CHAPTER 3

Dual Digitalization: A Framework for Digital Transformations of Higher Education

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Introduction

When the Norwegian government, at the outbreak of the COVID-19 pandemic, closed down the country on March 12, 2020, the University of Oslo used only one week to transition into digital education. Many universities around the world succeeded, more or less, in the same way

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(Crawford et al., 2020; Dick et al., 2020). How was this possible? The question is not trivial, because many other knowledge organizations, such as hospitals, were not able to do this.

One answer 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 financial systems, were implemented in the 1980s and 90s and owned by the university administration. Further, there has been a vibrant development of digital solutions for research at the various faculties. Based on this, we note that digitalization of the core university tasks has followed two different tracks, which we suggest to call *dual digitalization*:

- Educational solutions, such as Learning Management Systems (LMS), MOOCs, course websites, and library systems, were gradually implemented after 2000 when they became standardized and run by schools or the IT department.
- Digitalization of subjects was mainly developed locally by academics. In particular, research solutions were often decentralized, usually down to research groups or even individual researchers.

What happened in 2020? First, millions of students were transferred from campus to *virtual classrooms*, using tools such as Teams and Zoom (Crawford et al., 2020). One can imagine that the use of digital resources to lecture facilitates the interaction between student and lecturer leading to new pedagogical forms and institutional routines. Second, both students and academic staff and administration embarked on a fast experimentation and learning process on how to teach, learn, and administer digital education (Dick et al., 2020). The jury is still out regarding the long-term effects, but many researchers assume they will be far-reaching.

To investigate and elaborate on these deep and transformative processes we suggest a framework called *dual digitalization* for analysing these changes at a more fundamental level. Our research question is *how can we conceptualize and manage dual digitalization?*

We proceed by reviewing the research on digitalization, in particular, the two processes of digital logistics and digital subjects and summarize the discussion in a framework. The framework is described as a digital infrastructure with four key elements: digital education, digital subjects, boundary resources, and data. We present our method and findings

in Sects. "Method" and "Findings—Three Phases of Digital Innovation in Higher Education" and discuss the implications of our work in Sect. "Discussion".

Digitalization in Higher Education: Identifying and Connecting Separate Streams

Digitalization in Higher Education

Higher education is a central venue for the creation of new knowledge economies for the twenty-first 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 English-speaking countries, where strategies from private sector industries are seen as beneficial also for higher education (Commission (EC), 2012; Pucciarelli & Kaplan, 2016). Furthermore, some researchers have argued that universities fall behind other sectors in digitalization (Rodríguez-Abitia & Bribiesca-Correa, 2021). However, many universities have a stable financial structure based on state funding. This means that universities differ a lot and use other models for digital transformation/innovation than those used in other sectors.

Historically, universities were characterized by decentralized organizations to address local and regional as well as professional requirements (Sam & Van Der Sjide, 2014). There is, therefore, an inherent tension between the governments' ambitions to use centralized strategies dominated by strategic thinking (Pucciarelli & Kaplan, 2016), and the various professional specialties' need for self-management and control dominated by local optimization (Clark Burton, 1983). Further, digitalization provides a good overview of students' digital readiness (Kim et al., 2019; Horrigan, 2016). This provides a knowledge base appropriate to tailor the teaching to individual needs (Blayone et al., 2018).

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. The tendency is that the various professions are moving towards data science, to which we will return below.

Digitalization of Education

The lockdowns caused by the corona pandemic gave higher education institutions a disruptive shock and required them to establish communication technologies for digital teaching. Massive Open Online Courses (MOOCs) had a breakthrough in 2012 (Kaplan & Haenlein, 2016; Siemens et al., 2015) and were an established communication technology for online learning before Covid-19 (Siemens et al., 2015). In Scandinavia, MOOCs were mainly developed by academic staff, without a nationally governed strategy (Tømte et al., 2020). Moreover, technically, some of these technologies, such as Zoom (Lowenthal et al., 2020) and Teams (Martin & Tapp, 2019), were already in place but had to be configured to fit mainstream teaching. Furthermore, slightly larger teaching platforms such as Canvas (Wilcox et al., 2016) achieved an even more important role in teaching and learning. Educationally, there is a need to distinguish emergency remote teaching from high-quality online education. While emergency remote teaching is caused by crisis circumstances, high-quality teaching requires longitudinal engagement. This indicates that even if we responded quickly to the corona crisis, adaptations to a qualitative online education are a long-term process (Bond et al., 2021; Hodges et al., 2020).

We regard these issues as an important part of education in enabling flow and interaction between professionals or between professionals and students.

Digitalization of the Subjects

The digitalization of the subjects has taken place over time both in the natural sciences and in the humanities, as well as within the study of law and medicine. The discourse around these digitalization processes is, however, often directed towards strategy (Commission (EC), 2012; Pucciarelli & Kaplan, 2016) or towards learning problematics (Aagaard & Lund, 2019; Laterza et al., 2020). Strategy in the sense that digitalization creates increased efficiency opportunities, through centralized governance. Learning problematics since digitalization affects learning, and enables new learning methods (Aagaard & Lund, 2019; Henderson et al., 2017), as well as learning analytics (Viberg et al., 2018). The latter part of the literature is also occupied with pedagogical and epistemic changes caused by digitalization. Pedagogical changes in that digital

transformation also motivated a pedagogical shift within higher education, moving from teacher-led instructions towards more student-active teaching methods (Tømte and Lazareva this volume). This also includes changing pedagogical conventions regarding what is good teaching when education is transferred from physical to digital (Hermansen and Lund, this volume). Further, extant literature also points to epistemic changes caused by digitalization. With increased digital competency, more long-lasting online engagement is made possible (Hermansen and Lund this volume, Tømte and Lazareva this volume). This is also because digitalization transforms conditions for human activity include education, knowledge creation, and governance (ibid.).

We extend this discussion to include the digitalization of the subject towards a digital representation of professional knowledge. Within biology, this could be transforming the field from focusing on natural objects to an orientation towards digital objects (Kulathinal et al., 2020). Within law, this applies to the transition from books to digital sources (Øvrelid et al., 2020). In medicine, it is about how human biology is represented digitally (Elenko et al., 2015), and finally, in the humanities, digital corpuses that enable trawling in extensive amounts of data can be developed (Tangherlini & Leonard, 2013).

Data Science

The digitalization of subjects involves an orientation towards data science that also include domain-specific issues. It has been clear for some years that the digital environment in higher universities, primarily not only in research but also in education, generates enormous amounts of data. Well-known examples are particle physics, biology (DNA sequencing), meteorology (computation of weather data), medicine (precision medicine), and economics (econometrics). The potential for new approaches in research and methods is quite high (Berman et al., 2018; Daniel, 2018). This applies not only to the hard sciences. In the article "Trawling in the Sea of the Great Unread: Sub-corpus topic modeling and Humanities research," the researchers describe a quantitative approach that allows them to identify previously unknown or historically ignored patterns and literature (Tangherlini & Leonard, 2013).

In education, large amounts of data are also generated, since students leave digital traces in the digital environments that they use. Such developments give a set of new possibilities for analysing students' activities.

Learning analytics will become increasingly important as a resource for understanding new generations of students and how they choose to navigate in their studies (Viberg et al., 2018). The potential for research, learning, and pedagogy is similarly quite significant.

Summing-Up

As we have seen, higher education research has addressed various types of technology used for digitalization of education and subjects, but many questions remain. As this review has shown, most of the contributions are about specific aspects of digitalization such as learning analytics, logistics, pedagogy, and digital agency, which means that it is difficult to get an overall concept of this digital transformation. From the literature, it is not clear how these streams (digitalization of education and digitalization of subjects) are connected. Neither is it clear what the role of data is in the larger picture. To shed light on this, we propose a conceptual framework.

Framework

Based on our review of the literature, we suggest an overall framework, consisting of four elements: digital education, digital subjects, boundary resources, and data (see Fig. 3.1).

Education (Teaching and logistics) is process-oriented and deals with the digital classroom and LMS, the provision of digital materials, such as PowerPoints, video presentations, and the communication of learning outcomes, assignments, and exams.

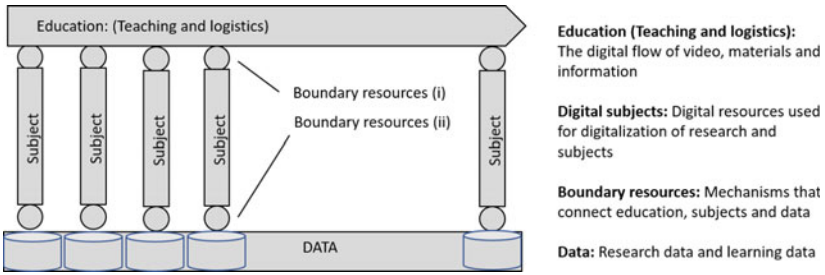

Fig. 3.1 A framework for dual digitalisation (*Source* Authors own)

Digital subjects are knowledge-oriented and deal with domain knowledge. In computer science, this could be programming, in medicine e-learning resources, in economics transactional data for learning econometrics.

Boundary resources are technical and social mechanisms that connect educational processes and data (Ghazawneh & Henfridsson, 2013). We suggest two types of boundary resources. One type (i) is exemplified by LMS functionality, which connects the teaching process with digital subjects. This allows the student to move quite seamlessly from the digital classroom to the digital resources. The other type (ii) connects digital subjects with larger volumes of research data.

Digital data is here primarily research data. It also includes volume data for statistical purposes and educational data for learning analytics. We should emphasize that the framework is conceptual (not a representation of reality), which we use as a sensitizing device in our further investigation.

Method

The background is a four-year project that investigated digitalization in higher education. The researchers engaged with faculties such as pedagogics, law, and medicine over time. 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 processes, and needs to be managed with this insight. A key aspect of digital infrastructures is the interplay between digital resources at the user level and the interconnected technologies with representations of the domain (Henfridsson & Bygstad, 2013).

Data Collection

The study is a thematic analysis based on interviews with expert informants. To ensure sufficient breadth, we selected key informants from faculties such as Law, Social sciences, Natural sciences, Medicine, Humanities, and Educational sciences. In addition, we interviewed managers and

Table 3.1 Practice area and informants

Digital practice area	*Informants*	*Teaching and logistics*	*Digital subjects*
Law	Professor Librarian	From manual to digital sources of law for teaching	Lovdata
Social sciences	Study leader	Use of Zoom and Canvas during the corona 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 NB
Educational sciences	Engineer and researcher	Digital solutions for teaching	Learning analytics
USIT	CIO Manager	IT architecture and digital services of UiO	TSD (services for sensitive data)

Source Authors own

experts from the IT department. The informants were selected for their expertise regarding digitalization. The interviews were semi-structured, lasting 1–2 hours, and focused on the areas of expertise of the informants, and their relation to digitalization. Because of the pandemic crises, several of the interviews were done digitally others physically. In addition to the interviews, we collected available archival materials, such as plans and reports, architectural documents, and web pages (Table 3.1).

Data Analysis

Data analysis was conducted in three steps (Pettigrew, 1985). First, based on empirical material from our study, and the literature, we conducted a chronological analysis of respectively digitalization of teaching and subjects. We framed the two streams as respectively digital flow and digital representation. Second, a thematic analysis of the expert interviews was conducted, identifying key topics and trends. As a part of this, an architectural analysis of the overall digital solutions at the university was conducted, comparing solutions at different levels. Finally, we did

Table 3.2 Data analysis process

Step	*Activity*	*Challenges*	*Result*
1	Chronological analyses	Identifying key events	Chronology of digitalisation at UiO (Fig. 3.2)
2	Thematic analyses	Analysing the two digitalization streams, as well as their interplay and convergence	Findings: Three phases of digitalisation
3	Comprehensive analyses	Analysing and assessing the underlying forces of the digital learning space	Discussion: How to conceptualize and manage dual digitalization

a comprehensive analysis, where we systematically used the framework (Fig. 3.1), to analyse the two digitalization processes; digital education, and digital subjects, boundary resources, and data. Lastly, we responded to our research question by analysing the underlying forces of the digital learning space (Table 3.2).

Findings—Three Phases of Digital Innovation in Higher Education

Based on the chronological analysis, we structure findings into three phases. We follow the development of two separate processes—digital education and digital subjects—how they convergence and become institutionalized in a shared digital space.

Phase 1: Two Separate Processes (Unintegrated Digital Resources)

As illustrated in Fig. 3.2 we identified two separate processes of digitalization. *The digital 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 much liked by the students. A new LMS, Canvas, was introduced ten years later, slightly more successful.

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

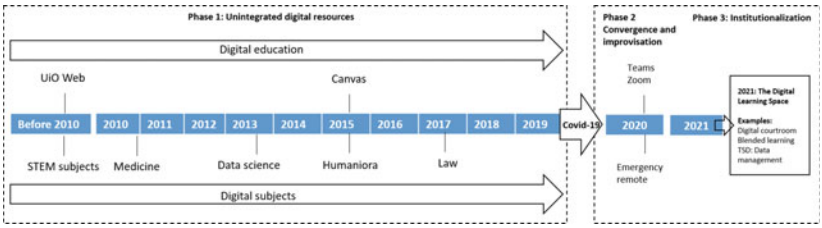

Fig. 3.2 Chronology of digitalisation at University of Oslo (*Source* Authors own)

1980s, some of them (for instance, meteorology) even earlier. But after around 2010 something new emerged, the disciplines became more data-oriented and also algorithm-oriented. An example from biology illustrates this; biology students used to go for walks in the woods to collect and analyse 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.

> 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. [Professor, e-learning expert]

At the Faculty of Law, a digital resource called *Lovdata* (including all laws and court decisions) was implemented in full-scale teaching. One reason was that the law firms increasingly expected new lawyers to be digitally competent. This system enabled a transition from manually oriented teaching techniques to digitally oriented teaching, learning, and examination. The dean at the faculty emphasized the increased learning mechanisms provided by the system:

> The students individualize the material through the semester, through notes, cross-teaching, and so forth. The reward is that Lovdata can be used on the exam. Earlier the students 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. [Professor, Law]

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 from newspapers, journals, books, and research material enabling a change of focus from concentrating on canonical texts to gain an overview of lesser-known stories and their impact at the time.

The development of digital subjects implied that boundary resources between subjects and data for enabling digital interaction had to be developed. E-learning in medicine implied that physical resources were made digital and that application provider interface (APIs) were used to implement this as a web solution (the e-learning portal). At the Faculty of Law, Lovdata became a digital resource by using APIs to enable the use of digital legal sources and by linking these sources to a specific case in Lovdata. In the Humanities, digital corpuses that facilitated access to digital libraries were created. Digital corpuses are interfaces that enable structured data harvest from extensive amounts of historical sources. These corpuses were potential game-changers in that "sleeping data" was brought into life and used in statistics and such.

Although each subject area underwent extensive digitalization, the data produced were quite fragmented. This was especially true of research data. As a result, the University of Oslo pioneered from 2015 a solution called TSD, a general solution to collect, store, and secure sensitive research data. By 2021, TSD had more than 1000 research projects.

Phase 2: Convergence of Education and Digital Subjects

The situation was dramatically changed with the Covid-19 lockdown in Norway in March 2020. The university closed immediately, and a central task group of deans and 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 homes at their parents. One expert informant commented:

> Most teachers responded by a combination of on-line 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 positively, accepting the situation, and participating on-line. 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. [Professor, Natural Science]

Then a process of improvization and experimentation started, with teachers and students in new roles. First, this process was conditioned by emergency remote education, since Covid-19 and the closedown of the country surprised everybody. Later, lecturers became increasingly knowledgeable and used various educational elements to improve the quality. We interpret this development as a *convergence* between the two streams, i.e., the logistics and digital subjects met in the digital classroom. The integration was made possible by the two types of boundary resources, described in Fig. 3.1. One example is how more advanced use of Canvas offers links between education and digital subjects. Canvas has interfaces towards a range of different educational modules and is as such a rich infrastructure for communication between teachers and students. An example is how Leganto is connected to literature. Leganto is a system for editing and publishing course curriculums. Leganto can be integrated with and be available via Canvas. We can therefore see Leganto as a boundary resource that connects teaching and subjects.

> For the students not having to copy articles and borrow books from the library, we register them in Leganto. Then they can access articles and books digitally. This entails a lot of extra work for us [teachers] but makes it easier for the student… They can order books directly from Leganto without using Oria [The library system]. [Professor, Humanities]

Within the Faculty of Medicine, the e-learning portal became a communication channel for subject-related digitalization in teaching, as a central part of a blended learning approach. Resources within the portal were also integrated with examination systems like Question Mark Perception and Inspera.

At the Faculty of Law, Lovdata became central in the education and examination of the students. During the semester, the students had configured their Lovdata profile with knowledgeable resources and were allowed to use this configuration on the exam. This also meant that physical books became redundant. The digitalization of sources of law can also be further expanded to include machine learning and artificial intelligence. The amount of legal sources is gradually becoming quite extensive. This necessitates systematic facilitation so that the lawyer can more easily get an overview of the relevant sources for a specific case. Machine learning and artificial intelligence can contribute to this.

These examples show that logistics and subjects were gradually converged. This was technically supported by boundary resources (such as APIs and other mechanisms) that enabled access to research data in advanced courses. The digital classroom 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. [Librarian, Faculty of Law]

Phase 3: Institutionalization in a Digital Learning 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 (Studiebarometeret, 2021), 71% of 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. These numbers illustrate, not surprisingly, that the social aspects of both structured education and student life play an important role, and were greatly missed. It is also important to emphasize that the students' at the University of Oslo were as productive as in previous years related to credit production.

Related to digitalization, 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. We see primarily two aspects of institutionalization.

First, the emergence of digital learning rooms. A compelling example from the Faculty of Law is the concept of a digital courtroom. 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 education and subject. The institutionalization of Lovdata in teaching means that the student acquires more digital skills as an integral part of knowledge development.

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. Within the digital humanities, the digital corpus similarly brings forward new institutional practices to conduct research.

> "Modern humanities research may use digital corpuses…"... "this enable the identification of new (or forgotten) texts, that challenges the canonical view, or that may bring more contextual insights around the canonical texts". [Professor, History of Ideas]

Second, we see that the management of data is becoming an area of concern and investment. Research data management has been called a "wicked problem" (Awre et al., 2015) since the fragmentation problem has proved very difficult to mitigate. However, the digital convergence of 2020 has highlighted the need for a more comprehensive and professional approach to research data, in particular as an educational resource. The success of the Tjenester for sensitive data (TSD) solution shows one way forward. Regarding TSD, steps are taken to ensure a gradual transition to a general research data platform for the whole university and perhaps beyond. In parallel, we observe the rise of data science as a general discipline for the university.

Discussion

Extant literature has demonstrated that higher education is an important venue for the new knowledge economies (Sam & Van Der Sjide, 2014), and that digitalization is a key means to realize this potential (Selwyn, 2016). Since knowledge creation at universities is highly decentralized in several research environments (Clark Burton, 1983), centralized strategies challenge the autonomy of the organizing logic (EU Comission, 2012; Pucciarelli & Kaplan, 2016). Transformation of higher education needs to consider this.

Our point of departure was that earlier literature divided digitalization efforts into two separate processes: digitalization of teaching and digitalization of subjects. While digitalization of teaching has concentrated on the educational matters such as the use of Moocs (Kaplan & Haenlein, 2016; Lowenthal et al., 2020; Martin & Tapp, 2019; Siemens et al., 2015; Tømte et al., 2020), and the division between emergency remote teaching and qualitative online teaching (Bond et al., 2021; Hodges et al., 2020); digitalization of subjects mainly focused on strategy (EU commission, 2012; Pucciarelli & Kaplan, 2016), or dataification (Kulathinal et al., 2020; Øvrelid et al., 2020; Elenko et al., 2015, Tangerlini & Leonard, 2013), and the pedagogical and epistemic consequences of this (Aagaard & Lund, 2019, Henderson et al., 2017, Viberg et al., 2018, Hermansen and Lund this volume, Tømte, and Lazareva this volume). Each of these areas of research gives important insight into higher education and selected aspects of digitalization. However few, if any of these studies, take the more integrated perspective on the relationship between the development of a more flexible and innovative digital infrastructure that includes both heavy- and lightweight IT and the development of content and resources in the subjects.

The implication is that we build on this insight but extend and reformulate how educational issues and subject issues converge and transform higher education. Our research question was *how can we conceptualize and manage dual digitalization*. We start by discussing the conceptualization.

How Can We Conceptualize Dual Digitalization?

We conceptualize dual digitalization by our framework (Fig. 3.1). We define dual digitalization as *the process by which educational issues converge with digital subjects, enabled by boundary resources and data*.

We argue that the convergence of the two streams led to a digital transformation of higher education, and finally established a *digital learning space*, integrated by boundary resources. This happened through two steps. First, when the Norwegian government, at the outbreak of the Covid-19 pandemic, closed down the country on March 12, 2020, the University of Oslo needed to respond quickly. The emergency reaction (Bond et al., 2021; Hodges et al., 2020) meant using the lecture material that we had on the subject matter, as well as using lightweight systems such as zoom to communicate the subject matter. The central IT unit (USIT) integrated zoom and outlook to reduce the barriers of online teaching. Lightweight systems like Zoom are easy to adopt. Gradually a reconfiguration of educational modes into a more qualitative hybrid model was made possible.

The transformation lies in the institutionalization of this convergence, which does not merge the two streams, but rather integrates them. 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 argue here that this was true before the corona crisis, and in the period right after the covid-19 lockdown, but that the rapid development during 2020 has created lasting and transformational changes. In contrast to the digital transformation of business organizations, which focuses on new business models (Vial, 2019), transformation of universities is more about relationships, and a redefinition of academic domains.

What is being transformed?

First, we argue that the converged infrastructure and the new practices change the relationship between students and teachers, by a redefinition of roles. The traditional 2 × 45 minutes lecture is less central and is being replaced by shorter, often pre-recorded video sessions. With many digital resources at hand, the role of the teacher will be less direct teaching and more of a facilitator of resources. This is in line with predictions of *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, p. 252).

Second, the campus is changing from a physical location to a hybrid, where the digital classroom 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.

Third, 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.

Theoretically, dual digitalization is a duality that grasps the interconnectedness between digitalization of education and digitalization of the subjects. While the first concentrate on the pedagogical and communicative flow of educational issues, the second focus on the incremental dataification of subjects. The two streams thus have complementary interests and adaptive abilities. Thus, we see dual digitalization as a duality of interdependent although analytically distinct elements.

How Can We Manage Dual Digitalization?

We have argued above that digital transformation of higher education is different from digitalization of businesses. For leaders and teachers, there are several challenges, but also opportunities. While some researchers have been critical of the lack of strategic management of higher education (Rodríguez-Abitia & Bribiesca-Correa, 2021), the rapid response to the Covid-19 crisis shows a way forward. And although there is tension between top-down (of educational issues) and bottom-up (digital subjects) approaches (Pucciarelli & Kaplan, 2016), our findings show that this tension is sound and should be leveraged. However, it should be supported by careful design and implementation of boundary resources. In addition, universities are different in its operation and such variants would need to be included in the strategic development of each institution.

We summarize the key issues in four points. First, the educational processes should be centralized and standardized, while digital subjects should remain decentralized and run by the academic groups, as indicated in the framework, Fig. 3.1. However, the digital infrastructure should appear seamless.

Second, boundary resources, connecting logistics and subjects, and providing access to data should be centralized and standardized. It is expensive and inefficient to do this locally. The consequences of centrally governed boundary resources logically add a lot of burden on the central IT unit. Moreover, the boundary resources must connect the user-oriented services with a digital platform core that stores and maintains all the data. To reach this maturity level, the tension between global and local IT resources needs to be reduced (Bygstad et al., 2019).

Third, the shared digital learning space is still fragmented and creates grave difficulties in facilitating qualitative education based on principles of interaction. The shared digital space, thus, should, for pedagogical reasons, be more integrated. This probably requires a platform structure that can facilitate the integration between different physical-hybrid learning spaces in such a way that the distinction is reduced.

Fourth, research data management is needed to more carefully enable data-driven decision-making, but should be organized as a collaborative effort. The TSD solution is a good example since it demonstrates how platforms can facilitate the management of massive amounts of data.

Conclusion

In summary, this paper explores the concept of dual digitalization. We define dual digitalization as *the process by which education converge with digital subjects, enabled by boundary resources and data*. First, we increase the understanding of the phenomena of dual digitalization by emphasizing its role in changing the relationship between student and teacher, its role in the hybridization of the digital and physical at the campus, and the role of dataification in changing the subjects. Second, we describe how dual digitalization can be managed. The logistics process should be centralized while the knowledge-oriented processes should be decentralized. Then, we find that the convergence of the two processes requires appropriate boundary resources, to create the digital learning space.

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