INF5210

INFORMATION INFRASTRUCTURES

DIGITAL EKSAMEN DELIVERABLE 2

Magnus Ofstad
Magnus Korvald
Vivek Kaul
Espen Johnsson
Bjørn Marius Von Zernichow

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Introduction

The University of Oslo (UiO) is now in the process of introducing digital examination as an alternative to paper-based examination. Digital examination will require changes to IT infrastructure, physical infrastructure and existing work processes and procedures involving students, censors and administrative personnel. UiO will prioritise the introduction of digital examination, as part of the innovation of teaching and learning. Digital examination will reduce manual work and possible sources of errors, and simplify overall work processes related to the examination (Hemsing, 2015).

In our report, we will focus on describing the case "Digital Exam in UiO" as an Information Infrastructure (II) in use or under planning/development. We will further define what makes an II, and how the case can be described as such. The complexity will be described in relation to complexity theories, based on - and referring to - existing research on II and complexity. The evolution of Digital Exam as an II is also investigated and discussed based on a framework which analyses II based on certain success criteria.

Our methods and sources of information are based on existing information infrastructure theories and research, interviews with two employees (in this report named "informant") involved in Digital Exam at UiO, reports from experiences with Digital Exam in UiO, and project related information available at the UiO Digital Examination website.

Terms and definitions

USIT

USIT supports UiO's main areas of commitment: research, education and applied knowledge. USIT is also a national centre of competency in IT for the higher education sector.

Innovation

"A self-reinforcing process by which new products and services are created as infrastructure malleability spawns recombination of resources" (Henfridsson and Bygstad, 2013).

Adoption

"A self-reinforcing process by which more users adopt the infrastructure as more resources invested increase the usefulness of the infrastructure" (Henfridsson and Bygstad, 2013).

Scalability

"A self-reinforcing process by which an infrastructure expands its reach as it attracts new partners by offering incentives for collaboration" (Henfridsson and Bygstad, 2013).

Theoretical framework - a socio-technical approach

In this project we're assuming that technology standing alone is not enough to create change. Despite the fact that personal computers have been around for ages. Paper-based exams have proven hard to replace. Studying current and future changes in the Digital Exam system, we have to take account of the complex relationships between societal factors and technology. In our approach, technological, cultural, organizational and social factors are integrated to explain changes in the exam system. Thus any changes is viewed as a bundle of factors coming together. The university is a socio-technical system, which include people and processes, as well as technological systems. Individual and institutional views on digitizing the exam system depends on organizational rules and regulations, as well as organizational culture, or "the way things are done around here" (Sommerville et al., 2012).

In this paper we will introduce the theory of II as a socio-technical approach to explain changes in the exam system at UiO. We have divided the total analysis into three parts:

In Part I, we will give a short description on how Digital Exam came about. Then we will define what makes an II and discuss how Digital Exam fits with the general theory of II.

In Part II, we analyse challenges, strategies and likely outcomes surrounding the evolution of the infrastructure. We will specifically use a framework proposed by Grisot et al. (2014) to analyse the evolution of Digital Exam in terms of installed base cultivation.

In Part III, we will discuss if the contextual conditions and evolutionary mechanisms of Digital Exam are considered sufficient to produce a successful outcome. We will use a configurational perspective (Henfridsson and Bygstad, 2013) in our analysis of causal paths to discuss if certain combinations of mechanisms (adoption, innovation and scaling - as defined in "Terms and Definitions") may lead to successful evolution of Digital Exam. In the case of a successful outcome, we will recommend following current strategies. In the event of unsuccessful outcome in terms of the framework analysis, we will propose alternative strategies.

Part I - Describing the II

Case description

The project Digital Exam started in 2012, with the goal that all the students at the University of Oslo should have digital examination instead of the regular paper examination within the foreseeable future (Ofstad et al., 2014). Within the same year as the project start, The Faculty of Law managed to conduct their first digital exam. It should also be mentioned that at the same time, other universities around in Norway were also testing technical solutions for conducting digital examinations on a course-to-course basis, so this was not something restricted to The Faculty of Law. Since then a lot has happened, and the project has spread to several faculties within the university.

One of the reasons that the faculty of Law managed to conduct their first digital examination within the same year as the project started, was the initiative taken by the faculty. The faculty wanted to conduct their own digital examinations without waiting for the central project; therefore the faculty received funding, and in cooperation with USIT managed to build a technical solution specially designed for the faculty.

For understanding the project structure, it is necessary to understand how the university operates. The University of Oslo has adopted something that is referred to as a “proximity model” (“Gjennomføring av nærhetsmodellen,” n.d.). This model states that all decisions should be taken at the lowest possible effective level. This means that the central university administration should not make decisions that could be made on a department level. The goal of the model is:

- The organization of the administrative services should follow a decentralized model that involves increased responsibility and authority at the local level.
- Where tasks require particular expertise or attention (in regards to funding etc.), there is still the possibility to elect centralized solutions.
- Less management and reporting: Aim to avoid a control regime, dominated by reporting and auditing

As a result of this organising principle, it is up each each faculty how they choose to adopt digital examination. This model has led to the effect that digital exams have been introduced individually and scattered in different parts of the University. It has not been part of an all-encompassing university effort. Today however, our informants says the project is in need of some overarching coordination effort.

Accordingly, we now have multiple different technical solutions, the first one being developed by USIT, and the second one being developed by a private firm called Inspera (“Inspera,” n.d.).

A central question in the interviews we conducted was: “why the university choose to adopt a second technical solution when The Faculty of Law, in collaboration with USIT, already had a solution ready”? The answer from our informants was that “the project still is in its very infancy, which is why there are no guidelines developed that forces the departments to use the same technical solution”. In addition, the solution developed by USIT did not fit the requirements posed by other faculties, namely The Faculty of Mathematics and Natural Sciences. We were also informed that as of now, there are no plans to force all faculties to use the same technical solution, once the project is out of its test-phase. This entails that we into the future could see digital examinations being carried out at the university of Oslo, using different technical solutions depending on the faculties.

It is also worth mentioning that as of January 2015, University of Oslo signed a deal with Inspera, making Inspera the primary provider of the technical solution that will be used in the project. This makes the University tied up to one provider at least until the deal with Inspera expires (but can still use existing technical solutions that predates this deal).

The project is still very much in the trial-phase, and the goal for this semester (autumn 2015) is to test the technical solution provided by Inspera on a large scale with 500 students (Henriksen, 2015). We have summed up the most important features of the structural properties in table 1 below.

Structural properties	Digital exam II
Organizing principle	● Local grassroot initiatives for Digital Exam ● Inspera provides a centralized solution ○ Serves more than one customer ● USIT provides an alternative and different solution to Digital Exam
Control	● Inspera solution is proprietary ○ Lockin - replacing the vendor solution requires work ● The university has an agreement with Inspira (anbud) that is (up to review) renewed every fourth year. (licensing-out with an option to extend the contract every fourth year)

Table 1. Structural properties

Defining an Information Infrastructure

At first hand we are likely to associate infrastructures with large physical objects like roads, bridges and power stations. Although infrastructure usually constitutes large entities in our mind, infrastructure has some invisible qualities. It somehow sinks “into the background” (Star and Ruhleder, 1996). We are noticing water running out of the tap, but are paying less attention to the plumbing, network of pipes and the water sanitation plant that makes up our water supply. Infrastructure is in many ways a “substrate”: something that other things is running upon (ibid, p. 112). It is the facilities and services which are enabling our modern way of live and it first becomes “visible upon breakdown” (ibid, p 113).

II doesn’t lend itself so easily to our colloquially understanding of infrastructure. Where are all the large physical installations? But, when we start thinking about it, it has many of the same qualities as the water supply. When we are turning on the computer we don’t think of all the servers, data centers, switches, hubs, routers or the network which creates internet connectivity. As users we are interested in executing some software, not looking into the hardware in which the program is running on. In many respects II is unique. It is the human users, i.e. the software developers, the designers and end users which make the infrastructure recognizable, discernible and valuable. The effort and involvement from the users plays a vital role in the development of IT capabilities. There is always some new software to be made, better solutions that can be advanced by information technology, and that’s why II constantly evolves and emerges in new arenas of the society. In fact, today II have become totally embedded in our society. Some view this as an infrastructural inversion. The new infrastructure is taking leadership and becomes the driving force behind societal change (Bowker, 1995).

Anyway, it is this constant interplay between machinery and human tinkering, which in our opinion characterizes information infrastructure. That’s why, we will define information infrastructure “*as a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their user, operations and design communities*” (Hanseth and Lyytinen, 2010).

This definition presupposes that IT-infrastructure in its purest form is somehow universally shared among members of a community. Principally, anyone can contribute to the development of the infrastructure, because there are no rules for who can develop and design new features and properties in the structure. This openness gives II a distinguishing quality of something that is continuously evolving in modular increments. The shared, open and evolving properties of II contribute to the fact that the diversity and heterogeneity of the structure and user-groups expands. Furthermore, the evolution of II is “both enabled and constrained by the installed base” (ibid). We rarely come across II that are completely finished. Strangely enough, there is seldom any clear goal that defines the final structure. Information technology will always have the possibilities to find new channels, new applications and new users. When new IT capabilities has been created, it is more likely to involve an expansion or slight modification of existing infrastructure than a radically new design from scratch. Somehow II “wrestles with the inertia of the installed base and inherits strengths and limitations from that base” (Star and Ruhleder, 1996). An II is a socio-technical system. In the university we come across a large and complex web of relations between technical and social issues (Hanseth and Lyytinen 2010, Star and Ruhleder 1996, Sommerville 2012, Hanseth and Monteiro 1997).

Digital Exam as an II

Internet, Wikipedia and the iPhone platform are obvious examples of II. We can easily tick of all the boxes when it comes to openness, shared, evolving and so forth. Our case, Digital Exam, doesn’t have the same evident properties, but it has some distinct features which make it meaningful to refer to it as an infrastructure. Mainly its functions have to run on an installed base. Its services have to be integrated into the existing IT system of the university, which we can see from the diagram in the appendix looks fairly complex (Appendix fig. 1). Moreover, it has to fit with the university teaching schedule, syllabus and organizational features. Our informants argued that there are organizational barriers rather than technicalities which pose integration problems. How Digital Exam has evolved on top of an installed base is commensurable with the II theory. Alignment, according to II, is most likely not the result of any top-down plans or decisions. “It is the achievement of a process of bottom-up mobilizations of heterogeneous things” (Ciborra et al., 2001).

An enterprise IT-system isn’t open and shared similar to the internet or the application ecology that surround the iPhone platform. If we look at the overall situation for Digital Exam today, i.e. several efforts from different faculties, advanced by individual pioneers, implemented individually and integrated into the infrastructure totally decoupled from each other. Then we can without problem state, that the infrastructure is sufficiently open to allow tinkering and bricolage within the technical system, even though the technical expansion of Digital Exam capabilities exclusively has been undertaken by insiders, largely teaching staff or administrative support who wants to achieve something in this area. The openness explains why a multitude of actors has been able to pilot Digital Exams from different faculties, often at the same time and usually in a no-coordinated fashion (see figure 2).

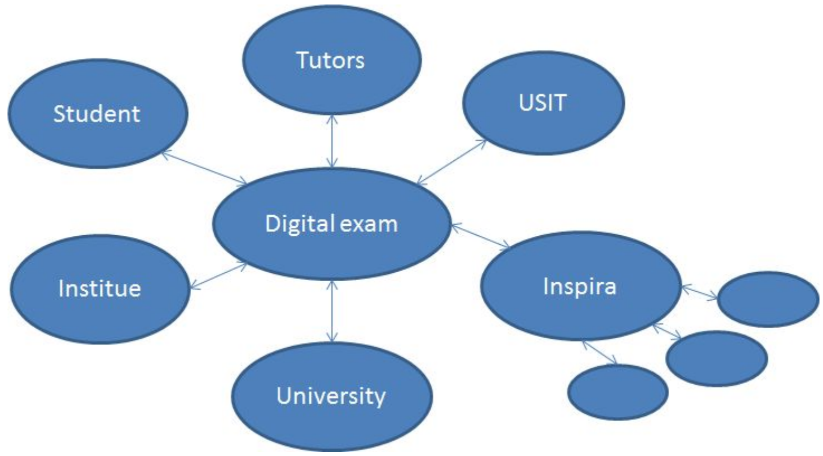

Figure 2. Actors in Exam Information Infrastructure

As a matter of fact, both of our informants emphasized that projects like Digital Exam was totally dependent on someone who were willing to take upon themselves the considerable task of developing a new capability inside the information infrastructure. Tasks like this didn't only involve technical challenges. In order to succeed, you had to be able to build alliances on both the administrative level as well as organize the concrete technical implementation. The impression of tinkering and bricolage in the early stages is in this perspective obvious and according to II typical for the evolution of technological solutions.

The Digital Exam infrastructure is today open in the sense that all courses that wants to apply and use Digital Exam as a tool for evaluation can do so. Contracts restricts other stakeholders than Inspera from providing new technical solutions that could potentially be integrated alongside the two existing solutions. This is however however not a technical constraint. The Digital Exam infrastructure is evolving from the existing installed base.

The university IT-infrastructure is in other words adequately customized to fit the need for the different Digital Exam systems. This is largely due to the openness of the system. As a technical matter of fact, the cloud based client server architecture is theoretically allowing a very high number of connections. Additionally, any computer running Windows or Mac that is connected to the internet, can become part of the infrastructure. This supports “bring your own device” to the exam or any other task which involve matters concerning the university IT-system. In many respects, certain parts of the Digital Exam system is shared among different actors (see figure 2). The Inspera solution is shared by different stakeholders. The secure browser used in this solution is open source. The examination server system is proprietary software and is cloud based. In its current form the Digital Exam mimics a traditional exam by being situated at a specific place at a particular time. The exam is conducted in a room where there is a limited set of resources. Ultimately, the technical capacity of the system can be very high and almost limitless compared to the need for physical resources on the examination site, such as computers, power outlets, desks and so on and so forth. However, it is regarded that the highest complexity exists on the organizational level, which we will discuss further in Part II.

Accordingly, we can tick of the shared and open properties that characteristically make up an II. When we look into the total makeup of the university IT-system, the evolving development of the infrastructure sticks out. From the early digitalization in the previous century, the infrastructure has evolved in modular increments, and over time the Cerebrum entity has developed into the central integration hub (Ofstad et al., 2014.). During the years the system also needed to be able to communicate with systems outside (Feide), and it had to cope with the growing FS entity (a database over all the students and their data properties). Technically, every conceivable introduction of digital exams has to deal with FS, Cerebrum and Feide at one point. Digital exam is nothing more than a new component plugged into the infrastructure (Ofstad et al., 2014). Today, it is simply a fact that both the Inspera exam solution and the university's own exam design is integrated into the system as a whole. The Installed base is in other words dominant in the system.

With respect to digital exams, the infrastructure has already grown into a heterogeneous set of stakeholders from different domains, faculties, institutes, public and private sector (see figure 2). The service has already attracted a diversity of students from different subject groups and the technical staff is involved in realizing digital exams. That a heterogeneous set of actors are involved is central in the II theory. Relationships within socio technical networks include both humans and non-human participants. Infrastructures studied on an organizational level have socio-technical complexity. The complexity entails that change only can take place through collaborations with humans and technology. Socio-technical networks undergoes a continuous process of re-evaluation and re-development. The negotiations that take place between actors within the network to uphold a certain order and stability, is the core of any technological development. It is the heterogeneity of the structure that makes the social process of aligning interests complex (Ciborra et al., 2001).

We have summed up the most essential parts of the Digital Exam information infrastructure in table 2 on next page.

Emergent properties	Digital exam II
Shared	● Inspera solution is shared by different stakeholders ● The secure browser is open source ● The examination server system is proprietary software and is cloud based
Open	● The cloud based client server architecture is theoretically allowing a very high number of connections ● Not allowing new IT capabilities (not open) ● Any computer running Windows or Mac that is connected to the internet can become part of the infrastructure - supports “bring your own device” ● Different institutions use same system ● Coexisting implementations (Inspera and USIT) ● Supports a multiplicity of disciplines and courses
Heterogeneous	● Stakeholders from different domains, faculties, institutes, public and private sector ● Diversity of users ● Technical staff required when mimicking traditional exam
Evolving	● Builds on installed base (computers on campus, bring your own device, the internet, web) ● Path dependent ○ The exams are created in the Inspera system and are tied to that system ○ Students and tutors get used to the system ● Inspera implements new functionality that is shared by all ● USIT solution is also available

Table 2. Digital exam II

Discussion of how the theory matches our case

In the paper on the Economics of Standards Hanseth describes infrastructures as public and shared by a community and information systems as systems used by closed organizations (Hanseth, 2000). In this regards, the Digital Exam could be viewed as a system used by a closed user group (students, teachers and technical staff), rather than open and public. However, Hespsø et al. uses the term "e-Infrastructure" when describing the introduction of a Microsoft SharePoint solution in the information infrastructure in an norwegian oil company (Hepsø et al., 2009). This is hardly a public infrastructure, but it is nevertheless easy to identify it as an infrastructure for the many employees of "NorthOil". The SharePoint is shared by the employees of "NorthOil" in the same manner as the Digital Exam is shared by students and teachers at the University of Oslo. Both solutions contains customization of an of the shelf product that is integrated into the existing infrastructure. Although the products are central components in the architecture, and apart the a degree of path dependency, the products can be replaced. This interdependable modularized structure of the infrastructure is in line with how Hanseth describes the evolving information infrastructures (Hanseth, 2000; Hanseth and Lyytinen, 2010). The innovation follows what Grisot et al. describes as the three steps for successful infrastructure innovations. First by enabling experimental activities such as the USIT implementation and the Inspera solution. Second, it now bootstrapping the new infrastructure by enabling course administrators to apply electronic examination to the course content. Thirdly by allowing continuous growth by supporting a growing number of users (Grisot et al., 2014). It can however be debated to what extent the architecture is enabling new services.

Part II - Evolution of Digital Exam

Role of architecture in the evolution of Digital Exam

In this section we will analyse the specific case of Digital Exam as an Information Infrastructure (II) implemented at UiO. On the topic of infrastructure innovation and the role architecture plays in II evolution, Grisot et. al (2014, p.198) "(...) discuss the role architecture plays in the innovation process (...)" and further investigate "(...) how the shifting architectural arrangements supports a cultivation strategy and positively shapes the resulting infrastructural innovation."

Related to II evolution, the authors identify three different types of innovation:

"(...) we identify three types of innovation related to II evolution, which we name innovation of, in, and on infrastructures. While innovation of infrastructures corresponds to the conceptualizations and implementation of a new infrastructure, including re-conceptualizing and re-engineering existing infrastructures, innovation in infrastructures denotes replacing or modifying existing components of an infrastructure without changing the constituting architecture. Finally, innovation on infrastructures signifies the extending of existing infrastructures by adding new modules on top of (or in addition to) what exists."

We will use the discussions provided by Grisot et al. (2014) as a framework when analysing our case of Digital Exam at UiO, identifying what role the architecture plays in the evolution of this specific case.

When it comes to the two different approaches to introducing Digital Exam at UiO, that is respectively the USIT and Inspera solution, the USIT approach that was first introduced, may be considered an innovation of infrastructure. This solution (called *digeksd*) was a new conceptualisation of Digital Exam implemented as a new infrastructure. As illustrated in the integration diagram provided in the appendix, *digeksd* has a tight coupling to surrounding services, such as FS and Cerebrum. This tight coupling and interfacing with several services is a further confirmation of the solution as an innovation of infrastructure. System architecture is developed and fully integrated in UiO's already existing information infrastructure.

Inspera Assessment (Inspera), on the other hand, may be described as an innovation on infrastructure, implying that the solution is developed on top of or in addition to the II of UiO that already exists. The cloud based back-end solution is hosted, managed and maintained by Inspera, and the front-end solution, the safe exam browser, is the user interface. Inspera's system architecture is loosely coupled to UiO's already existing infrastructure, illustrated by the fact that, according to our informant exam data from Inspera must be manually entered in FS. In this sense, Inspera has less integration towards FS and UiO's infrastructure, as opposed to USIT's approach, and could be considered an innovation on infrastructure.

The way both the USIT or Inspera solution appear as of October 2015, they could be classified as an innovation in infrastructure, as defined by Grisot et al. (2014, p.198). Considering both solutions as already existing in UiO's II, though still being subject to innovation and evolution, the solutions may be modified or replaced depending on how the II evolves and which architecture scenario UiO chooses. Both the USIT and Inspera solution may be modified or replaced in the future (Hemsing, 2015).

Grisot et al. (2014, p.199) defines a top-down approach as a strategy where "(...) functional requirements are assumed to be specified beforehand for the whole lifetime of the infrastructures (...)" and the authors state that further innovation processes are assumed to not not take place after implementation. The opposite strategy, considered to form the basis of a successful II, is suggested as the bottom-up approach where "(...) standards are not specified and agreed on up front — they are emergent, flexible, and dynamic".

According to our informants, both the USIT and Inspera solution are to great extent characterised by being initialised by local initiatives in a typical bottom-up driven, evolutionary approach. UiO management has not proposed any detailed centralised requirements for the introduction of Digital Exam, and the project depends today on voluntary test runs coordinated and initiated by motivated users (I.e. teachers) at faculties in coordination with administrative and IT personnel. The innovation of Digital Exam as an infrastructure at UiO is still in early stages. Department of Informatics has conducted and evaluated test runs of Digital Exam using Inspera in a few selected subjects (Langmyhr, 2014), while the Faculty of Humanities has completed test runs on the USIT solution. As a result, there exist two parallel approaches, which may be considered a natural evolution as the infrastructure evolves into a solution accepted in later stages. For now, the bottom-up strategy allows for an experimental and incremental approach in developing an infrastructure that specifically addresses the needs of users.

Governance

Going further, one of our informants emphasized that Digital Exam was in need of some coordination activities from the leadership of the university. Digital exam had raised a lot of issues that had to be resolved on an organizational level. Changes in work routines had to be addressed. Roles within the organization might have to be changed. And still they had not found any good answers to the gridlock-problem of having all the students taking their fall and spring exams in the span of a few weeks. They had to find suitable localities and solve the issue surrounding whether the students or the university should provide the computers. The issue of scaling the Digital Exam is therefore considered an organisational question just as much as a technical one.

Challenges of Digital Exam: bootstrapping and adaptability

So far Digital Exam has been a story of local initiatives that has steadily been growing in size. We have called this for a bottom-up approach to technological development in lock-step with II-theory. Grisot et al. (2014) suggest that "(...) bottom up approaches face two main challenges: bootstrapping and adaptability. Bootstrapping is the challenge of how to attract and motivate users to start using a new technology, while adaptability is the challenge of how to avoid lock-in effects".

Bootstrapping the Digital Exam depends on getting early adapters from different university faculties. In that case, it is the course management and teachers of each course that can decide to take on this new approach to examination. There is also a considerable push coming from the students themselves who would rather write on a computer than on paper. Thus, the Digital Exam infrastructure is enabling the teachers and professors to examine students using digital tools. Equally, the infrastructure is enabling students to answer and deliver exams using a computer rather than on archaic technologies such as pen and paper. The system provides a set of different tools, like multiple choice and free text. However, it does not support external tools like LogiSim and Emacs (Langmyhr, 2014).

Both the USIT and Inspera solutions face these challenges. To a certain extent, the solutions are already integrated in the UiO infrastructure, and the systems still need to be bootstrapped. As discussed above, the bottom-up approach attracts new motivated users in an incremental and experimental manner, and the approach is so far successful. The challenge is however to develop a system that is attractive enough, that provides benefits over traditional paper-based exam, in order to attract the remaining users who are neutral or not motivated in relation to the project.

The informants argue that one of the challenges will now be to develop system functionality that offers the users additional and enhanced learning benefits that is integrates with existing infrastructure of information systems, work practices, processes and curriculum. The integration of Digital Exam must be adopted to the curriculum of each subject. The benefits of Digital Exam must also outweigh the disadvantages in order to attract management as a user or stakeholder in the project, a potentially critical factor in future evolution and shaping of the information infrastructure.

The adaptability of the project in terms of expanding the use of a Digital Exam solution to potentially new areas of application, providing functionality that satisfies all users' needs at all faculties, remains to be investigated. So far, both the USIT and Inspera solution have attracted users that have generic functionality requirements such as basic word processing. The challenge that remains unsolved, is how to attract users expand to other faculty subjects that have specific needs such as the use of LogiSim to draw and simulate circuits, Emacs to edit program code and gcc to translate and test program code (Langmyhr, 2014). The evolution of the information infrastructure will to a great extent depend on how the Digital Exam project adapts to new functionality requirements, an essential criteria that must be fulfilled to attract new users and bootstrap the solution.

The Evolution

In previous sections, we have argued that the Digital Exam initiative is a shared, open, heterogeneous and evolving installed base. We will interpret the evolution of Digital Exam "(...) as a process of cultivating the installed base" (Grisot et al., 2014). The "installed base" is considered to be what is already existing, I.e. "(...) existing work practices, human resources, standards, technological artefacts, organizational commitment". The authors state that "a cultivation approach acknowledges the existence of the installed base, and it seeks to address change in an incremental and gradual manner" and identify three aspects that may be characteristic to a cultivation strategy: process-orientation, user mobilization, and learning.

The authors define process-orientation as an incremental approach in which technology and existing institutionalised practices gradually merge and change the infrastructure. User mobilisation is defined as a distributed control where no formally mandated use exist, and "(...) users need to be mobilized and motivated to use the new technology". Learning is defined as a selection process in which designers select well-functioning parts from the less functioning.

Grisot et al. (2014) analyses the evolution of a patient-hospital communication system in a Norwegian hospital over a ten year period, and we will use this framework in our summarised analysis of Digital Exam as a new information infrastructure (see table below).

Evolution of Digital Exam as Installed Base Cultivation		
	Installed base	**Cultivation activity**
Process-orientation	- Existing practices for conducting traditional paper-based exam - Existing institutionalised work practices and approaches to learning at different faculties - Professional experiences of teachers, administrative and IT personnel	- Both faculty members/ teachers, administrative staff, USIT and students are involved in design activities. Specifically teachers and students are providing user feedback.
User mobilisation	- Paper based exam, challenges with content disposition and editing - Paper based administration and censoring of exam, possible sources of induced errors - Time and cost consuming manual work processes/ procedures including sorting deliveries and post delivery and transportation of papers between administration and censors - Paper based exam not in alignment with future UiO initiatives to digitalise work processes	- Proposing flexible solutions that allow for technology to meet changes in pedagogical content. - Offering immediate benefits to users, such as manual work reduced or time reduction, increased pedagogical/ learning benefits - Offering a solution that is adaptable to different faculty needs
Learning	- Experiences from similar, parallel running exam digitisation projects in Norway (ex. UiA) - Responses from early users (teachers/ students) and testers of the systems - Legal requirements for digitising processes in universities, including privacy concerns	- Selecting functionality and processes/ procedures already investigated and chosen in other Norwegian universities.

Part III - The future of Digital Exam

Digital Exam: a Successful Infrastructure?

We will discuss Digital Exam in the framework proposed by Henfridsson and Bygstad. They propose to analyse II based on specific pinpointed success criteria. The criteria can be categorized into contextual conditions and mechanisms. The contextual conditions focuses on whether the architecture are loosely or tightly coupled and whether the control of the II is decentralized or centralized. The mechanisms supposed to contribute to success are adaption, innovation and scaling. We have summed up how Digital Exam fits with this framework in the table below. We are now going to discuss how we reach these final revelations.

Case	**Contextual Conditions**		**Mechanisms**			**Outcome**	**Combination**
	Arc	**Con**	**A**	**I**	**S**		
UiO Digital Exam	1	1	1	1	1	1	AIS

1 = actualized
0 = unactualized

The table above illustrates future presence of the **combination** of mechanisms enabling **evolution** (Henfridsson and Bygstad, 2013). Mechanisms are defined as: Adoption (A), Innovation (I) and Scaling (S). According to the authors, "...the actualization of a single mechanism is insufficient to for leading to a successful outcome" and "...the actualization of the *innovation* mechanism is not a necessary condition for success if the adoption and scaling mechanisms are interacting in the same evolution process".

In the Digital Exam case, still in i critical bootstrapping phase, this implies that both adoption by new users and scaling by attracting new partners should be present in order to enable evolution of the II and produce a successful outcome. Preferably, innovation should also take place, but this is not required to enable a successful infrastructure. In the Digital Exam II, adoption, innovation or scaling alone will not enable evolution.

According to (Henfridsson and Bygstad, 2013)), an *architecture* is either loosely coupled (1) or tightly coupled (0). The *control* is either decentralized (1) or centralized (0).

Mechanisms are either actualized (1) or unactualized (0).

Outcome is either successful (1) or unsuccessful (0).

The Analysis

Contextual Conditions

Architecture

Provided that Inspera is the preferred solution, the front-end exam browser interface and back-end cloud based architecture allows for flexible integration and scaling. The architecture follows service oriented architecture principles and is loosely coupled allowing components to be added, changed or removed with reasonable effort invested. The architecture is actualized.

Control

As previously discussed, the II emerged as a result of local initiatives and bottom-up strategies. Even if the II now is centrally managed, project plans still encourage local initiatives and entrepreneurial activities to emerge within a defined scope. Control is still decentralized, but the project faces a challenge of being centralized if the assigned project group restricts the mandate of the rest of the organization.

Mechanisms

Adoption (A)

Adoption imply that resources are allocated following user growth. Thus, increasing user adoption leads to increased funding of the project. Historically, the project has followed a scheme of adaptive growth as resources has been added incrementally to the project following the different phases. The budgets are increasing accordingly for the upcoming years, leading up to full scale adaption in from 2019. Thus, the resources are linked to the number of users of the Digital Exam infrastructure.

Innovation (I)

As we stated earlier, Digital Exams contains elements which can be described as innovation of, on and in infrastructure. Digital exam was first introduced as a new feature in the infrastructure at the faculty of law by adding new modules attached to the IT-system. Later other faculties decided to make a solution where no components were integrated into the infrastructure. The so-called Inspera-solution is only communicating vital data into the system. However, the two solutions is constantly up to review, and we can’t say for certain that one solution is at the stage where it’s get locked in as the one and only solution. Innovation is therefore an ongoing part of the Digital Exam project.

Scaling (S)

"The scaling mechanism refers to a self-reinforcing process by with an infrastructure expands its reach as it attracts new partners by creating incentives for collaboration" (Henfridsson and Bygstad, 2013).

The project Digital Exam started as a pilot project, with an inhouse solution developed by USIT. Later the project adopted a proprietary solution (Inspera) that expanded the project's reach by attracting new departments to join the project. This is because the proprietary solution by Inspera allowed new functions that was not possible with the in-house solution.

The project also tries to attract new partners (fagansvarlig/professorer) by creating promises that the workload would be less when it comes to grading the exams, seeing as this would be done by the system (multiple choice blir automatisk rettet).

Combination

All three mechanisms, AIS (adoption, innovation and scaling), are present.

Outcome

The combination and presence of AIS increases the likelihood of producing a successful outcome for Digital Exam. The presence of a loosely coupled architecture and decentralized control will also increase the success factor.

Conclusive remarks

In this text we have described Digital Exam as an information infrastructure. The description has focused on information infrastructure concepts from the course litterature. We have discussed how our case matches the information infrastructure literature.

In the second part of this deliverable we have identified challenges related to changes in the Digital Exam infrastructure. We have described strategies that have been used to bootstrap the infrastructure, as well as proposing strategies to improve the Digital Exam information infrastructure.

We have found that the bootstrapping strategies has been founded in local bottom-up initiatives and described the emergent properties of the information infrastructure as a shared, open, heterogeneous, evolving. Further, we have proposed cultivation activities for the infrastructure. Finally, we have classified the infrastructure in terms of the mechanisms: innovation, adaptation and scalability.

Based on our discussions and analysis, we will suggest to continue the innovation of the II using the same or similar strategies to cultivate installed base, mobilize users and learn from parallel running exam digitisation projects in Norway. Current bottom-up strategies have been effective in getting early users to adopt the system, but the II might face new challenges of bootstrapping as the project success now depends on attracting new users from several university units not yet included. The II must successfully meet new requirements and attract new collaboration partners. Hence, if a later analysis reveals challenges with one or more critical factors to enable growth (I.e. bootstrapping, adoption, scaling), alternative strategies might be considered to enable continued growth and success of the II.

References

Bowker, G., 1995. Information Mythology and Infrastructures. Prometheus 13, 276–277.

Ciborra, C., K, Cordella Braa, Dahlblom B , Failla A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E., Simon, K.A., 2001. From Control to Drift: The Dynamics of Corporate Information Infrastructures. Oxford University Press on Demand.

Gjennomføring av nærhetsmodellen [WWW Document], n.d. . University of Oslo. URL http://www.uio.no/for-ansatte/arbeidsstotte/prosjekter/internt-handlingsrom/nerhetsmodellen/ (accessed 10.14.15).

Grisot, M., Hanseth, O., Thorseng, A.A., 2014. Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution. Journal of the Association for Information Systems 15, 197–219.

Hanseth, O., 2000. The economics of standards. From control to drift: The dynamics of corporate information infrastructures 56–70.

Hanseth, O., Lyytinen, K., 2010. Design theory for dynamic complexity in information infrastructures: the case of building internet. J. Inf. Technol. Impact 25, 1–19.

Hemsing, G.A., 2015. Prosjektbeskrivelse for: digital eksamen [WWW Document]. University of Oslo. URL http://www.uio.no/for-ansatte/arbeidsstotte/prosjekter/digital-eksamen/ (accessed 10.13.15).

Henfridsson, O., Bygstad, B., 2013. The generative mechanisms of digital infrastructure evolution. Miss. Q. 37, 907–931.

Henriksen, K., 2015. Snart digital eksamen for 500 SV-kandidater [WWW Document]. University of Oslo. URL http://www.sv.uio.no/om/aktuelt/aktuelle-saker/2015/snart-digital-eksamen-.html (accessed 10.14.15).

Hepsø, V., Monteiro, E., Rolland, K.H., 2009. Ecologies of e-Infrastructures. Journal of the Association for Information Systems 10, 2.

Inspera [WWW Document], n.d. . Inspera Assessment. URL http://www.inspera.no/ (accessed 10.14.15).

Langmyhr, D., 2014. Digital eksamen i INF2270. University of Oslo.

Ofstad, M., Skachkova, O., Pfeiffer, F., Kjevik, T., 2014. Digital eksamen. University of Oslo.

Sommerville, I., Ian, S., Dave, C., Radu, C., Justin, K., Tim, K., Marta, K., John, M., Richard, P., 2012. Large-scale complex IT systems. Commun. ACM 55, 71.

Star, S.L., Ruhleder, K., 1996. Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. Information Systems Research 7, 111–134.

Appendix

Fig.1 UiO information infrastructure. Cerebrum marked in orange.