	Digital corpus at the National Library
Educational sciences	Engineer and researcher	Digital solutions for teaching	Learning analytics
USIT	CIO Manager	The digital services of UiO	IT architecture

Table 3
Data analyses.

Step	Description	Tasks	Result
1	Chronological analyses	Identifying key events	Chronology of digitalisation at UiO (Fig. 1)
2	Thematic analyses	Analyzing the two digitalization streams, and the interplay and alignment	Findings: Three phases of digitalization
3	Comprehensive analyses	Analyzing and assessing the underlying forces of the digital learning space	Discussion: The digital learning space

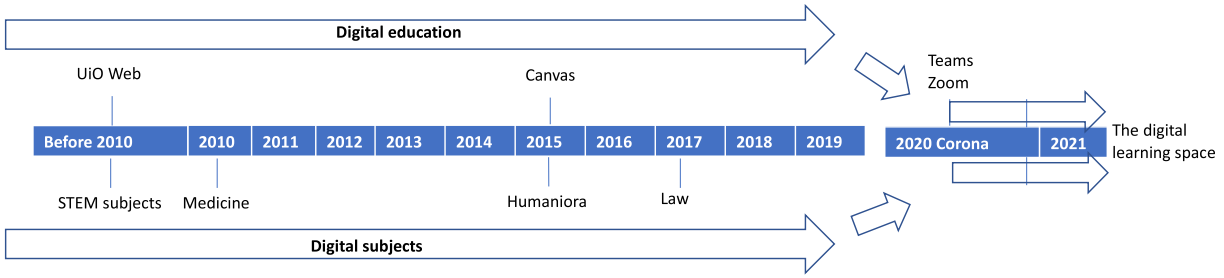

Fig. 1. Chronology of digitalization at University of Oslo.

years later, slightly more successful. Although promising, these technologies were used only to a limited degree, especially in particular online universities around the world. In most of the universities, education was primarily conducted in physical locations.

The *digital subjects'* stream emerged bottom-up, as different disciplines developed digital solutions. Several of the STEM disciplines, such as physics, chemistry, and mathematics, started digitizing their data in the 1980s, some of them (for instance meteorology) even earlier. However, around 2010 something new emerged, the disciplines became more data-oriented and algorithm-oriented. An example from biology illustrates this; biology students used to go for walks in the woods to collect and analyze plants. Today they (unfortunately, some might think) sit in the lab, programming gene sequencing in Python. At the University of Oslo, several subjects were digitalized in this period.

Within the Faculty of Medicine, the section for medical informatics was appointed to develop and implement a large e-learning package for medicine students. The initiative arose partly to experiment with new teaching forms, and partly to satisfy students' expectations of digital resources as a part of the learning process. A unit called section for medical informatics was appointed by the faculty to implement an e-learning system. Approximately 150.000 Euro is allotted annually to these projects.

> "The initiative does not come from the departments, but from the ground floor: the teachers. We try to involve students in all projects - their view is important because the product is for them, but students are usually far more than "viewers" - they often produce most of the resources under the guidance of teachers."

Even if the Faculty of Law has a long history of digitalization, a more systematic approach to digitalization of subjects had to wait until 2000 when Lovdata was implemented. Lovdata had functionality for looking up sources of law, but the system use was limited, and the digitalization of the subject was slow. Physical books were still dominating in both education, research, and examination until 2017 when a new version of Lovdata was implemented in full-scale teaching.

At the Faculty of Humanities, some researchers collaborated with the National Library to create extensive digital corpuses to enable effective searching in vast amounts of data. It is especially the studies of modern history that were changed as a result. The change lies primarily in the fact that the availability of extensive amounts of data from newspapers, journals, books, and research material enables a change of focus from concentrating on canonical texts to gaining an overview of lesser-known stories and their impact at the time.

Technically, the development of digital subjects implied that boundary resources (Ghazawneh & Henfridsson, 2013), i.e., API and other mechanisms for integration and digital interaction had to be developed. E-learning in medicine implied that physical resources were made digital and that APIs were used to implement this as a web solution (the e-learning portal). At the Faculty of Law, APIs were developed to enable use of digital legal sources and by linking these sources to a specific case in Lovdata. In the Digital Humanities, students could use digital corpuses that enabled extensive identification of digital sources.

4.2. Phase 2: Alignment of education and digital subjects

The situation was dramatically changed with the Covid-19 lock-down in Norway in March 2020. The university closed immediately, and a central task group of deans and the CIO made the necessary arrangements for digital classrooms (Zoom and Teams), access and security mechanisms, and online support. Within one week, the whole university operated as a digital organization, with teachers in home offices and students in campus lodgings or home at their parents. One expert informant commented:

> "Most teachers responded by a combination of online and pre-recorded lectures on Zoom. Only a few teachers felt that they were overwhelmed by technology, and reported that they were unable to lecture this way. The students have responded relatively

positively, accepting the situation, and participating online. We do, however, know much less about the students that do not turn up in the Zoom lectures, and we worry that some of them give up."

Then a process of improvisation and experimentation started, with teachers and students in new roles. We interpret this development as the *alignment* of the two streams, i.e., the educational and digital subjects streams met in the digital learning space. Even though most of the teachers were able to produce lectures online, the subjects that had already established building blocks for alignment between education and subject had some advantages. We use three examples from Law, medicine, and humanities.

After 2017, Lovdata is not only used to educate law students but also to digitalize the subject. Lovdata has functionality to link digital references within the system. The use of colors and drawings is comparable to previous paper aids but contributes by referring to related sources of law via links. This makes the use of the digital system dynamic and practical. During the semester, the students configure their Lovdata profile with knowledgeable resources and may use this configuration on the exam. The system also checks what comments and references that may be accessed on the digital exam.

The learning outcome for the student is according to the Dean of education, substantial.

> "The practice changes the subject. Earlier the student used learning tools no one controlled, there was no clear learning strategy, and the preparation work (done through the semester) was not awarded. Now the practice of law is done more correctly, with less focus on memorizing and more reward given to use of juridical method through the semester. Even if the exam becomes a search competition, which rewards the nerds, the work done through the semester is rewarded.

From autumn 2019, Lovdata is used in all compulsory subjects in the law study, as well as Norwegian courses (some courses like criminology, as well as optional courses with other challenges that do not have an equally urgent need for legislative data, will not use it). At the end of 2019, 70 courses and about 4500 students used Lovdata in the educational process as well as the exam.

Since Lovdata is required for the exam, the students will also use it throughout the semester. This also meant that physical books became redundant. The last book was printed in 2018. The digitalization of sources of law can be further expanded to include machine learning and artificial intelligence. The strategy has met some criticism. A person said, "It is a shame if the legal faculty is in the lead to tearing down the symbol of the Norwegian state of law".

A second example is e-learning in medicine which not only improves education by enabling self-study for students through digital resources but also digitalizes the subject. This applies to images, such as X-rays, eye diseases, skin diseases, and sound, for example, auscultation training. Furthermore, movies are used for case histories, e.g. in psychiatry and clinical communication, and procedure visualization. Animation can be used to visualize process dynamics such as physiology and disease processes, and simulation helps to understand the processes and consequences of interventions. Thus, both practical and cognitive skills are developed.

… technology is used to "link together material in learning hierarchies so that one can go seamlessly from overview learning to in-depth learning." … "Through e-learning fragmented disciplines can get virtual homes that bind the fragments together in an integrated presentation. E-learning is also used for student activating teaching through the use of virtual patients and interactive quizzes. These many facets make e-learning an integrated knowledge system."

Based on this, we can say that e-learning also digitalizes the subject. Resources within the portal were also integrated with examination systems like Question Mark Perception and Inspera. The e-learning portal, thus, has become a communication channel for subject-related digitalization in teaching, as a central part of a blended learning approach.

A third example is from the humanities. Some subject areas within humanities – like history of ideas - have historically been occupied with identifying and understanding historical periods as well as their cultural thoughts and drivers. Examples are the renaissance, the enlightenment, and romanticism. Researchers have then investigated particular canonical thinkers and thoughts within these periods.

Digitalization projects that digitize manual newspapers and books improve the accessibility to popular literature. An example of such an initiative is the National Library in Norway that systematically digitizes its entire collection. Researchers then create digital corpuses by using algorithms. These corpuses can be used to search in large databases.

> "We collaborate with the National Library as part of the research and education. NL digitizes the entire Norwegian text corpus … and this provides enormous opportunities … At the same time, tools are needed to systematize access to these extensive amounts of data."

> "We are working with a researcher at the National Library to improve access and research opportunities … and he has been involved in several projects we develop at the University."

> "NB has as a part of the extensive digitalization efforts developed *a national infrastructure for language technology* where you can develop more specific searches. An example is N-Gram, which is a sophisticated structure that enables searching in more structured text sets. Doctoral degrees have been written where this technique is used, and internationally there is an environment for this."

This example demonstrates how huge amounts of digitized material can be seen as an important source for education and research. It also shows that it is necessary to create algorithms that structure the searches in such extensive amounts of data. The data provides access to a comprehensive amount of unknown data, which can potentially change the subject's perspective. The three examples show that the digitalization efforts are both educational and a part of the digitalization of the subject. It also demonstrates the alignment between these two processes. New educational practices and digital subjects may lead to institutionalization, which we describe next.

4.3. Phase 3: Institutionalization in a shared digital space

In the spring of 2021, the end of the pandemic was still uncertain, as were the long-term effects of digital experiences. In a nationwide survey,[2] 71% of the Norwegian students replied that the learning outcome was poorer and that 50% felt lonely. Also, 71% felt that the amount of education had been reduced after the lockdown in March 2020, with large variations between institutions. In poorer countries, where Internet access is more scarce, the outcomes were notably worse (Aristovnik et al., 2020). These numbers illustrate, not surprisingly, that the social aspects of both structured education and student life play an important role, and were greatly missed.

However, in another survey, UiO collected data from 9450 students and found that even if the students felt that the quality of teaching went down; their actual progress was not hampered. On the optimistic side, there were signs that some aspects were in the process of being institutionalized. Our findings indicate some changes that might be lasting. After the convergence of the two streams, teaching and digital subjects will continue as separate processes, but they will be integrated into the digital learning spaces.

A key aspect of institutionalization is the emergence of a digital learning space. An example is from education in programming. The digital learning space consisted of both logistical elements such as video conference and digital subjects, such as programming lessons and data analysis. One of the informants, however, commented:

> "This digital classroom consists of many elements, it is Zoom and Canvas and discussion forums, and exercises and data, video clips and simulations. These elements are not integrated, which means that the students have to integrate them. This is not optimal, and I spend considerable time trying to mitigate this. One of the challenges for the students is that the mix of technologies and procedures vary, depending on the subject and the teacher."

A more mature example of a digital learning space, however, is from the Faculty of Law. The Digital Courtroom is a comprehensive digital platform for legal learning that includes various stakeholders like students, teachers, law firms, court administration, and judges. This means that Lovdata and other digital resources are embedded in a major reorganization of both the education and the subject. The institutionalization of Lovdata in teaching means that the student acquires more digital skills as an integral part of knowledge development.

Digital courtroom institutionalizes digital practices at the faculty of law. We may regard the digital courtroom as an ecosystem where several stakeholders like students, teachers, law firms, court administration, judges, and the university administration can interact regularly through sharing experiences and collaborating on knowledge creation. The digital courtroom is an educational ecosystem that "enable students to learn by conducting digital proceedings, preparing and handling court documents and perform other actions required in dispute resolution exercises" said one informant. It provides several digital offerings that facilitate deep experiential learning. This is done by facilitating the use of and experimentation with digital resources that can be used in legal practice. It also facilitates new forms of investigation by using modern technologies such as artificial intelligence and machine learning. Pedagogically, the digital courtroom can be used for identifying new teaching methods and research-based education.

Within Medicine, the e-learning portal is a central part of *blended learning practice* and a pioneer in identifying how medical objects can be digitalized. The introduction of e-learning in medicine entails a more dynamic organization of teaching that includes the use of digital resources in blended learning. E-learning is anchored in professional environments. An example is from pathology where they closed down the physical labs and used digital images accessible within the e-learning solution. The solution is integrated into the teaching, and is especially popular as exam preparations. The expert lecturer commented:

> "A couple of days ago, one of our retired teachers held a course for medical students (under the auspices of the students themselves) on ECG. The teacher has just developed a large e-learning resource about ECG which he used and advertised for. In the days before the course, the use was almost zero (it was shortly after Easter). The day after the course, there were 1000 side hits on the resource."

Within the digital humanities, the digital corpus similarly brings forward new institutional practices to conduct education and research. This facilitates the creation of new educational methods where students can learn to use language banks and similar to develop precise search engines. This practice potentially changes the object of teaching and research from the occupation of canonical texts and thinkers, towards "the great unread". This transition may facilitate more contextual insights into thought streams and ideas in particular historical periods. A new service is quantitative analyses of media references, provided by the National Library. Illustrated in Fig. 3 below, are registered frequencies of classic Norwegian authors, mapping the public interest over time.

These practices also introduce new research methods. Close reading and understanding of texts will still be very important for hermeneutical investigations, but now interpretation can be combined with corpuses that enable students to collect and filter large amounts of data.

5. Discussion

We return to our research question; how can we develop a shared digital learning space at a university? In assessing this, we discuss the technical aspects (alignment of dual digitalization), the pedagogical aspect (redefinition of roles), and the organizational aspect, by relating our findings to the international discourse on digital transformation of higher education.

[2] Studiebarometeret

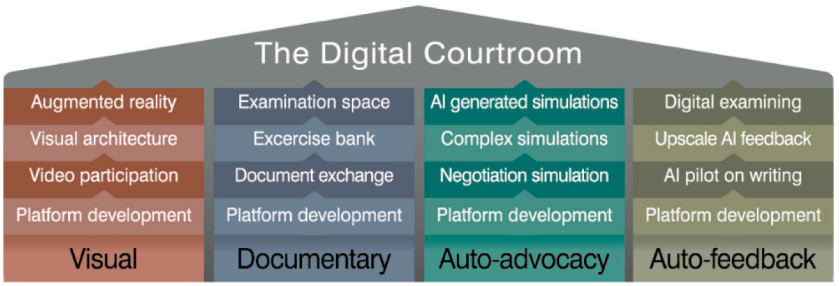

Fig. 2. Digital courtroom.

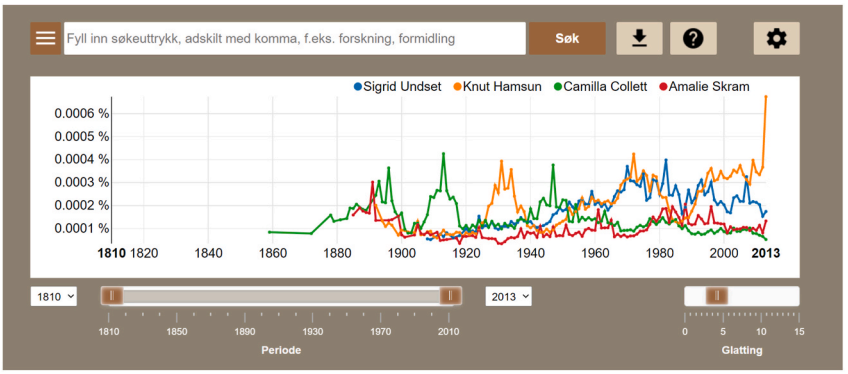

Fig. 3. Digital humanities.

We regard the digital learning space as the organisation and sequencing of activities for learning (Ellis & Goodyear, 2016). It is constituted by three mechanisms, as illustrated in Fig. 4. We discuss each of these in this section.

5.1. *The alignment of dual digitalization*

In the previous section, we showed how the alignment of the two digitalization streams enabled the emergence of a digital learning space, allowing students and teachers to interact relatively seamlessly (Gafurov et al., 2020). We have analyzed this process as an evolving digital infrastructure (Hanseth & Lyytinen,2010), where technical and social elements interact and integrate. We see the evolution as a combination of bottom-up processes, where subjects are gradually digitalized by internal actors, and top-down processes where strategic and logistical needs are served by larger and shared solutions. This balance of centralized governance and local autonomy is in tune with the modern university configuration. The alignment does not merge the two streams, but rather integrates them, as illustrated in Fig. 1.

Examples from our findings are Lovdata, which both address educational purposes, while at the same time digitalize the subject of law. Lovdata is primarily part of a top-down strategy from the Faculty but is integrated with an emergent bottom-up tendency primarily driven by subject development. Another example is e-learning at the Faculty of Medicine. E-learning is part of a faculty strategy

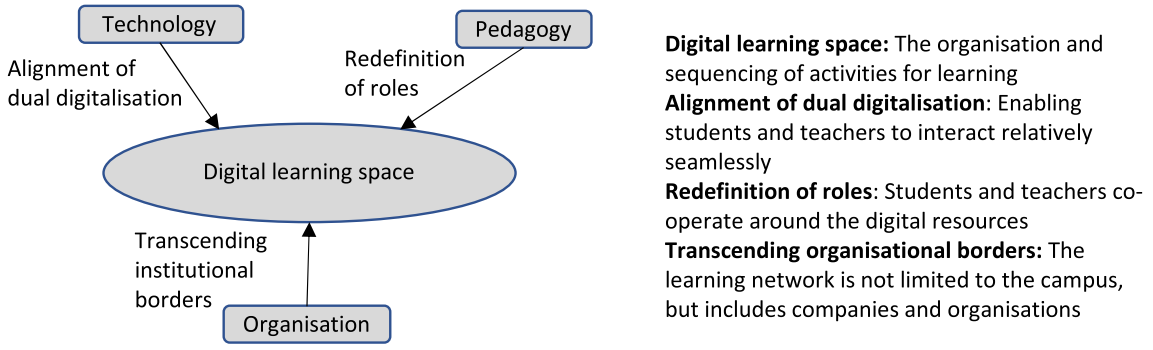

Fig. 4. The digital learning space.

to facilitate educational activities through a blended learning approach. Simultaneously, however, the activity also digitalizes the subject of medicine. For e-learning to be an effective strategy it needs to be anchored to bottom-up activities emerging within each particular subject area. Our last example came from digital humanities. Within this area, former hard copies of newspapers, books, and other types of articles were digitalized and made accessible through a large database at the National Library. To enable searching in these big data, sophisticated search engines like N-gram were developed. Digital humanities are the result of a combination of a top-down strategy where huge amounts of "physical data" are digitalized, and a bottom-up digitalization of the subject.

It is important to realize that the digital learning space is enabled by a large digital infrastructure, i.e., the interconnected systems and networks of the university and other Internet resources. Research has shown that a modularised digital infrastructure offers rich opportunities for continued innovation, through recombination (Henfridsson & Bygstad, 2013). This enables continuous innovation of new affordances. In our case, the alignment of the dual streams of digitalization made many new recombinations possible, such as the digital courtroom, and other innovations.

The digital learning space is not a predefined solution, and it is not one space, but many (Ellis & Goodyear, 2016). Bomsdorf used the term *plasticity* to describe the ability of a digital learning space to retain suitability for learning in different, changing contexts (Bomsdorf, 2005).

5.2. The redefinition of roles

The technical solutions are enabling the digital learning space, but it must be enacted by students and teachers. As our University of Oslo case shows, the intense experimentation during the Covid-19 crisis changed some old-age practices.

Pedagogically, it offers the opportunity to experiment with new learning forms, such as new roles for teachers and students, exploration of large volumes of data, and the involvement of actors outside the university (Jackson, 2019). It is illuminating to describe this development as a redefinition of roles. The traditional 2 × 45 min lecture becomes less central, and is being replaced by shorter, often pre-recorded video sessions as part of the teaching trajectory. With so many digital resources at hand, the role of the teacher will be less direct teaching and more as a facilitator of resources. The teacher's role involves designing and monitoring activities over time. Lectures (long or short) are only one activity that matters; to facilitate the students' learning trajectory teachers need access to new types of data, such as student engagement with digital sources.

We showed in our study how Lovdata, at the faculty of Law, facilitated self-learning activities amongst the students. By using and configuring Lovdata during the semester students improved their digital competency and teachers can concentrate on cultivating the most challenging issues. We also showed, from Medicine, where the e-learning platform became a blended learning solution that relieved some of the work burdens of the professors. The e-learning solution is also facilitating the transition towards a more flexible educational situation, where resources can be orchestrated for educational purposes. In the same line, within digital humanities, the digitalized corpus at the National Library facilitates a transition towards new forms of educational interaction, where students maintained the ability to interpret texts, while also learning to create sophisticated search engines. This may also imply that additional teaching resources with particular digital competencies can be drawn upon.

These examples are in line with predictions of the *digital organization* (Snow et al., 2017). However, we fully agree with Dick et al. (2020) who observed that the increased dependence on online platforms for course management and video conferencing requires these systems to be as seamless, and inclusive as possible, and added, «The environment in which online classes are offered must be robust enough to be seen to equal that provided face-to-face» (Dick et al., 2020). The data streams must be tailored for the teachers' tasks.

The campus is changing from a physical location to a hybrid, where the digital learning space will be a permanent feature. The consequences of this remain to be seen, but perhaps the social arenas and personal supervision will be the key affordances of the physical campus. Also, the increased access to algorithms and data is changing most subjects, in various ways, even redefining the domain. The increased importance of data may also indicate that data science is developing into a foundational discipline.

5.3. Transcending organizational borders

Organisationally, there is not one digital learning space, but many, and they intersect with hybrid and physical spaces (Ellis & Goodyear, 2016). In pursuing knowledge, a student may move from a lecture to Wikipedia to an international discussion group on social media, and to an industry webinar – all rather effortless. Several researchers have argued that the future university should include actors outside the university in the teaching and learning processes (Hazemi et al., 2012; Jackson, 2019).

A compelling example of transcending organizational borders is the digital courtroom of the Faculty of Law, a solution described in the previous section. The digital courtroom is an ecosystem where several stakeholders can interact in a simulated environment. Students and teachers can enact roles as barrister, judge, and defendant. However, this solution also allows for participation from law firms, court administration, and judges, for instance in assessing the interpretation of new laws or new court proceedings. The opportunities illustrate that the digital learning space enables new forms of knowledge development, including new actors outside the academic institution.

5.4. Summing-up: Digital transformation of higher education

We have argued above that digital transformation of higher education is different from the digitalization of businesses. Digital business transformation is about new business models (Vial, 2019) and the emergence of a new organizational identity (Wessel et al., 2020). Considering our evidence, we believe that these criteria do not work for higher education.

In this study we chose a more limited approach; as the key mission of a university is to develop knowledge, we focused on the emergence of the digital learning space. Through our empirical investigation and the current literature, we identified three underlying forces. First, we found that the alignment of digital education and digital subjects provided a technical foundation. Second, the digital learning space was enacted and harnessed by redefinition of roles between students and teachers, allowing for new and deeper learning forms. And third, the digital learning space enables universities to transcend the physical and institutional borders, and engage in interactions with the broader society (Jackson, 2019).

Does this sum up to a digital transformation? We believe it does, although the transformation has just started. Some researchers have warned against this conclusion, arguing that digital technologies are used gradually and pragmatically by the students and that there is no transformation (Henderson et al., 2017). We agree that this was true before the Covid-19 crisis, but that the rapid development during 2020–21 has created lasting and transformational changes. With increased attention moving from dual digitalization to digital learning spaces the potential for transformation greatly increases.

Based on the research our key recommentations are:

- Universities should adopt a learning-centric approach to digital transformation, i.e., establish a shared learning space, integrating technologies, pedagogies and organisational measures.
- Professors and lecturers need to redefine their role, moving from lecturing to orchestrating digital resources.
- Students should enhance their capacity to work in complex hybrid settings where different forms of digitalization take place.

5.5. Limitations and further research

This was an exploratory study, and many questions remain, which could be investigated by in-depth case studies in specific areas. One issue is a more detailed understanding of collaborative learning in the digital learning space. As showed by Soller (2001), computer supported collaborative learning requires support for complex student interactions, such as students challenging each other with asking questions, explaining opinions and reflecting upon knowledge. Do the current digital tools provide an appropriate psychological and social environment for this? Our study did not include data on these issues, but other researchers, such as Collazos et al., 2021) have shown that the current digital LMS tools only partly support emotions and situational awareness.

Another issue which was not addressed in this study is the role of management. We have emphasized the alignment between digital education and digital representation, as a precondition for the emerging digital learning space. What is the role of top managers in achieving this? This is not trivial, because top managers have generally a strategic focus, not engaging with the complexities of digital representation in the various subjects. And closely related, what is the role of middle managers, such as department managers and local teaching co-ordinators, who need to orchestrate the interplay of people and digital resources in practice. Further, what is the role of the university IT departments, in establishing the necessary technical foundations?

Another fruitful avenue for research is to investigate the emergence of digital learning space in less developed economies. While the basic elements of digital learning space may be similar, the technologies used are often lighter tools, such as mobile devices (Reddy et al., 2017).

6. Conclusion

The Covid-19 crisis accelerated the digital transformation of higher education, and in this study, we focused on the emergence of a shared digital learning space. Empirically, we investigated the digitalization of the University of Oslo before and during the Covid-19 pandemic, to analyze the transformation. Theoretically, we were motivated by the concept of digital learning space, and our research question was, how can we develop a shared digital learning space in higher education?

We identified three underlying forces of the digital learning space. First, the alignment of digital education and digital subjects provided a technical foundation. We have analyzed this process as an evolving digital infrastructure, where technical and social elements interact and integrate. We see the evolution as a combination of bottom-up processes, where subjects are gradually digitalized by internal actors, and top-down processes where strategic and logistical needs are served by larger and shared solutions. Second, the digital learning space was enacted and harnessed by redefinition of roles between students and teachers, allowing for new and deeper learning forms. With so many digital resources at hand, the task of the lecturer will be fewer lectures, and to act more as a facilitator of resources, and to monitor activities and results over time. And third, the digital learning space enables universities to transcend the physical and institutional borders, and engage in interactions with the broader society. Organisationally, there is not one digital learning space, but many, and they intersect with hybrid and physical spaces. The opportunities illustrate that the digital learning space enables new forms of knowledge development, including new actors outside the academic institution.

We argue that these three development, including the speed with which they evolve, together indicate that higher education has started a full digital transformation.

Sample credit author statement

Bendik Bygstad: Conceptualisation, Writing, Data collection. Egil Øvrelid: Conceptualisation, Writing, Data collection Sten Ludvigsen: Conceptualisation, consistency in argument Morten Dæhlen: Conceptualisation, reviewing.

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