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ORGANIZATIONAL AND PEDAGOGICAL IMPLICATIONS OF IMPLEMENTING DIGITAL LEARNING PLATFORMS IN DANISH COMPULSORY SCHOOLS

BY
ANDREAS LINDENSKOV TAMBORG

DISSERTATION SUBMITTED 2019



AALBORG UNIVERSITY
DENMARK

Organizational and Pedagogical Implications of Implementing Digital Learning Platforms in Danish Compulsory Schools

By

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Dansk resume

Denne afhandling undersøger implementeringen af digitale læringsplatforme i den danske folkeskole. Siden 2016 har de danske kommuner været forpligtede til at indkøbe og implementere en digital platform, der bl.a. er udviklet med henblik på at understøtte læreres pædagogiske arbejde og øge elevers lærings (KL, 2014).

Afhandlingen består af 6 artikler, der belyser 1) organisatoriske aspekter i forbindelse med implementeringen af platformene i konteksten af fremtidsværksteder afholdt i forbindelse med et større forsknings og 2) matematiklæreres pædagogiske anvendelse af platforme i deres planlægning og gennemførelse af undervisning. Afhandlingens undersøgelser har været gennemført i perioden fra d. 1. januar 2016 til 31. marts 2019.

Afhandlingens søger at besvare følgende forskningsspørgsmål:

- 1) Hvordan deltager interesserter i den organisatoriske implementering af platforme, og hvilke mulighedsrum og udfordringer opstår i forbindelse hermed?
- 2) Hvad er implikationerne af den pædagogiske implementering af platforme for matematiklæreres arbejde?

Metodisk har jeg adresseret det første af disse spørgsmål ved at undersøge skolederes, læreres, kommunale konsulenters og lokale vejlederes perspektiver på potentialer og problemer relateret til digitale læringsplatforme. Det empiriske fundament for disse undersøgelser består af observationer af de ovenfor nævnte aktørers deltagelse i fremtidsværksteder og design workshops afholdt i et større forskningsprojekt, hvor i alt 16 skoler fra hele Danmark deltog. Disse workshops blev dokumentere gennem videooptagelser, feltnoter og interviews afholdt umiddelbart efter, at

workshoppene var gennemført. På baggrund af denne data undersøger afhandlingen to aspekter af den organisatoriske implementering:

- 1) Hvad er aktørgruppernes perspektiver på platformene, den indbyrdes relation mellem disse perspektiver, og hvordan influerer dette på mulighederne for at implementere platformene?
- 2) I hvilken udstrækning kan faciliteret udvikling ny måder at bruge platformene på afhjælpe det pædagogiske personales oplevede begrænsninger ved platformene?

Datagrundlaget fra de ovenfor nævnte workshops gjorde det muligt både at identificere udfordringer i forbindelse med organisatoriske implementering (i hvilke tilfælde var der uoverensstemmelser mellem de deltagende aktører, og hvad bestod disse uoverensstemmelser i?) og at undersøge, i hvilken udstrækning og hvordan, de deltagende lærere var i stand til at udvikle måder at bruge platformene på, der afhjælp de oplevede uhensigtsmæssigheder.

Metodisk har jeg undersøgt afhandlingens andet forskningsspørgsmål gennem observationer og interviews af matematiklæreres brug samt oplevelse af at bruge læringsplatforme til at planlægge og gennemføre undervisning. Observationerne af læreres planlægning med platforme fokuserede på relationen mellem læreres pædagogiske beslutninger og designet samt funktionaliteten af interfacet i den platform, de anvendte. Gennem klasserumsobservationer og interviews af matematiklærere har jeg desuden indsamlet data om læreres brug af platforme i klasserumsundervisning. Disse observationer var rettet mod at undersøge relationen mellem læreres pædagogiske arbejde og deres brug af platformen samt betydningen for dette af, at platformene integrerer og afkræver lærere at anvende læringsmål fra det nationale curriculum i platformene.

Afhandlingen fremfører en række empiriske fund. For det første identificerer afhandlingen, at aktørgrupperne, der er involveret i implementeringen af platforme (lærere, skoleledere, lokale vejledere og kommunale konsulenter) har meget forskellige perspektiver på potentialerne og uhensigtsmæssighederne forbundet med platformene. Disse forskellige synspunkter udmønter sig i forskelligartede og i nogle tilfælde kolliderende strategier i aktørernes strategier for at deltag i implementeringsprocessen. Disse forskellige strategier udgør en hindring for implementering af platforme og for at aktørerne kan nå til enighed om, *hvorfor* platformene i det hele taget bør anvendes. I den hektiske hverdag på skoler, overses sådanne grundlæggende spørgsmål ofte, inden centrale beslutninger om brugen af platforme træffes.

Læringsplatforme er blevet til I en tid præget af politiske konflikter i uddannelsessektoren, og dette har haft negative implikationer for læreres opfattelser og fortolkninger af platformene og intentionerne bag deres implementering. Facilitering af workshops, der understøtter lærere i at tage ejerskab for, hvordan de kan bruges, kan åbne for genfortolkninger af platformene. Dette skabte muligheder for, at platformene kunne anvendes i overensstemmelse med lærernes pædagogiske værdier. Afhandlingen identificerer, at når aktørerne på skolerne er nået til enighed om, *hvorfor* platformene skal anvendes, er det muligt at gentænkte og –designe konkrete måder at anvende platformene på, der ikke kompromitterer lærernes ønsker for pædagogisk praksis. Denne mulighed er dog betinget af, at der allokeres ressourcer og ekstern støtte eller facilitering varetager af personer, der ikke har aktier i, at platformene skal bruges i et bestemt omfang eller til et bestemt formål. Afhandlingen viser dog, at der er begrænsninger ved disse genfortolkninger, især i situationer, hvor platformenes design og

funktionalitet er inkompatibel med læreres værdier og syn på god undervisning.

Læringsplatorme afkræver matematik lærere at definere et eller flere læringsmål, når de anvender platforme til at planlægge og/eller gennemføre undervisning. Afhandlingen dokumenterer på den ene side, at denne egenskab ved platformene i nogle tilfælde kan understøtte lærere i at træffe kvalificerede beslutninger angående valg af undervisningsmaterialer, planlægning og organisering af undervisning rettet mod at formidle bestemte faglige pointer og indholdsområder til deres elever. På den anden side viser afhandlingen, at platformene integrerer læringsmål på måder, der begrænser typen af læringsmål, lærere kan arbejde med. I nogle tilfælde opleves denne integration af læringsmål som snæver og instrumentaliserende. I den forstand oplever matematiklærere platformene som begrænsende og ufleksible, og at opbygningen af platformene ikke kan rumme de krav, matematikundervisnings mange facetter nødvendiggør. I disse tilfælde tyer matematiklærere til andre platforme eller digital løsninger, der er mindre begrænsende.

English summary

This thesis investigates the implementation of digital learning platforms in Danish compulsory schools. The digital learning platforms have been mandatory for every municipality in Denmark to purchase and implement since 2016.

The thesis consists of 6 individual research papers that address the 1) organizational implementation of the platforms in the context of future workshops held in a larger research project and 2) mathematics teachers' use pedagogical enactment of the platforms for planning and classroom teaching. The research presented in the papers have been conducted in the period from January 1st 2016 to March 31st 2019.

The over-all question of this thesis has two parts and asks:

- 1) How do stakeholders in schools engage in the organizational implementation of digital learning platforms, and what opportunities and challenges emerge in this work?
- 2) What are the implications of the platforms' pedagogical implementation for mathematics teachers' work?

Methodologically, I have addressed the first of these questions by investigating school leaders', teachers', municipal consultants' and local supervisors' perspectives on the potentials and problems regarding the platforms. The empirical foundation for these investigations was future workshops held in the context of a larger research project involving 16 schools across Denmark. These workshops were documented by video recordings, field notes and interviews of the participating actors' held after the workshops had been conducted. I used this data to investigate two main aspects of the organizational implementation:

- 1) What are the actor groups' perspectives on the platform, the mutual relation of these perspectives, and how does it affect the opportunities of implementing the platforms?
- 2) To what extent the pedagogical staffs' perceived shortcoming of platforms' functionality could be overcome by developing new ways of using them?

The data from these workshops allowed me both to identify the organizational challenges in the implementation process (how and about what did the parties disagree) and to investigate to what extend teachers were able to overcome the challenges by redesigning their enactment of the platforms.

Methodologically, I investigated the second question by observing mathematics teachers' planning and teaching with platforms and interviewed them about their experiences of these practices. The observations of teachers' planning with platforms focused on the relation between teachers' pedagogical decision and the functionality and design of the interface in which these decisions were made. Through classroom observations, I collected data about mathematics teachers' usage of digital platforms in their classroom teaching.

The focus of these observations was to investigate the relation between teachers' pedagogical work and their usage of platforms, and the role that the platforms' integration of learning objectives in the curriculum standards played in therein.

The thesis presents several empirical conclusion. First, the thesis identify that the different actor groups' (teachers, school managers, local supervisors and municipal consultants) involved in the implementation of platforms have highly diverse perspective on the challenges and potentials of the platforms. These different viewpoints of the platforms' manifest in different and

sometimes colliding strategies of the actors' participation in the implementation process. This challenge the implementation of the platforms and agreeing on the first step in addressing this issue is reaching an agreement of *why* the platforms should be used. In hectic every-day life at schools, these foundational matters are often overlooked before important decisions on the implementation is made.

The learning platforms came about in the context of a wider political conflict, which have had negative implications on teachers' conceptions and interpretation of the platforms and the intentions of implementing them. Facilitating workshops that supported teachers in taking charge of their use of the platforms opened for a re-interpretation of the platforms that enabled teachers to develop usages of them that were aligned with their pedagogical values. The thesis identifies that when agreement have been reached on *why* platforms should be used, teachers' experienced deficiencies of the platforms can be overcome by re-thinking and -designing the concrete ways of using them. Doing so however requires allocated resources and preferably external and un-biased facilitation. There were, however, limits of these re-interpretations, and the design experiments showed cases were the design or functionalities of the platforms were incompatible with the teachers' wished and values and alignment therefore not was possible.

The platforms require mathematics teachers to specify one or more learning objectives for their lessons. On the one side, the thesis document this can support teachers in making qualified choices of what teaching materials to use, and how to design, organize and frame exercises in ways that support student learning. On the other side, some mathematical competencies, skills or knowledge cannot be articulated fully or adequately as a learning objective. The platforms are in this respect inflexible, as their design do not reflect the

internal variance among the components of schools subject's. Teachers' response to this inflexibility is to replace the platforms with other available technological solution that are less structured.

Chapter 1: Introduction

In this thesis, I investigate the implementation of digital learning platforms in Danish compulsory schools. The thesis has a dual focus on 1) the organizational implementation of digital learning platforms and 2) mathematics teachers' pedagogical enactment of the platforms and the implications of this for their pedagogical practices. Since 2016, it has been mandatory for every municipality in Denmark to purchase a digital platform and to implement them in the Danish public compulsory school (Kommunernes Landsforening, 2014).

In many countries, there has been a growth of initiatives in educational sectors in terms of implementing digital platforms or similar technologies (Johnson, Adams & Glauman, 2015; Johansson & Glauman, 2014; Lu & Law, 2012).). From a general point of view, there seems to be more valid and obvious reasons for implementing digital platforms than ever before. The amount of digital resources such as e-textbooks and online teaching materials that are available through the digitalization of textbooks has made it complex for teachers to choose, combine and redesign curriculum materials that meet a specific group of students' learning goals (Abar & Barbosa, 2011). Digital resources for teaching are often found on various websites and platforms, portals and fora, requiring teachers to navigate many digital sites when planning a lesson (Nokelainen, 2006). This is an issue related to the digitalization of teaching materials, a problem that digital learning platforms can address by providing teachers and students with a single entry point that helps them to navigate a complex landscape of available resources and teaching materials. Digital learning platforms can potentially contribute to solving this problem, as many schools in Western countries have the means to provide every student with a device (Greaves, 2012).

Many digital platforms are designed with multiple purposes, such as supporting teachers' planning, teaching, and assessment of students' learning (Dede & Richards, 2012). Combined with one-to-one computing, this allows teachers to use the platform both inside the classroom (e.g., to distribute lesson plans, tasks, and activities to students) and outside the classroom (e.g., to plan lessons and evaluate students' work). This essential feature provides new opportunities for teaching and learning (Richards & Walter, 2012).

Such aspirations for platforms as the ones described above are seen in both research and policy literature; they are neither new nor unique to the case of digital learning platforms, but they apply more generally to educational technology. An example of similar hopes was seen in the initial stages of the implementation of both interactive whiteboards and iPads in Denmark. In retrospect, the implementation of these technologies is better known for not bringing the desired changes than for revolutionizing the educational sector. In Denmark, interactive whiteboards remain largely unused (Arstorp, 2012), and Danish municipalities' investment in iPads has been criticized for the naïve assumption that the technologies in themselves will improve teaching and for the lack of reflection on how they should be used to enrich pedagogical practices (Bundsgaard, 2010; Mehlsen, 2016).

The challenges of implementing technology in school contexts have been studied widely and are well documented, and the research literature provides several explanations for this challenge of implementing technology in schools. One aspect is that mining the educational and pedagogical potential of new technologies requires a substantial level of craft-knowledge on the part of the user (Ruthven, 2009). These requirements are not necessarily clearly reflected in budgets, implementation plans, or the amount of resources allocated for professional training. Moreover, making full use of a given technology often

requires that schools have a certain level of technological prerequisites, which can be difficult to live up to (Selwyn, 2011; Selwyn, Banaji, Hadjithoma-Garstka, & Clark 2011; Selwyn, Nemorin, & Johnson, 2017). Another aspect is that educational policy, in the words of Selwyn (2008), often seems to be driven by the state of the art (what in theory is possible with new technology) rather than the state of the actual (what an actual school context looks like and to what extent schools are capable of benefitting from the newest technology) (Selwyn, 2008). Regardless of these evident challenges, there is no sign that the flow of new digital technology into the educational sector will decrease. On the contrary, reports suggest that educational sectors will be met by an increased amount of new digital technologies to incorporate into schools' organizational and pedagogical practices (Becker, Cummins, Freeman, & Rose, 2017). Encountering new technology is therefore likely to become the norm, creating a context in which practitioners at schools are expected to be professionally competent when navigating these innovations.

The errand of this thesis is thus not to evaluate whether the results gained by implementing new digital platforms are worth the investment, nor (only) whether the platforms lead to better or worse teaching – instead, this thesis is based on a preliminary acknowledgement that the emergence, and to some extent requirement, of using new technology is a part of the reality that school practitioners face. From this outset, the thesis deals with questions of how practitioners cope with this reality and what challenges and new opportunities these current premises bring – both for schools as organisations and for teachers' pedagogy. The current implementation of digital learning platforms provides a particularly good starting point for pursuing this aim, as the technology in question has implications for almost every aspect of teachers' work. Simultaneously, it represents a major organizational challenge for schools to implement this technology in ways that improve teaching without

compromising the professional authority and autonomy of the individual teacher. The thesis thus seeks to answer the following research questions:

How do stakeholders in schools engage in the organizational implementation of digital learning platforms, and what are the implications of the implementation of the platforms for mathematics pedagogical teachers' work?

The elements of this thesis thereby foreground practical issues related to platform implementation; I do this by examining the users' perspectives, describing how teachers and other stakeholders in school contexts navigate the implementation, and illustrating with which priorities and difficulties they do so. Before I introduce a more elaborated and precise version of the research questions of the thesis, I will outline the structure of the thesis.

The Structure of the Thesis and the Chapters that follow

The thesis consists of six individual research papers that share a common focus on one of two levels of platform implementation. Below, I provide a brief overview of the six papers, their aim and the context in which they were written.

Paper 1 is a literature review conducted as a preparatory element of a large-scale research project that sought to support the implementation of digital platforms, in which I partook in 2017. This paper focuses on reviewing the existing international literature about digital platforms and on mapping the identified challenges and opportunities in using such platforms for educational purposes. I co-wrote this paper with Andreas Riehker Bjerre, Lars Birch Andreasen, Thomas Albrechtsen and Morten Misfeldt and is currently under review in the journal LearningTech.

Paper 2 is entitled “Planning Geometry Lessons with Digital Learning Platforms”. I presented this paper at the CERME Conference in 2017 in Dublin and has been published in the “Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education (CERME10), 2018”. The paper presents a study conducted at the beginning of my PhD project, which, as indicated by the title, investigates mathematics teachers’ planning of lessons with a digital learning platform called Meebook.

Paper 3 is entitled “Mapping Situations in Implementing Learning Platforms”. I co-authored this paper with Benjamin Brink Allsopp. It has been published in “Interactivity, Game Creation, Design, Learning, and Innovation – 6th International Conference, ArtsIT 2017”. This study was carried out in the context of the large-scale research project in which I partook during my PhD briefly mentioned above. It investigates and maps teachers’, school leaders’ and municipal consultants’ beliefs about learning platforms and their implementation as they were articulated in Future Workshops held at two schools in the context of the research project.

Paper 4 is entitled “Implementation of Learning Platforms - Use, Values and Cooperation” and is published in the journal “Learning and Media”. I co-authored it with Morten Misfeldt, Lone Dirckinck-Holmfeld, Ane Qvortrup, Camilla Kølsen and Lærke Ørsted Svensson. This paper was also written in the context of the large-scale research project mentioned above, investigating teachers’ perceived pedagogical implications of implementing digital learning platforms and discovering the opportunities to support them to overcome the platforms’ shortcoming. This paper is published Danish, which I have translated into English in order to include it in this thesis.

Paper 5 is entitled “Tools, Rules and Teachers – The Relation Among Curriculum Standards and Platforms When Teaching Mathematics,” and it is published in the International Journal of Educational Research. This paper is a theoretical paper that identifies the limitations of the theoretical framework I used in Paper 2 regarding the characteristics of the Danish learning platforms. This paper extends the framework in order to support describing the specific issues related to teachers’ work with digital learning platforms that integrate national curriculum standards. I co-coauthored the paper with Morten Misfeldt, Benjamin Brink Allsopp and Jonas Dreyøe.

Paper 6 is entitled “Mathematics Teachers’ Documentations Work in the Context of Digital Platforms.” By using theoretical contributions developed in Paper 6, in this paper, I investigate four mathematics teachers’ use of digital platforms for classroom teaching. In particular, we focus on investigating the relation between mathematics teachers’ documentation work and their usage of digital platforms as well as the platforms’ role in mediating the curriculum standards.

A central aim of this wrapping is to describe the relation among these six individual research papers, both in terms method, theory and the empirical and theoretical results generated in the thesis. In the wrapping, I pursue this aim in 7 chapters that each are centered on describing different aspects of the relation between the papers and reflection upon their coherence.

Chapter 2 describes my way into the PhD project and my academic and personal motivation to conduct the study. Here, I also explain the motivation for the individual papers included in my thesis and the origin of the focus and research questions they address. This narrative displays the insights that

occurred during my project, the choices I made to respond to them and how these choices are presented in the six papers.

Chapter 3 outlines the political context surrounding the educational sector 2013-2019, as this period have been dominated by issues and debates, that have had implications for the current situation in the Danish school system. This include describing the Danish digital platforms and how they are different from other technologies.

Chapter 4 introduce an elaborate description of the research questions of the thesis of focus on describing the philosophical foundations of my approach to answering them.

Chapter 5 outlines how, in spite of their differences in foci and aims, the six papers together contribute in studying the implementation of digital platforms. To do this, I draw on Century and Cassata's (2016) definition of implementation research to and a distinction between an organizational and practical pedagogical level of implementation. The argument presented in this section is that the papers within either one of the two levels of implementation is characterized by a consistent interpretation of the key elements of implementation research.

In Chapter 6, I describe the methodological approach deployed across the papers. This section describes the methodological approaches applied to address the two sub-questions of the thesis and concludes with reflections of how and to what extent the empirical studies of the thesis together constitute a coherent research design.

Chapter 7 summarizes the empirical and theoretical findings across the papers presented into an answer of the research questions posed in the thesis. I conclude this section with reflections on the level of evidence of the research

presented in the thesis and by pointing to new important areas of research emerging from the conclusions generated in the thesis.

I will begin by describing the background for the implementation of the platforms and some of the key characteristics of the technology in relation to other existing platforms.

The Platforms and Their Political Origin: The User Portal Initiative

The decision to implement learning platforms in Danish compulsory schools dates back to 2014 and the so-called “User Portal Initiative” (KL, 2014). A year prior, the government and two opposition parties (*Venstre* and *Dansk Folkeparti*) agreed to develop what at that time was referred to as a “user portal” as part of a strategy aiming to improve Danish compulsory schools (KL, n.d.). In October 2014, the government and Local Government Denmark specified the details of the realization of the User Portal Initiative (KL, n.d.). The result of this specification was that two digital platforms were to be developed and implemented in the Danish compulsory schools in the period from 2016 to 2020. The two digital platforms included a digital learning platform and a communication platform. At this point, the digital learning platform was described as technologies that should seek to support and improve students’ learning and teachers’ teaching; further, they should be able to interact with digital teaching materials, national tests, and national measurements of students’ wellbeing (KL, n.d.). The communication platform should focus on communication and knowledge-sharing between all actor groups in both compulsory schools and the daycare system (pedagogues, teachers and administrative workers from daycare, pre-school, and lower secondary school) (KL, n.d.). Moreover, every employee working in this sector should have the same single entry point to access information about the

children. Whereas the communication platform should be developed centrally in a collaboration that included information technology (IT) staff among the municipalities organised in the so-called KOMBIT¹, the government and Local Government Denmark decided that the digital learning platforms should be developed using another strategy. Instead of centrally creating one national learning platform, as in the case of the communication platform, the aforementioned decided to make a functional specification of the requirements for the platform. It was then put to private manufacturers to build digital learning platforms that lived up to these requirements. The responsibility of choosing, purchasing, and implementing a digital platform was then given to the individual municipalities. The documents that described this approach argued that the underlying rationale was to give municipalities the freedom to choose platforms that were in line with their particular requirements, and existing strategies.² The list of functional requirements was released in early January 2016; they specified 64 requirements that every platform should contain.

The Platforms and Their Features

Among other things, the 64 requirement specifications for the digital platforms included that the learning platforms should allow the user to develop courses and student plans, monitor students' progress and wellbeing, assess students, and administer teaching materials (KL, n.d.). The requirements also specified technical and infrastructural requirements, such as that the platform should allow data to be exchanged and integrated among different platforms and that it should be user-friendly (KL, n.d.). A central aspect of the functional requirements was the prominent role of learning objectives (KL, 2016). This

¹ KOMBIT is an organisations responsible for coordinating ICT collaborations among Danish municipalities. KOMBIT is owned by The Local Government Denmark.

² <http://www.kl.dk/PageFiles/1314105/bpi-oplaeg.pdf>

is illustrated in the following excerpts from the functional requirements of the digital learning platforms:

- “The learning platform must support the work with objective-oriented learning in teaching sequences. It must be possible to work with the competence objectives that the Ministry of Education defined”.
- “It is the responsibility of the pedagogical personnel, optionally in collaboration with the students, to interpret the objectives in the curriculum to reach specific objectives of what a student should be able to do or know at the end of a teaching sequence; it must be possible to do this work in the learning platform”.
- “The learning platforms shall support the preparation and description of the series of activities that will lead to the fulfillment of the learning objectives, enabling teachers to use the lessons planned in the platform in classroom teaching and to assess students’ work”.

(KL, n.d., 2–27; my translation).

After the release of the requirement specifications for the platform, several private manufacturers developed solutions from which the Danish municipalities could choose. These included MinUddannelse, Meebook, Itslearning, KMD Educa, MOMO, and Easy IQ; of these, the majority of Danish municipalities purchased MinUddannelse or Meebook.³ All these platforms share the characteristic of living up to the 64 functional requirements, but they differ in *how* they do so in terms of design, interface, and features and functions that are additional to the 64 base requirements. I investigate the implementation of two of the platforms described above:

³ <https://www.folkeskolen.dk/586577/ekspert-vurderer-hvilken-laeringsplatform-er-bedst>

MinUddannelse and Meebook. Below, I have inserted screenshots from the interfaces of these two platforms. They show the interfaces that the Meebook and MinUddannelse platforms provide for designing a new course, for teachers' opportunities to make personal notes, and for using learning objectives.

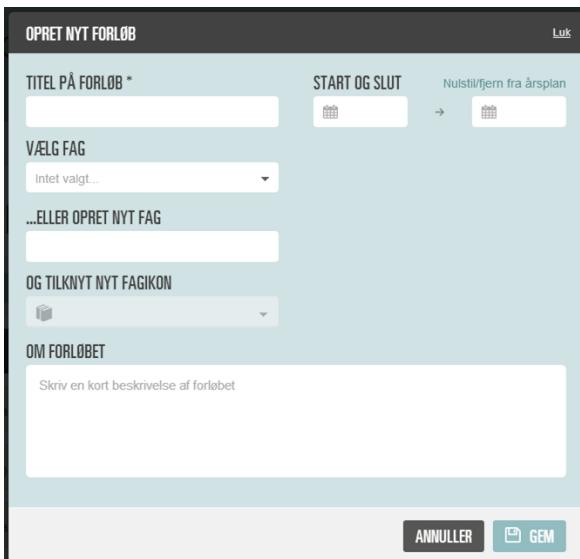


Figure 1. The teacher interface in Meebook used for creating a new course. The teachers can specify a beginning and an end date, a title, a subject, add an icon, and write a brief summary of the course, all of which the students can see.

Figure 2 shows the teacher interface to plan a particular lesson. The available features in this tab are described in the caption (for a more elaborate description, see Paper 2).

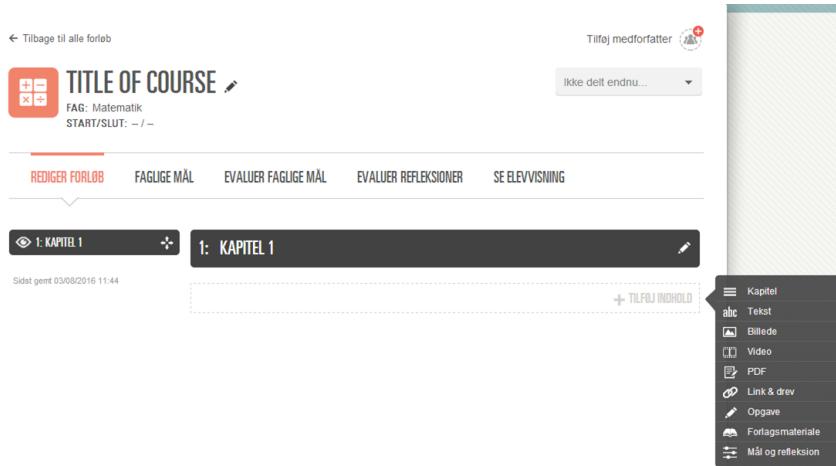


Figure 2. The teacher interface in Meebook for selecting the content to include in a lesson. Teachers have the opportunity to write their own text and add videos, pictures, content from textbook material, and the like.



Figure 3. A screenshot of the interface in Meebook where teachers define the learning objective. When they have defined a learning objective in the box on the left side of the picture, they are required to specify a measurement scale

(can/cannot, understand/does not understand, done/not done, etc.). The small black box on the right side allows the teacher to access the national standards. However, it is not mandatory for teachers to specify what (if any) national standard the lesson addresses.

The following figures illustrate the teacher interface that is available in MinUddannelse in correspondence to the interface of Meebook shown above.

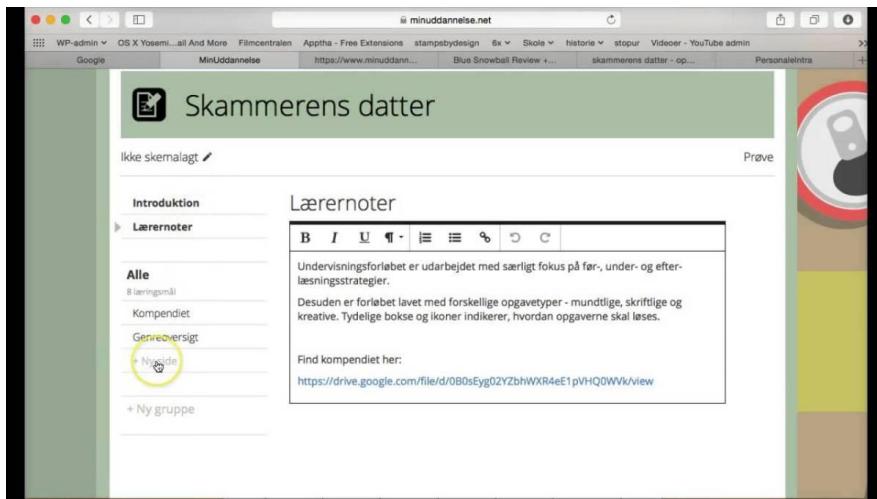


Figure 4. The interface in MinUddannelse where teachers create a lesson.

 **LÆSNING:**
Eleven kan læse enkle tekster sikkert og bruge dem i hverdagssammenhænge
22 elever med dette læringsmål

 **FREMSTILLING:**
Eleven kan udtrykke sig i skrift, tale, lyd og billede i nære og velkendte situationer
22 elever med dette læringsmål

 **FORTOLKNING:**
Eleven kan forholde sig til velkendte temae gennem samtale om litteratur og andre æstetiske tekster
22 elever med dette læringsmål

 **KOMMUNIKATION:**
Eleven kan kommunikere med opmærksomhed på sprog og relationer i nære hverdagssituationer
22 elever med dette læringsmål

Figure 5. An overview of the current learning objectives the students are working towards provided by the teacher interface in MinUddannelse.

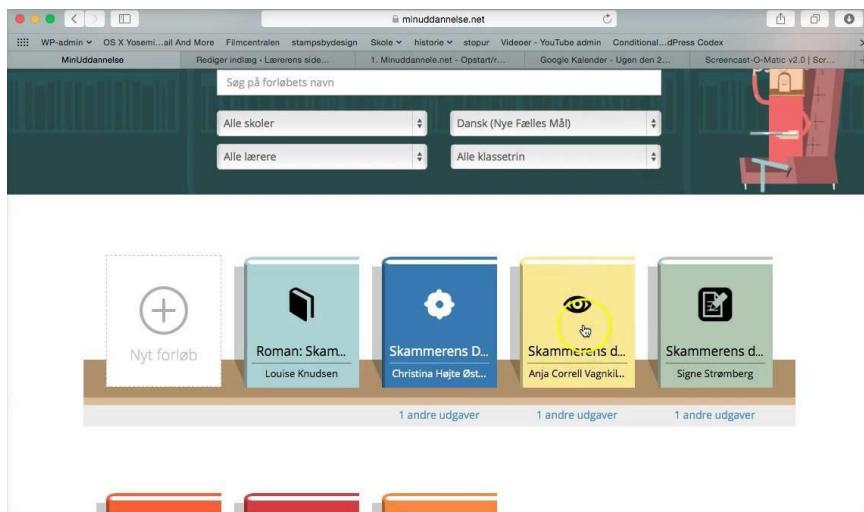


Figure 6. *The teacher interface in MinUddannelse where teachers can create a new course.*

As evident from the figures above, there are differences in the design and of the platforms. I do not intend to elaborate on these differences of the two platforms and their potential implication of using either one. The reason for this choice is that, as I intend to access the viewpoints of the stakeholders of the platforms in the implementation, I will mainly concentrate of describing the platforms as they appear to the actors having to implement of use them. However, all the Danish platforms living up to the 64 functional requirements share features that distinguish them from other types of available platforms, which I believe to be significant. In the following, I will therefore briefly describe a selection of these platforms and the Danish platforms' relation to them.

An Outline of Available Platforms and Their Relation to the Danish Platforms

The Danish digital platforms represents one type of platforms in a landscape of many other types of available platforms developed to be used by students, teachers and administrators in school contexts for various purposes. In this section, I will briefly introduce some of these different types of platforms to define the Danish digital platforms in relation to other types of available technology. The section do thereby by no means present a comprehensive overview of available platforms, but merely aims to serve as a foundation for emphasizing the particularities of the Danish digital platforms.

LMS, CMS and VLE

The abbreviations in the heading above refer to Virtual Learning Environments (VLE), Course Management Systems (CMS) and Learning Management systems. LMS is perhaps one of the most frequently used terms

in the field of digital platforms, referring to platforms that are primarily developed to support teachers in *managing students' learning* (Watson & Watson, 2007). According Watson and Watson (2007), LMS

"is the infrastructure that delivers and manages instructional content, identifies and assesses individual and organizational learning or training goals, tracks the progress towards meeting those goals, and collects and presents data for supervising the learning process of an organization as a whole (Szabo & Flesher, 2002). An LMS delivers content but also handles course registration and administration, skills gap analysis, tracking and reporting (Gilhooly, 2001)" (Watson & Watson, 2007, p. 28).

Teachers and students are meant to use this type of platform, but primarily, it supports *teachers* in keeping track of and managing students' learning and the administrative aspects of this.

According to Watson and Watson (2007), CMS is a different type of platform in that, again as indicated by the name, it was primarily developed to manage *courses*. Unlike LMS, CMS does not provide teachers/instructors with content; instead, it

"provides an instructor with a set of tools and a framework that allows the relatively easy creation of online course content and the subsequent teaching and management of that course including various interactions with students taking the course" (Watson & Watson, 2007, p. 29)

In CMS, the teacher/instructor is considered as the main user. The platform allows teachers to manage their courses using tools to plan teaching and infrastructure that facilitates interactions among students and teachers.

To some extent, VLE can be considered as the precursor of both LMS and CMS. Literature about VLE from the late 1990s defines this type of platform

as technology developed primarily to provide a digital environment in which students can learn. Britain (1999) described a VLE as

“An internet based platform, which contain learning resources and activities and enables interactions in lessons and courses among students and teachers. It usually supports teachers in assessing students and overviewing their participation” (Britain, 1999).

As indicated by the quote above, besides being a digital environment where students can learn, a VLE also provides teachers an interface, in which they can monitor or overview students' activities and participation.

Although the terms LMS, CMS and VLE's to some extent may be beneficial in distinguishing the key features of platforms, modern platforms are likely to be built to include a combination of the characteristics of these types of platforms. In this respect, the three terms are perhaps better understood as analytical than as empirical categories, as the distinctions they introduce more often than not are transcended by the available technologies.

Due to the technological developments and the amount of material technology that are readily available in most Western schools, there have developed new kinds of digital platforms that are more advanced than what previously have been the case. An example of this is dashboards, which I briefly will describe below.

Dashboards

One of the newest digital platforms is related to the fields of learning analytics (LA) and educational data mining (EDM). Both of these research fields are relatively new⁴ and are organised as two separate fields that use different

⁴ They have both existed since 2008 (Larsson & White, 2014).

approaches and strategies to aggregate and use data in educational contexts⁵. The fields share a common challenge of providing practitioners, students, and parents with intelligible and applicable representations of the research outputs they are capable of producing (Schwendimann et al., 2017). This common challenge has resulted in a growing field of research that focuses on so-called dashboards, which have come to overlap with the literature about digital learning platforms (Verbert et al., 2014). Dashboards are defined as

“a single display that aggregates different indicators about learner (s), learning process(es) and/or learning context(s) into one or multiple visualizations” (Schwendimann et al. 2017, p. 37).

One of the main interests of this field and the technologies developed therein is to build user-friendly dashboards that visualize data in meaningful ways (Schwendimann et al., 2017). However, dashboards seldom occur as an isolated research object, as these technologies often appear as integrated interfaces in digital platforms such as Moodle (Schwendimann et al., 2017).

According to a recent review in this field (Schwendimann et al., 2017), dashboards are most often developed in university contexts. The authors considered this to be a limitation and argued for the potential of building analytics dashboards specifically for K–12 contexts. Unlike other types of digital platforms, dashboards are seldom designed in accordance with an explicit pedagogical approach. There seems to be a trend in these types of technologies: they are developed to support either self-monitoring, the

⁵ According to Larusson and White (2014), EDM focus mostly on automated methods for investigation, uses automated adaption models and predictors. LA, on the other hand, uses human led methods of generating data that typically informs human action and practitioners' decision-making (Larusson & White, 2014).

monitoring of others, or administrative monitoring (Schwendimann et al., 2017).

Digital Teaching Platforms

Defined by Richards and Dede (2012), digital teaching platforms are another type of platform to recently emerge. According to Richards and Dede (2012), a digital teaching platform has three essential requirements. Firstly, it is a digital technology, which includes interactive interfaces for both students and teachers. *Teachers* are thought to use the administrative tools in the platforms to build lessons and exercises for students and to manage and evaluate the work returned by students in the platform (Richards & Dede, 2012). For assessment, digital teaching platforms provide teachers with support in creating tests, assigning them to students, and viewing students' results. For *students*, a digital teaching platform allows them to complete assignments and assessments. Moreover, the teaching platform supports both group work and individual work. The second essential requirement of a digital teaching platform is that it provides teachers with the content for teaching and enables the assessment needed to evaluate students' performance in this content. This includes exercises, instruction guides, interactive elements, activities, special-purpose applications, and multimedia materials. The third and final requirement of a digital teaching platform is that it

“supports real-time, teacher directed-interaction in the classroom. It includes special tools for managing classroom activity; monitoring progress on assignments; displaying student work, demonstrations and challenges on interactive displays; managing group discussions; and coordinating all large-group and small-group activities”. (Richards & Dede, 2012, p. 2)

Moreover, Richards and Dede (2012) emphasized that digital teaching platforms were based explicitly on constructivist pedagogical approaches. To

some extent, digital teaching platforms thus merged several features of CMS, LMS, and VLE, as they were developed to be used by students and teachers and both support students' learning and teachers' teaching. They are distinct from these three technologies in that they allow teachers to use them in real time. In this respect, they are similar to the Danish platforms.

The Danish Digital Learning Platforms

As described above, the Danish learning platforms is a part of an ambitious strategy for digitalizing the Danish public sector called "The User Portal Initiative". Unlike other types of digital platform, the Danish learning platforms do not provide teachers or students content (teaching materials or other similar pedagogical resources), but only the infrastructure for developing, uploading and sharing content. The platforms are however required to have a "forløbsbygger" (course builder), which are designed to work as a template that can scaffold teachers in their planning of lessons and courses within the learning platform. The platforms are also required to be able to provide teachers with access to publishers' online textbook materials. One of the most essential and unique features of the Danish platforms is that they integrate the Danish curriculum and the objective oriented to teaching, which is the main pedagogic rationale of the curriculum. Concretely, this requirement specification of the platforms include that they shall integrate the national curriculum. As described in paper 4, a new set of curriculum standards was implemented in Danish compulsory schools in 2014 (Undervisningsministeriet, 2015). Contrary to the previous standards, the new curriculum focused on learning objectives that was organized in competence areas, skills and knowledge. The perceived workflow for teacher when using this curriculum was that they should begin by selecting learning objective, and then interpret it and 'break it down' into a more concrete objective for a specific lesson.

Differences between available platforms and the unique features of the Danish platforms

A central commonality between the different platforms described above is that they essentially are developed for the same core actors: students, teachers and administrators. On a specification level, the Danish platforms share a number of commonalities with digital teaching platforms, in that both types of platforms are developed to be used by both teachers and students in real-time teaching. Unlike digital teaching platforms, but similarly to CMS, the Danish platforms provide teachers the tools to plan activities and lessons. The tools provided by the Danish digital platforms is, according to the 64 requirement specifications, entangled with the legislative curriculum standards. As described earlier, the practical implication of this is that the platforms provide teachers support for planning and teaching their lessons in a way, in which they are required to define learning objective from the curriculum standards. Although the Danish platforms do not provide teaching materials or content in themselves, they provide a template or a frame based in the Danish curriculum, which teachers are required to use. Moreover, as the Danish digital platforms have been developed by private manufacturers from a governmental initiative, they represent odd hybrids between a commercial and a state-initiated product. These are unique features of the Danish learning platforms, which in some respect makes their implementation difficult to compare to the implementation of other types of platforms in different contexts. An implication of these particular characteristics of the platforms is that they became entangled in an ongoing political debate in the Danish educational sector, which have had implications for how the stakeholders in Danish compulsory schools have related to the platforms. In chapter 3, I will describe this political context in more detail to provide an overview of the conditions in which the studies of the thesis have been carried out. In the next chapter, I will however concentrate on describing my way into the thesis, the

processes, in which I have been engaged and the choices I made along the way.

Chapter 2 – Entering the Field of Digital Platforms

This thesis consists of findings reported in six different studies carried out in the period from January 2016 to March 2019. Though these papers all study the implementation of digital learning platforms in Danish compulsory schools, they do so in different contexts and with different aims. The purpose of this section is to describe how the empirical focuses in these papers, in spite of their differences, are related to each other. The chapter describes this in the form of a narrative that begins by accounting for my initial personal and academic motivation for conducting the PhD project. I then describe the individual studies of which the thesis consists, the insights they bring with them, and how these insights informed the scope, design, and aim of the study that followed. I begin the chapter by describing my way into the PhD project and the academic and personal motivation that led me to conduct the study.

The Starting Point – Digital Support of Learning Objectives

After graduating from Aalborg University in Copenhagen in 2014, I was hired as a research assistant in IT and Learning Design at Aalborg University. During this employment, I participated in a research project that aimed at developing and testing a prototype of a digital tool to support teachers' use of learning objectives (Misfeldt, 2016). The background for this project was a new curriculum reform launched in 2014 (UVM, n.d.; Undervisningsministeriet, 2014). This curriculum was based on learning objectives and introduced a new approach to teaching in compulsory schools. Whereas the previous curriculum described a desired change in students' knowledge, skills, ways of working, etc. after a certain grade level, the new curriculum described learning objectives for each subject that students should acquire after a certain grade level (Undervisningsministeriet, 2015). In addition to this new structure, the Danish Ministry of Education developed

guidelines that described a new workflow for teachers to follow when using the new curriculum (Undervisningsministeriet, 2014). According to these guidelines, teachers should begin planning a lesson by choosing a certain objective from the new curriculum. The teacher should then interpret this objective within a particular context, phasing it in with his or her own words and using it as the foundation for designing a lesson that would support students in fulfilling this objective (Undervisningsministeriet, 2014). Teachers were also encouraged to articulate this learning objective to the students before beginning the lesson it addressed. The Ministry of Education believed that defining learning objectives would function as an anchor teachers' for evaluating the students after the lesson had been taught. This approach to teaching was labeled “*målstyret undervisning*” (“objective-oriented teaching”) and was inspired by the results from evidence-based meta-studies, especially the results published in John Hattie’s book “Visible Learning” (Hattie, 2009).

In 2015, shortly after the new curriculum had been implemented, the Danish Evaluation Institute (EVA) published an evaluation of teachers’ experiences of using the new curriculum (EVA, 2015). This report showed that teachers considered the learning objectives in the curriculum to be broad, leaving wide room for interpretation, which was difficult for teachers to maneuver. Moreover, the evaluation showed that teachers in the Danish compulsory schools found it difficult to comply with the new suggested workflow related to the curriculum—especially mathematics teachers requested digital tools that could support this process (EVA, 2015).

The aim of the research project in which I partook was to develop and test a digital prototype that could support teachers in using learning objectives in their everyday teaching practices (Misfeldt, 2016). This prototype was

developed as a digital platform with an interface that allowed teachers to access the new curriculum digitally. The interface provided the teachers with a “Goal Arrow,” which was a visual representation of a learning goal with three taxonomic levels. This tool sought to support teachers in accessing the new curriculum digitally. The purpose of the Goal Arrow was thus to provide a tool that supported teachers in structuring, interpreting, differentiating, and articulating the objectives for their teaching.

This project involved approximately 80 Danish language and mathematics teachers who experimented with using the prototype in their planning and teaching for a period of eight weeks. During the project, three workshops were held at each of the participating schools. At these workshops, researchers and teacher trainers from the project provided the teachers with technological and pedagogical support in using the Goal Arrow (Misfeldt, 2016).

My primary role in this project was to conduct an interview study of 15 teachers at eight schools across the country about their experiences of using the prototype. These interviews in particular focused on investigating the implications of the digital support of incorporating learning objectives from the curriculum into their teaching. A main finding from this interview study was that the interviewed teachers had different interpretations of what a learning objective was and what role it should play in teaching (Carlsen, Hansen, & Tamborg, 2015). Some teachers were of the impression that learning objectives were fixed after they had been articulated in the Goal Arrow. Therefore, these teachers felt obliged to pursue the learning objective no matter what happened in the classroom (Misfeldt & Tamborg, 2016). These teachers often metaphorically compared learning objectives to a straitjacket and felt that the digital manifestation of the learning objectives made it difficult for them to amend them if needed—not because this was not possible

in the digital prototype, but because the digitalization enforced a conception that the objectives were final and binding.

In contrast, others thought of learning objectives as initial *aims*. These teachers were of the impression that learning objectives could be revised along the way if needed (Misfeldt & Tamborg, 2016). Moreover, this group described the articulation of learning objectives before coming to class as a crucial part of their mental preparation for the purpose and aim of the given lesson. However, the study also showed that in some cases, the Goal Arrow seemed to cause teachers to question their right to amend the initial set learning objectives in situations where their teaching unfolded in ways they had not predicted and that did not correspond to the predefined learning objectives. In contrast, the study also showed that the digital support of learning objectives that the Goal Arrow provided empowered the teachers.

Besides supporting the teachers' assertiveness regarding the aim and purpose of their lessons, the teachers used the learning objectives articulated in the Goal Arrow as a benchmark to make better and more qualified decisions about what resources, working formats, etc. to include in a particular lesson. The interview study indicated that learning objectives and the digital support of using them could have important implications for teachers' planning and teaching of lessons for better or for worse. However, the study only investigated this from teachers' utterances about their practices, not from observing their planning practices by using the platform.

Shortly after this research project ended, the Ministry of Education and Local Government Denmark decided that the municipalities in Denmark should purchase and begin implementing a digital learning platform during the 2016/2017 school year (Undervisningsministeriet, Finansministeriet, KL, 2014). This learning platform was one of the components of the User Portal

Initiative, which was an ambitious digitalization strategy for the public sector (BPI, 2014). As previously argued, the learning objectives played as prominent a role in the learning platforms as they did in the Goal Arrow.

In several ways, these digital platforms had characteristics similar to the Goal Arrow; they provided teachers with an interface to access the curriculum and to use learning objectives as a resource to plan, teach, and evaluate their lessons. In this case, however, every teacher was required to use the learning platform. Due to the scale of the national implementation process, teachers only had limited training in using the system (both pedagogically and technically), and they had nowhere near the same access to support from experts as had been the case in the project described above. Moreover, the Goal Arrow project yielded several general empirical findings, which were likely to be reinforced in the context of a nation-wide implementation of digital learning platforms. Among other things, the project showed that the implementation of digital technologies that supported objective-oriented learning was demanding for the involved teachers and for the design of the technology (Misfeldt, 2016). In particular, the project identified a strong need for flexibility in the digital technology, as it needed to both facilitate cooperation among teachers and to accommodate their different preferences in terms of, for example, workflow and pedagogical beliefs (Misfeldt, 2016).

As indicated, the Goal Arrow project had primarily investigated teachers' work with the digital platform from interviews and had thus not generated empirical insights into how teachers were actually using the platforms in the various aspects of their teaching. A natural way to begin my PhD project therefore seemed to be getting insight into teachers' practices with platforms.

The Initial Study – Mathematics Teachers’ Planning with Learning Platforms

I initially decided to study how teachers planned lessons with the digital learning platforms; there were several reasons for this. As described in the section above, learning objectives and the new curriculum played an important role in the functional requirements for the digital learning platforms. Although there had been a heated debate about how learning objectives in the learning platforms were constraining teachers’ teaching in the classroom, few studies investigated how teachers were using the platforms in their planning practices. Moreover, mathematics teachers’ planning has seldom been studied (Grundén, 2017) in spite of the common recognition that it is important (Superfine, 2008; John, 2006).

At the beginning of my PhD project, I had little information on how teachers were using digital learning platforms to plan their lessons; to what extent; and not least, where this practice took place.⁶ Knowledge about these aspects was critical in order to choose the appropriate research methods and develop the research design for my study. For this reason, I decided to begin my research project by conducting a pilot study. The primary purpose of the pilot was to provide information about teachers’ use of the learning platforms for planning lessons and to experiment with data collection strategies to approach this research object. Another important objective of the pilot was to investigate which theoretical frameworks could support me in answering the research questions.

I began looking for informants to participate in my project. As this was in the beginning of 2016, many schools had not yet begun implementing and using

the platforms, and even fewer teachers used a platform as part of their daily work. My criteria for choosing informants were therefore pragmatic and included that the teachers were mathematics teachers, that they worked at a place where a platform was implemented or in the process of being so, and that the teachers actually used a learning platform to plan their lessons. After many emails and phone calls to school leaders and teachers, I managed to recruit three mathematics teachers who worked at a school near Copenhagen. This school had purchased the Meebook platform before it was a political requirement and had already begun to gradually implement it in 2014. The teachers who agreed to participate in my study were all female, but they varied in age and level of seniority. In general, the teachers had a positive stance toward the digital learning platform. The three teachers worked as part of the same team centered on mathematics, but they taught students at different grade levels. They had found it highly meaningful to collaborate in planning lessons and had integrated Meebook as an essential tool in their collaborative planning. These three teachers convinced the manager at the school that they should have time reserved for planning in the same time slot at least once every fortnight, allowing them to meet to jointly plan lessons 1–2 weeks ahead of time. At these meetings, they would discuss what topics to focus on, which teaching materials and resources to use, what learning objectives to pursue, and how to practically and pedagogically arrange the lessons. They noted all their decisions regarding these matters in Meebook at their joint meetings. Afterwards, each teacher could download this text into her own folder, make the specifications and adjustments that were needed for her particular class, and share it with her students. In relation to my intention to study mathematics teachers' planning of lessons with the digital learning platforms, these subjects provided an ideal setting for investigating this.

Methodologically, I used a combination of video-recordings, observations, and individual interviews with each of the teachers. For theory, I drew on instrumental genesis (Guin et al., 2005). There were several reasons for choosing this framework. First, it was a well-established and domain-specific theoretical approach within the field of mathematics education research, and it contained concepts able to support an in-depth and detailed analysis of teachers' (and students') work with technology. The framework also viewed artifact-mediated activities as dialectical rather than one-sided (Haspekian, 2005). Thus, the framework helped me to avoid over-emphasizing either human activity or technology. Moreover, the framework provided a granular vocabulary to investigate the relation between the teachers' pedagogical work and the interface of the digital learning platform at a micro level.

This study resulted in Paper 2 in this thesis, illustrating that platforms' integration of learning objectives played a crucial role in the decisions the teachers made when planning lessons. More specifically, I found that integrating learning objectives into the platforms could support teachers in choosing resources that corresponded with their intentions for students' learning; however, *how* the learning objectives were incorporated in the interface of the platforms was important. I also provided empirical evidence that the learning objectives in the platforms worked as epistemic mediators for teachers in lesson planning, but that this was due to the teachers' instrumentalization of the platforms rather than the other way around. Besides these empirical findings, the study proved that instrumental genesis worked as a highly valuable theoretical approach to describe teachers' work with the platform in a precise manner. Overall, I managed to fulfill many of the original purposes I had by completing this study.

The interviews I conducted included perspectives among the informants that were interesting but beyond the scope of the small-scale study. Particularly, the respondents talked about the difficulties and resistance some of their colleagues had in terms of using the platforms in their work. At this point, I was already familiar with such viewpoints, as the digital learning platforms had been heavily debated in Denmark. As the teachers who participated in my study were generally positive toward the platform, the questions regarding teachers' concrete reasons for such resistance remained unanswered in the context of this study.

Another viewpoint the respondents frequently brought up but that I did not address in the context of this study was the organizational implementation process, how this had played out at the school, and its significance for how the teachers at the school presently worked with the platforms. In the interviews, I began by asking the teachers questions regarding their educational and professional backgrounds, their age and seniority, when the platform had been purchased and implemented, and what the entire process looked like. When I designed the interview guide prior to the interviews, I thought of these items as background questions and not as part of the research object that I was investigating. However, the teachers dwelt on these questions much longer than I had anticipated and provided relatively elaborate answers on the subject. This piqued my interest in the organizational aspect of the implementation process. However, the information this study yielded regarding this matter was insufficient, as it was a by-product of a study designed with an entirely different purpose. Moreover, this study only included teachers and thereby told a story from a one-sided point of view, as it did not include the perspectives of the other actors involved in the implementation process.

The Platform Project

Half a year into my PhD project, I had the chance to participate in a research and development project financed by Styrelsen for IT og Læring, the Ministry of Education, and KL. The project investigated and supported the implementation of digital learning platforms in Danish compulsory schools. This project was conducted with my main supervisor (Morten Misfeldt) as the principal investigator, ILD LAB at Aalborg University in collaboration with University of Southern Denmark, the Alexandra Institute, University College of Southern Denmark, and University College Absalon. The project was based on interventions and on a participatory research design that used a combination of future workshops (Jungk & Müller, 1984) and design workshops to engage stakeholders at the schools in implementing the learning platforms. The project included 16 schools from across the country that would participate in workshops facilitated by project researchers. The intention in facilitating these workshops was to support the schools in developing strategies and concrete ways for teachers to use the platforms to help them in their daily pedagogical work. The project received a research grant in August 2016, and the initial preparations were scheduled to begin in early September. Though this project and my own PhD project shared a focus on teachers' use of digital learning platforms, the two projects also had substantial differences that called for careful consideration in terms of participation.

Whereas my project until this point had exclusively been a descriptive study, this other project was based on interventions that sought to support stakeholders in schools to develop well-functioning implementation processes. My participation in the project would therefore require that I abandon the descriptive researcher role in favor of an interventionist one. One of the key advantages of the project was that it would provide access to data that had previously been difficult to obtain. However, the interventionist

nature of the project implied that these data would be generated within contexts that were very different from the ones that I had previously been using. Another key difference between my own project and the larger was the specific focus on mathematics teachers in my project and the larger project's focus on pedagogy and general didactics. For example, the teachers participating in the workshops taught many different subjects, and not necessarily mathematics. Though data from the workshops provided insights into different stakeholder perspectives on the digital platforms, this meant that they would not provide specific insights into the perspectives of *mathematics* teachers.

In spite of these differences between the agenda of the platform project and my own, I decided to participate in the project. This choice was based on several practical and intellectual aspects of its design. On a practical level, the research project involved 16 schools. Up until that point, I had difficulty recruiting respondents, and participating in this project would provide access to a quantity of data that would have been a challenge to obtain on my own. Moreover, the future workshops gathered different stakeholders involved in the implementation of the platforms into one room. Further, the workshops were facilitated such that each of these stakeholders would be able to utter his or her concerns and resistance toward the platforms as well as his or her vision regarding how they could enrich teachers' daily work. Information regarding the different stakeholders' perspectives on the platforms would be highly valuable in understanding the kinds of problems that emerge in teachers' and other actors' use of such technology, and possibly, how such problems could be overcome. This research design thus allowed me to approach empirical settings that in other circumstances would have been highly difficult or impossible to access.

As a participant in the project, I got the opportunity to facilitate four workshops at two schools that were using different platforms. The participants included teachers (of mathematics and Danish), local supervisors, school leaders, and municipal consultants who had initiated the implementation process at the schools and still provided pedagogical support via training super-users (teacher that were specially trained in using the platforms) at the schools. As mentioned, these workshops drew on inspiration from future workshops (Jungk & Müller, 1984) and design workshops. As a part of the future workshops, the participants first articulated their essential critiques of the learning platforms; they then went on to describe their visions of how the learning platforms could be integrated into their schools as meaningful tools. After this process, the workshop facilitators introduced resources from design thinking to support the participants in designing platform usage experiments as attempts to fulfill their visions. Besides supporting the schools in implementing the platforms, these settings also allowed for unique and highly interesting insight into the participants' main critiques and visions regarding the platforms, which the stakeholders agreed were important to pursue.

In the context of the present thesis, my participation in this project resulted in two concrete studies: Paper 3 and Paper 4. Paper 3 takes its starting point as the two workshops that a colleague and I facilitated and investigates how the participating stakeholders related to the learning platforms. Further, it explores where they agreed or disagreed and the implications for this regarding the implementation process that happened afterward. Paper 4 examines the two workshops held in the project and discusses the implications of digital learning platforms on teachers' pedagogical work. Moreover, this paper discusses to what extent the methods applied in the project (future workshops and design workshops) could help the pedagogical personnel at the schools to achieve their desired visions regarding the platforms.

Together, these papers provided rich insights into how different stakeholders collaborated in platform implementation and shed light on their different perspectives of the benefits and challenges related to using them. They also showed that for the stakeholders, the platforms represented a discursive and technological manifestation of values. In many cases, these values collided with the conceptions of good teaching among the teachers. Especially, Paper 4 illustrated that differences between the values of teachers and platforms to some extent could be dealt with and overcome through facilitating spaces that allowed for re-interpreting the platforms and thus building a sense of ownership. In this sense, my participation in this process gave me valuable insights regarding the implementation process and teachers' perceived relation between the platforms and the pedagogical values.

Tools, Rules and Teachers –Extending the Documentational Genesis

In this paper, we explored the relationship between teacher practice, technological infrastructure, and the national curriculum standards using one teachers' experience as a focal point for developing the theoretical relationship between national curriculum and resource systems as it became apparent in new digital learning platforms. We presented a learning platform that connected national standards with specific learning objectives for lessons or teaching sequences and described how this tool was tested with teachers. We analyzed the specific example in detail using a combination of curriculum theory and documentational genesis. We used this case to show how the intentions of the national curriculum standards became an integrated part of the teachers' documentational genesis within the learning platform. Rules and national curriculum standards were part of the teachers' resource systems together with the learning platform; this resource system influenced the

planned and enacted curricula and impacted the teachers' work in ways that we could not easily predict.

Mathematics teachers' documentations work in the context of digital platforms

Until this point, the studies reported in this dissertation had focus on teachers' planning with platforms, organizational aspects of their implementation and on developing theoretical approaches that were capable of studying the phenomena emerging in teachers' work with platforms. The final paper of the thesis thus sought to investigate mathematics teachers' usage of digital platforms for classroom teaching. Building on the theoretical insights generated in paper 5, paper 6 sought to investigate the relation between Danish mathematics teachers' classroom teaching and their usage of the digital learning platforms. The empirical foundation for this paper consisted of observations and interviews of four teachers collected from August 2017-January 2018. This paper showed that teachers' choice of integrating digital platforms in their classroom teaching depended on their perceptions of the usefulness of the platforms' translation of the curriculum standards. Depending on the goals of these in teachers' work, the platforms occasionally provided a frame for epistemic or pragmatic mediations or lead a constraint that bring instrumentations that compromise teachers' intentions and goals. Moreover, the paper shows that the transparency of teachers work enabled by platforms may imply that other stakeholders may interfere in teachers documentation work, and that this might imply be that the usage of platforms may be directed towards other goals than pedagogical ones defined by other actors than teachers themselves.

All of the studies above are characterized by studying a particular type of learning platform that have been implemented in the midst of political

conflicts in the Danish educational sector. These factors have had significance for the types of data I have collected and my opportunities of recruiting respondents. In the following section, I will describe these elements of this context in more detail.

Chapter 3: The Danish context

In this chapter, I will describe the background of the studies presented in this dissertation. There are two aspects of the background of the implementation of platforms of particular interest for this context, which I will concentrate on describing here. These aspects regard the nature of the Danish digital platforms compared to other types of platforms, and the political landscape of which these platforms have been a part. These aspects are closely related, as the feature that distinguish the Danish digital platforms from others is the same feature that have entangled the platforms in the political debate about compulsory schools in Denmark. I will therefore begin the following section by briefly reviewing the types of digital platforms that are available. The purpose of this is to distinguish the Danish platforms from these other available technologies and describe the particularities of the Danish platforms and their implementation. After having done this, I will proceed to describe the political conflicts in the Danish educational sector from 2013-2019, and the role that the Danish digital learning platforms have played in this conflict.

The Political Contexts of the Studies

In the period from 2013 to 2019, in which I conducted the studies described above, the Danish compulsory school were an object for several conflicts between the Danish teacher union (The Danish Teacher Association) at the one side, and The Danish Ministry of Education and Local Government Denmark at the other. These conflicts have had great implications for teachers' attitude to their work, their relation to their employers, to the current curriculum that are integrated in the platforms and not least to the digital learning platforms themselves. As the studies of this thesis have been carried in the context of these conflicts, I will devote this section to describing these

debates and conflicts as they have defined a set of premises in which I had to navigate in the studies.

The Danish Situation 2013-2019

Breakdown in Union Agreements on Teachers' Working Hours

Danish teachers employed by a municipality are hired on agreement terms, which are centrally negotiated between the Danish Teacher Association, who represents the employees, and Local Government Denmark, who represents the employers; the agreement is negotiated every fourth year. In 2013, these negotiations led to heavy conflict between the two parties. This disagreement particularly regarded the flexibility of teachers' working hours: In previous negotiations (in 2008), the agreement included an upper limit of 25 lessons (lasting 45 minutes each) that teachers could be required to teach per week. Prior to the negotiation, a report had estimated that teachers spent approximately 40% of their working hours teaching, whereas they spent the remaining 60% on planning lessons, cooperating with colleagues, in meetings, and collaborating and communicating with students' parents.⁷ Whereas the Danish Teacher Association wished to maintain these central agreements about the distribution of teachers' working hours, Local Government Denmark wanted to eliminate them and allow local agreements to be made. Among other things, the argument for this on the side of the employers was that experienced teachers were likely to be able to teach more hours than younger and less experienced teachers. By removing the legislative specification of teachers' working hours, school managers would have the opportunity to set their own priorities regarding teaching allotment. Another central aspect of the requirements put forward by the employers was that teachers' working hours had to fall within the hours of 8–4 PM, and that

⁷ <https://politiken.dk/indland/art5442710/Hemmelige-dokumenter-om-1%C3%A6rernes-arbejdstid-blev-smidt-i-skraldespanden>

school managers were free to make it mandatory for teachers to conduct all their work at school. This was an important issue, as Danish teachers traditionally had done much of their planning and assessment of students from home. The employees and the Danish Teacher Association considered these requirements to be an expression of mistrust that would introduce a radical shift in the balance of power in favor of the employers. The parties continued disagreeing, ultimately resulting in a breakdown where Local Government Denmark “locked out”⁸ approximately 67,000 teachers who had been employed under union-negotiated terms. After a 25-day lockout, the conflict was settled via legislative intervention made by the government. The intervention, which came into effect in August 2014, forced an agreement through that was in line with many of the terms put forward by Local Government Denmark.

The legislative intervention specified that teachers had the right and duty of being present at the school during all their working hours, including when planning and evaluating lessons. Previously, there was no requirement that teachers should do their planning at the school. Moreover, teachers’ working times now had to be placed within their scheduled working hours (8 AM–4 PM); therefore, teachers could not communicate with students’ parents outside these hours.⁹

Among teachers and the Danish Teachers Association, the general impression of the breakdown in both the negotiations and the law meant to solve the conflict was that it represented mistrust toward the teachers. They felt that the fixation on teachers’ working hours was based on a preconception that teachers were working less than 37 hours per week. After the conflict, many

⁸ “Look out” is when the employer side in a union conflict exclude employees from their jobs (the opposite of a strike).

⁹ https://www.dlf.org/media/962619/dlf_Lov409-pdf.pdf

teachers quit their jobs, and investigations of this phenomenon indicated that a main reason for this was the changes made by the conflict.^{10,11}

The New Curriculum in 2014

Not long after the conflict described above, a new issue emerged in the Danish debate about compulsory schools—a new curriculum. This curriculum was presented in late 2013 and was scheduled to come into effect for the 2015/2016 school year. Whereas the previous curriculum from 2009 had described the content of teachers' lessons, the reform focused on describing students' expected learning outcomes. This reform included goals regarding students' knowledge, skills, and competencies within the different areas of each subject taught in school. According to the Ministry of Education, this structure constituted a more simple and precise specification of the objectives and aims of compulsory schools, which would be more applicable for teachers to use in their teaching.¹²

The new curriculum was presented at a hearing in December 2013 and was immediately heavily criticized by the Danish Teacher Union. Shortly after the hearing, the union publicly declared its concern regarding the curriculum reform and encouraged the government to withdraw it.¹³ Its main concern was that the structure of the curriculum over-emphasized learning objectives. As the objectives in the curriculum were relatively detailed, the union expressed a fear that the new curriculum would deprive teachers of their professional autonomy and instead force them to steer their teaching toward external and

¹⁰ https://www.dlf.org/media/962619/dlf_Lov409-pdf.pdf

¹¹ <https://www.dlf.org/media/10280343/f2-ucc-hvorfor-stopper-laererne-i-folkeskolen.pdf>

¹² <https://uvm.dk/folkeskolen/fag-timetal-og-overgange/faelles-maal/historisk/historisk-oversigt>

¹³ <https://www.folkeskolen.dk/538605/dlf-ny-lov-kan-snaevre-undervisningsbegrebet-ind>

politically decided objectives. The Danish Teacher Association acted upon this concern by formally responding to the hearing with an appeal to the government to withdraw the revision.¹⁴ Besides the above-mentioned concerns, the official appeal was based on arguments that the new curriculum overlooked international experiences that a focus on detailed learning objectives would lead to 1) a fragmentation of school subjects, and 2) an instrumental approach to teaching.¹⁵ Moreover, the union argued the new curriculum was a product of a closed process that had failed to allow practitioners to give feedback and in any way participate in the work leading to the new curriculum. The curriculum and the particular role of learning objectives have been discussed heavily ever since, and recently, the legitimacy of the research evidence behind the reform has been questioned.¹⁶ Because of this dispute, many teachers have expressed their dissatisfaction with both objective-oriented teaching and the curriculum itself (see Paper 4 for an elaborate description of this situation).

Digital Learning Platforms and the Curriculum Reform

In the middle of the disputes described above, yet another conflict emerged. The issue at the center of this conflict was the digital learning platforms. It began in late 2013 with the launch of the User Portal Initiative and the introduction of the requirement specifications for the platforms in October 2014. As previously described, a key aspect of the functional requirements was that their interface should incorporate support for teachers to integrate learning objectives from the curriculum into their planning, teaching, and assessment of students (KL, 2014). The requirements instantiated a direct legal link between the platforms and the curriculum, including its underlying

¹⁴ <https://www.dlf.org/media/974303/20140124113503170.pdf>

¹⁵ <https://www.dlf.org/media/974303/20140124113503170.pdf>

¹⁶ <https://www.folkeskolen.dk/651460/skovmand-laeringsmaalstyring-var-ikke-baseret-paa-forskning>

pedagogical approach: objective-oriented teaching. Both Meebook and MinUddannelsel realized this linkage by requiring teachers to define a learning objective in order to create and distribute a lesson in the platform to their students.

Not long after the release of the requirement specifications, the Danish Teacher Association published an informational guide for teachers about the imminent requirements of having to use a digital learning platform.¹⁷ This guide informed them about what the union referred to as the “risks” associated with using the platforms. According to the union, the main risk was that the platforms promoted a learning objective-oriented approach to teaching, and that this could have severe constraints for teachers’ opportunities to plan meaningful teaching.¹⁸ The guide also warned teachers that using a digital platform could be highly time-consuming; it recommended that teachers benchmark the time spent on the platform against the actual value it brought in terms of increased quality of teaching.¹⁹ As is apparent from this advice, the union was skeptical of the learning platforms from the beginning. As described in Papers 3 and 4, teachers across the country felt a similar skepticism, and debate about the actual usefulness of the platforms continues, much of it focusing on their learning objectives. This is considered particularly problematic, as a key feature of the User Portal Initiative was that the Danish municipalities were obligated to purchase and implement a digital learning platform. Some raised the concern that the digital platforms would

¹⁷ <https://www.dlf.org/medlem/inspiration-til-laererarbejdet/digitale-laeringsplatforme#hvilke>

¹⁸<https://www.dlf.org/medlem/inspiration-til-laererarbejdet/digitale-laeringsplatforme#hvilke>

¹⁹<https://www.dlf.org/medlem/inspiration-til-laererarbejdet/digitale-laeringsplatforme#hvilke>

compromise teachers' freedom, professional autonomy, and integrity.²⁰ As I will elaborate in further detail later, the digital platforms have been the topic of vivid political debate, and many teachers have been against the platforms for pedagogical reasons.

This resistance toward the platforms culminated in 2017 when the second-largest municipality in Denmark applied for a waiver not to use the platforms. The Danish Minister of Education responded to this application (in a Facebook post) by underlining that the requirement was only for municipalities to *purchase* and *implement* a learning platform—whether teachers actually *used* them was their own affair.²¹ The Danish debate about digital platforms is increasing in complexity, and there is no consensus about whether the platforms are for the better or the worse. The debate is most often heavily polarized and characterized by a lack of concrete empirical examples that document any claims of shortcomings or benefits the platforms might have for teaching and learning.

The political landscape described above had implications for both the nature of the data I collected and my opportunities to collect it. The data collection strategies I deployed at the different levels of the implementation translated into a unique set of challenges. The main data sources at the organizational level consisted of observations conducted at future workshops, whereas the data sources at the practical pedagogical level consisted of observations of teachers planning and teaching as well as interviews. As my thesis consists of six individual papers, I conducted the data collection in the context of different specific political conflicts. The visualization presented in Figure 7 below

²⁰<https://skoleliv.dk/debat/art6701085/Drop-læringsplatforme-spar-penge-og-få-mere-undervisning>

²¹ <https://www.folkeskolen.dk/625975/riisager-jeg-kraever-ikke-at-i-bruger-laeringsplatform>

provides an overview of the timely relations between my data collection and the current political context.

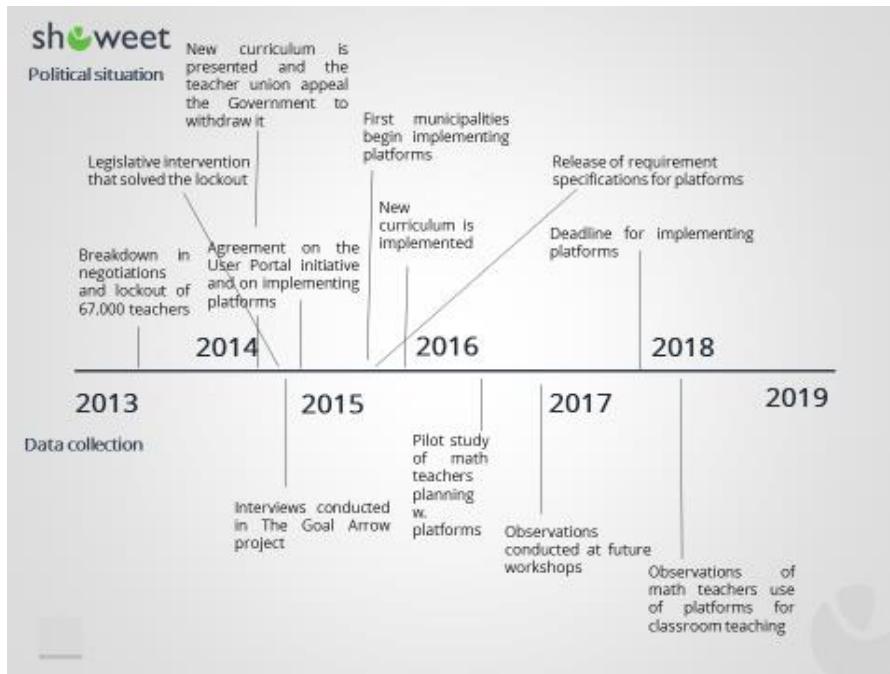


Figure 7. An overview and timeline of the political context of data collection.

As already indicated, the political contexts translated into different types of challenges for data collection at the two levels of implementation. In Chapter 6, I return to the issues and premises this political landscape brought for doing research and the way in which I navigated them. In the following section, however, I describe the research question and sub-questions I address in this thesis and the philosophical foundations underlying the studies they include.

Chapter 4: The Research Questions and the Philosophical Foundations of The thesis

As stated in the introduction, this thesis seeks to investigate the following research question:

How do stakeholders in schools engage in the organizational implementation of digital learning platforms, and what are the implications of the implementation of the platforms for mathematics pedagogical teachers' work?

My approach to answer this research question is to divide it into two separate sub-questions addressing what I refer to as two different levels of the implementation. These levels regard 1) how schools as organizations cope with implementing the platforms, and 2) how mathematics teachers implement the platforms into their planning and classroom teaching. I refer to these levels as *the organization level* and *the pedagogical practical level* of the implementation process. The distinction between these levels is reflected in two sub-questions that are phrased as follows:

- **Organizational level:** *What are the mutual relation between actor groups' in schools perspectives on digital platforms, how does this affect the opportunities of a successful implementation, and to what extent can the pedagogical staff overcome their perceived limitations of the platforms?*
- **Practical pedagogical level:** *How do mathematics teachers pedagogically enact digital learning platforms, what are the underlying reasons for these enactments, and what are the implications for their pedagogical work?*

At *the organization level*, I focus on investigating the perspectives that the actor groups involved in the organizational level have about the platforms. These actor groups include teachers, local supervisors, school managers, and municipal consultants. The studies at this level investigate how the mutual relations among their perspectives affect the chance of having successful implementation. In the studies at this level, I investigate how, to what extent, and under what circumstances teachers and staff are able to overcome their perceived limitations of the platforms. Unlike the practical pedagogical level, I do not investigate this among teachers of a specific subject. As I have described previously, this rather is rather a result of conditional factors than on an active choice.

In the *practical pedagogical level*, I focus specifically on mathematics teachers' use of digital platforms in their planning and teaching. A primary reason for this choice is the lack of research that investigates teachers' work with digital platforms in subject-specific contexts. Although the Danish platforms, like many other platforms, are developed for general pedagogical and not subject specific purposes, previous research has indicated differences in teachers' use across the disciplines they teach (Hansen & Petersen, 2018). The digital platforms in Denmark have been heavily debated, and the platforms have in particular been accused of integrating a rigid interpretation of learning platforms that fits poorly with subjects where aesthetics are a key element, such as literature, music, and art (Holgersen, 2016). In contrast, mathematics teachers have been requesting technologies such as digital platforms to support their use of the new curriculum standards (EVA, 2015). Moreover, the use of technology (whether digital or not) in mathematics education and mathematics education research has always been an essential element of the subject (Dreyfus, 1993).

This structure of the research question implies that this thesis has two different strands, each of which focuses on different aspects of the implementation process. As will become apparent, their differences required that I study them using different theoretical concepts and methods. In the following section, I describe how and why I have chosen such an approach, reflecting upon the advantages and disadvantages this has brought. I discuss these matters as issues in the framework of philosophy of science.

Philosophical Foundation of the Thesis: An Analytical Strategic Approach to Philosophy of Science

Here, I describe the underlying philosophical foundations of the thesis. As a discipline, philosophy of science typically regards questions of what qualifies as science, the purpose of science, and the ontological and epistemological foundations of the scientific production of knowledge (Guba & Lincoln, 1994; Hacking, 2003; Esmark, Laustsen, & Andersen, 2005). As Andersen (1999) argued, philosophy of science primarily addresses the ontological foundations of a given research project, and from there, quickly moves to questions regarding method. One of the potential implications of such an approach is that the researcher risks disconnecting the foundational considerations of a study from questions of how and on what premises a given object is researchable as well as what methods and data sources are adequate (Esmark, Laustsen, & Andersen, 2014). To avoid such a disconnection, I drew on an approach entitled analytical strategy (Esmark, Laustsen, & Andersen, 2014). In brief, analytical strategy addresses philosophy of science questions by taking the theories and concepts that are used in a given study as a starting point. From this outset, analytical strategy foregrounds consideration of how and on what premises the use of a concept or theory makes an empirical object researchable. Analytical strategy is thereby an approach that can be labeled

within a constructivist paradigm, in which the term “theory” in general terms refers to the tools that are involved in the scientific production of knowledge rather than a hypothesis of the relation between cause and effect (Guba & Lincoln, 1999; Esmark, Laustsen, & Andersen, 2014). This constructivist outset in analytical strategy is evident in that empirical objects are not considered to exist independently of our description and observation of them (Andersen, 1999). Rather, observations and descriptions of empirical objects are considered to be a product that is conditioned by the means we use to describe them. For the researcher, such means are often theories and concepts. The exercise within analytical strategy is for the researcher to better articulate how and on what premises the chosen theories and concepts allow for observing, describing, and studying an empirical object. In this respect, the term “strategy” in analytical strategy demarks that a researchers’ observation and description of a given object is (and should be) the result of a deliberate choice of concepts (Andersen, 1999).

An analytical strategic approach distinguishes between methodology and method: methodology is related to a researcher’s specification of the ontological and epistemological implications the use of a given concept has for the use of concrete methods; it thereby belongs to the philosophical realm. Method refers to the techniques of collecting, formatting, and processing data (Esmark, Laustsen, & Andersen, 2014). Though methodology and method are mutually dependent, they are two different things. Here, I devote my attention to matters of methodology, whereas I address the practical methods I used in the thesis in Chapter 6.

My choice of theories and concepts guided which research questions I could answer and which sources of data were adequate. As I explain, this had

significance for how I phrased the research and sub-research questions and what concepts informed them.

The Structure of the Research Questions and their Analytical Strategic Consequences

As indicated by the research questions presented above, I address two levels of the implementation process: the organizational level and the practical pedagogical level. The distinction between these levels is visualized in Figure 8 below; it illustrates how I interpret the overall research questions in two sub-questions:

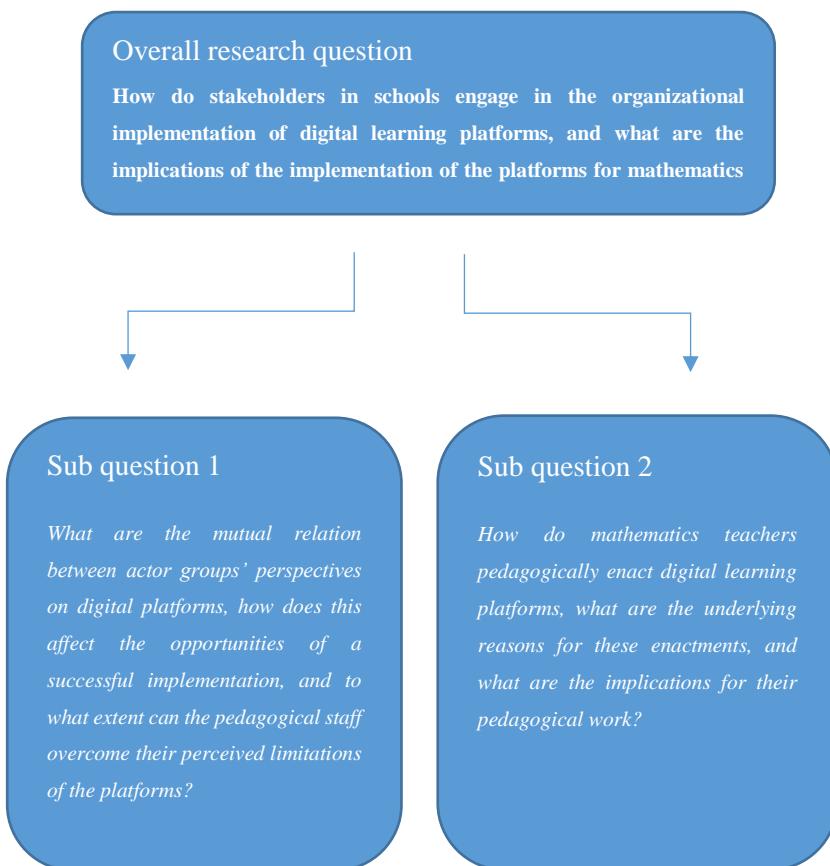


Figure 8. *A representation of the relation between the main research questions and sub-questions of this thesis.*

It is important to note that the starting point for choosing an analytical strategic approach was my interest in creating concrete questions that would address specific aspects of the implementation process. In this respect, I apply a pragmatic approach to the analytical strategy in that I use it as a tool to narrow down a broad question defined independently from an analytical strategic approach—not to pose the initial overall question.

Throughout this thesis, I refer to these levels as the practical pedagogical level and the organizational level of the implementation. As indicated by sub-question 1 in the figure, the organizational level concerns how the actor groups involved in the platform implementation view the learning platforms, what they consider to be the main issues and potentials of the learning platforms, and to what extent they are able to successfully implement the platforms. The practical pedagogical level addressed in sub-question 2 regards teachers' pedagogical usage of the learning platform in different contexts and the platforms' role in teachers' pedagogical practices.

As stated above, an analytical strategic approach is based on the foundational assumption that the concepts we use allow us to describe and study an empirical object on a particular set of premises. Therefore, our choice of concepts both has significance for the questions we are able to ask/answer and for what data sources are appropriate to use in the pursuit of answering those questions. As I study different empirical objects in the two sub-questions, different concepts have informed both how I have phrased and how I seek to answer them. The organizational level is informed by cultural logics (Nielsen, 2012), a concept developed to study collaboration in school contexts. The practical pedagogical level is informed by instrumental and documentational

genesis (Guin et al., 2005; Trouche, 2004; Gueudet & Trouche, 2009), which are theoretical approaches that researchers developed to study mathematics teachers' work with digital artifacts and resources in various aspects of their pedagogical practices. This operationalization of the research questions is visualized in Figure 9 below.

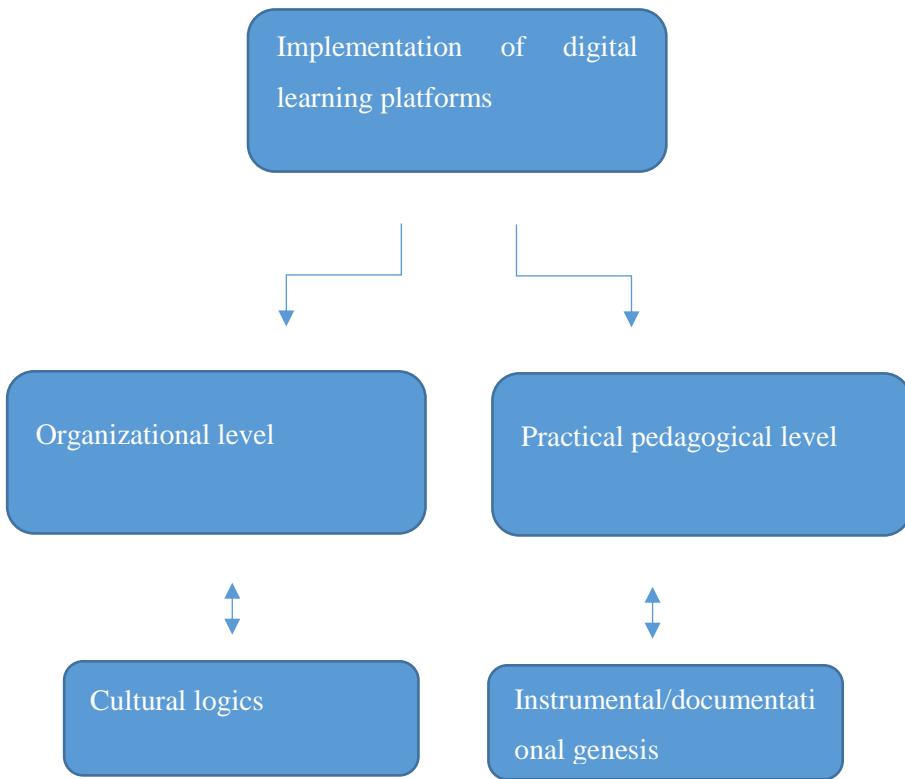


Figure 9: A representation of the relation between the theoretical concepts used in this thesis, the two levels of implementation and the overall theme of the thesis: implementation of digital learning platform.

As previously stated, the term “strategy” in the analytical strategic approach demarks that the use of a concept is a product of an intentional choice—

choosing a concept for a study allows us to study an empirical object on a particular set of premises. Using different concepts to study different aspects of the implementation therefore requires a series of questions to be addressed. I have already explained my reasons for separating the research questions into two sub-areas, and two questions remain:

- From what priorities have I chosen the concepts at the two levels?
- What are the advantages and disadvantages of using two different concepts?

In the following section, I address these questions beginning with my priorities in choosing concepts. Both levels in the two sub-questions have several domain-specific characteristics, which played a role in my decision to choose different concepts to study the two levels.

Approaches and Priorities in the Choice of Concepts

The Organizational Level

The organizational level of the implementation of the digital platforms involved the cooperation of multiple actor groups occupying different jobs. As shown in Paper 1, previous research have identified that different actor groups have different perspectives of the platforms and different ways of relating to them – particularly regarding their concerns about the changes digital platforms will bring for their job (Lochner, Conrad & Graham, 2015). Based on this insight, I found it likely that such different perspectives of the platforms would play a significant role in the organizational implementation process of the Danish digital platforms, and the relation among the perspectives of the involved actor groups would have implications for the implementation process. This was the initial rational for investigating how actor groups involved in the implementation of platforms perceived the

platforms at a local level. To reach this aim, I needed a concept that could provide analytical precision in identifying how actor groups related to the platforms. Moreover, I needed a concept that were able to study this from at a discursive level that did focused on how a group of people, and not only a particular person, related to the platforms. This would allow me to study how the problems related to the digital platforms were framed locally. In the public debates and conflicts about the usefulness or implications of platforms, it has often been difficult to pinpoint the exact roots of the problems. For schools to navigate in the implementation process, an important initial step to understanding the root of the disagreements, which could be made possible from studying the local framing of the platforms among the actors involved in the implementation process.

In my previous research, my colleagues and I used a concept called cultural logics to study the implementation of a teacher-training concept with colleagues from Aalborg University (see Tamborg, Allsopp, Foug, & Misfeldt, 2017). Nielsen (2012) developed the concept of cultural logics to study teachers' collaboration in teams. Cultural logics comprise the stable orientations in actors' actions and utterances, sometimes referred to as dynamic stabilities (Nielsen, 2012). They are dynamic in that actors constantly act differently and utter different viewpoints in different situations (Nielsen, 2012). They are, however, stable in that the seemingly different actions and utterances reflect the same general priority and orientation, called cultural logic. Nielsen (2012) developed this concept within the context of a research project aiming to study teachers' collaboration in teams. Her research illustrated that these collaborations tended to be oriented toward practical matters (i.e., the distribution of textbooks, agreeing on meeting schedules, etc.) and seldom toward pedagogical matters (Nielsen, 2012).

In our way of using this concept, we investigated collaborations involving actors in different positions to study the different cultural logics among stakeholders involved in the same collaboration (Tamborg, Allsopp, Foug, & Misfeldt, 2017). A key benefit of this approach in this context is that these logics are connected to the profession of the actor. This way of using cultural logics allowed us to pinpoint the different and sometimes incompatible priorities or viewpoints of the actors involved in the same project. As previous research identified such different viewpoints to be a common challenge in the implementation of digital platforms (Lochner, Conrad, & Graham, 2015), I decided to focus on this aspect in the implementation of digital platforms in the Danish compulsory schools.

The qualities of cultural logics (Nielsen, 2012) described above made it well suited to study the organizational aspect of implementing learning platforms, as it allowed me to study the priorities of the different actors involved in the implementation process. This facilitated investigating how these cultural logics related to one another and how the interrelations among the logics affected the chances of a successful implementation. As the concept of cultural logics was developed to study stability in actors' actions and utterances, it mainly takes a discursive approach to the study of collaboration and devotes less attention to the materiality or technology that might be involved in this collaboration. In this case, this was a beneficial characteristic of the concept, as there had been heavy conflict between employers and employees during the implementation process, with the effect of many different ways of relating to and talking about the platforms). Due to its discursive focus, cultural logics enabled me to study these different viewpoints and ways of relating to the platforms in detail. The concept supported me in finding the underlying cause of the divergent perspectives of the platforms and the priorities underlying

these perspectives. In this way, cultural logics facilitated a locally situated discursive analysis of local perspectives of platforms and their interrelations.

The Practical Pedagogical Level

This level focuses on mathematics teachers' use of digital platforms, particularly in their lesson planning and classroom teaching. As I argue in Chapter 2, this aspect is seldom studied. Fortunately, my previous participation in the Goal Arrow project provided experiences that I have built upon here in choosing a framework. In this project, we found that teachers used the same technology in very different ways. This implied that the material properties of the technology had different implications for the teachers depending on the particular practices it was used for. Thus, I needed a framework that could account for the relation between the inherent properties of the platforms and the tasks for which the platforms were used. The Danish platforms can be used for a number of different purposes, and it is highly likely that the implications of the platforms' inherent properties may be different depending on which activities they mediate. As I intended to focus on mathematics teachers, another key priority was to choose a framework that was developed within this field of research.

Mathematics education research is a field that has a long tradition of studying teaching and learning mathematics with different types of technology (Dreyfus, 1993). Perhaps one of the most influential theoretical frameworks with which to do this is the instrumental approach to didactics (also known as instrumental genesis) and its "sister" framework, the documentational approach to didactics (also known as documentational genesis). Instrumental genesis and documentational genesis are both frameworks that were developed within mathematics education research. Instrumental genesis has its origin in psychology; Guin and Trouche (1998) adopted and modified it.

Instrumental genesis studies a subject's (often teachers' or students') goal-directed use of an artifact and considers how the goal of the subject and the artifact affect one other (Guin & Trouche, 1998).

The approach distinguishes between artifacts and instruments, and it considers an artifact to be a cultural social construct that mediates human activity. In contrast, an instrument is considered to be the product of a subject's use of the artifact (Gueudet & Trouche, 2009; Gueudet, Buteau, Mesa, & Misfeldt, 2014). An instrument can thus be defined as usage + artifact and is, contrary to an artifact, considered to be a psychological construct emerging from the concrete use of an artifact.

The focus of analysis driven by the instrumental genesis framework is often the genesis of the emerging instrument and the implications of this for teaching or learning mathematics. Moreover, analyses can identify instrumentalizations (cases in which the subject's use of an artifact shapes the artifact) and instrumentations (cases in which the artifact shapes the subject's activity) (Gueudet & Trouche, 2009).

Documentational genesis shares many of the foundational thoughts of instrumental genesis, but with a slightly different vocabulary and focus. Whereas instrumental genesis distinguishes between artifacts and instruments, documentational genesis distinguishes between resources and documents. In documentational genesis, a resource is broadly considered to be "anything likely to intervene in teachers' documentation work" (Gueudet & Trouche, 2009, p. 200), whereas a document is, similar to an instrument, considered to be the end-product of a resource + utilization (Gueudet & Trouche, 2009). The concepts of instrumentalizations and instrumentations are also integrated into the documentational approach. However, this approach emphasizes that teachers have documentation systems, and that studying the evolution of these

systems can provide an insight into studying teachers' professional changes (Gueudet & Trouche, 2009).

In the context of teachers' work with digital platforms, the different emphases in instrumental and documentational genesis each have benefits. Instrumental genesis enables us to study how the platforms mediate teachers' work without over-emphasizing the platforms' properties or how they are being used. The psychological focus in instrumental genesis enables studying the relation between mathematics teachers' pedagogical decisions and the platforms' properties. The framework also allows for investigating how different aims among teachers using the platforms result in different experiences of opportunities and constraints as well as varying pedagogical practices. In this thesis, this was necessary in order to investigate the different types of implications the platforms had depending on how teachers' used them.

For mathematics teachers, the digital learning platforms enter already established practices: routines that include specific ways of using a selection of resources. The Danish digital learning platforms provide teachers with a potentially new infrastructure to handle most of their pedagogical work, but the digital platforms might be more compatible with some resource systems than others. This makes it important to understand how mathematics teachers navigate their resources with or without the platforms, what new resources the platforms enable, and with what pedagogical implications. Moreover, it allows me to pursue questions of whether the platforms have any constraints in terms of what resources are available and how these can be used.

Instrumental and documentational genesis differ significantly from the notion of cultural logics in terms of their perspectives on technology and what they emphasize in studies of teachers' use of technology. The instrumental and documentational approaches focus on the relation between the property of

digital platforms and a subject's use of it and give less attention to how the subject *relates* to it. Oppositely, cultural logics focuses on how subjects relate to the platforms, but it does not consider the material properties of that artifact.

Advantages and Disadvantages

A main rationale for separating the research questions was that it allowed me to imbue the research studies with domain-specific concepts, which I developed and refined according to the particularities of the given domain. Cultural logics (2012) was particularly developed to study actors' collaboration in school contexts. Its focus on identifying stable values and priorities in stakeholders in education reflects that education is a domain in which these are of immense importance (Nielsen, 2012). Similarly, instrumental genesis has features that reflect the accumulated knowledge of the specificities of mathematics teachers' work with digital technology. Instrumental genesis (Guin et al., 2005) was developed to study teachers' pedagogical usage of artifacts (both digital and analogue) and the implications of this usage in lesson planning and classroom teaching. Moreover, this theoretical framework has a built-in classification system reflecting what is important in mathematics education research: the distinction between epistemic/pragmatic mediation; between mediations oriented toward the subject, the object or the task; and finally, between instrumentation and instrumentalization. These concepts brought an empirical sensitivity of in the framework to investigate whether the usage of the platforms allowed teachers a professional autonomy and to discuss the nature of the pedagogical decisions made by teachers under the influence of the platforms.

There are also a number of disadvantages to separating the research questions into two different levels. Although I studied both the teachers' pedagogical activities related to the implementation of platforms and the organizational

aspects of the implementation process, the separation of the research question implies that I examined these processes in isolation from each other. The distinction between the two levels of implementation thereby introduces a sharp distinction between the micro and the meso level of the implementation process, which fails to account for how these relate to and mutually affect each other. This challenge is enforced by the fact that instrumental and documentational geneeses are psychological approaches that do not provide lenses to investigate systemic aspects at the organizational and political levels. I have handled this limitation in several ways. Firstly, my colleagues and I have developed an extension of the documentational genesis that compensates for its lack of focus on the importance of how resources are entangled with political agendas (see Paper 4). Concerning how the two levels relate to one another, I developed an overarching framework that integrated the two levels of implementation by building on implementation theory.

Chapter 5: Theoretical Approach

As previously described, the papers in this thesis study different aspects of the implementation of digital learning platforms in Danish compulsory schools and use different theoretical resources to do so. In Chapter 1, I described how the use of different theoretical concepts at the two levels led to different types of research questions resting on different philosophical foundations. A common interest across the two levels was to study the implementation of the digital learning platforms. In this chapter, I describe what I mean by “implementation” and how the two levels address the study of platform implementation. The aim of this chapter is to articulate an overarching framework across the two levels of implementation represented in this thesis.

My starting point in this effort is based on a definition of implementation research originating from a recent review of implementation research that Century and Cassata (2016) conducted. In this definition, they argued that implementation research studies involved four central elements: enactment, innovation, factors of influence, and outcomes. It was a key point that these elements were studied and conceptualized differently depending on the given study (Century & Cassata, 2016). After having described this definition and its origin, I now aim to illustrate how the papers at the organizational and the practical pedagogical level interpreted these five aspects differently according to the theoretical frameworks informing them. By using Century and Cassata’s (2016) definition of implementation research, I show how the theoretical frameworks and concepts that I used to study the two levels of implementation allowed for interpretations of the four elements that address the relevant research questions regarding the implementation of digital learning platforms in a Danish context.

The chapter is organized into two main sections. In the first section, I define implementation research and argue the general need for such an overarching and generic definition in mathematics education research in light of recent movements in the field. In the second section, I describe the two levels of implementation and the interpretation of the four elements of implementation research that the frameworks used at the different levels have led to.

Implementation Research in Mathematics Education Research

Implementation is a research object that has been of interest to practitioners and researchers in education and mathematics education for decades (Spillane, Reiser, & Reimer 2002). Nonetheless, it is still relatively young as a named field of study in educational research (Century & Cassata, 2016). One implication of the lack of organization in this field is that there are only a few explicit and coherent definitions of implementation that can guide research (Century & Cassata, 2016). Indeed, this is also the case for mathematics education research. Unlike other disciplines in education,²² mathematics education research had not succeeded in establishing fora, journals, or the like devoted to supporting, describing, or evaluating implementation processes (Century & Cassata, 2016). Only recently has interest in implementation research in mathematics education emerged. At the Congress of European Research in Mathematics Education (CERME), which is one of the largest communities within mathematics education, a thematic working group focusing on implementation was established in 2016. One of the most remarkable characteristics of the papers presented in this first thematic

²² A journal in health care science entitled *Implementation Science* was founded in 2006.

working group²³ was perhaps their level of diversity. The papers integrated many separate sub-fields of mathematics education research, including students' proportional reasoning (Ahl, 2017), teachers' professional development (Ärlebäck, 2017), and curriculum design (Kuzle, 2017). These are fields that are otherwise organised as separate sub-fields that deal with research objects and mainstream theoretical and methodological approaches. In the introduction to the proceedings, the leaders of the thematic working group gathered these otherwise diverse papers presented in the group by drawing on Nilsen's (2015) point that implementation research must have one of the following three aims:

- Describing and/or guiding the process of translating research into practice,
- understanding and/or explaining what influences implementation outcomes, and
- evaluating implementation

(Nilsen, 2015 in Jankvist, Aguilar, Ärlebäck, & Wæge, 2017).

As the work group leaders argued, all the papers presented in the workgroup indeed addressed one of the three above-mentioned aims. In that respect, it was clear how they all addressed implementation matters. However, the papers tended to adopt frameworks based on the characteristics of the innovation that were being implemented. For example, studies of the implementation of new approaches for teacher collaboration drew on theory regarding teachers' collaboration (Tamborg, Allsopp, Fougt, & Misfeldt, 2017), and studies of the implementation of new ways of counting were based

²³ All the papers are published in the proceedings from the conference, which are available from http://www.mathematik.uni-dortmund.de/ieem/erme_temp/CERME10_Proceedings_final.pdf

on number theory (Ejersbo & Misfeldt, 2017). Typically, the use of such theories was not followed by an explicit description of how the study defined and conceptualized implementation processes or fit into implementation research. Thus, it was not entirely clear how the papers in the working group qualified as implementation research.

In spite of this seeming lack of clarity, there were several reasons to maintain the use of theoretical frameworks from established sub-fields of mathematics education in implementation research fora. Although domain- and innovation-specific theories from mathematics education research are not considered to be implementation frameworks, the majority of these theories have a built-in focus on how to investigate, support, or evaluate implementation processes (Jankvist, Aguilar, Ärlebäck, & Wæge, 2017). Domain-specific theories from the sub-fields of mathematics education research often provide concepts that are appropriate for implementation research purposes. Moreover, researchers have refined domain-specific theories from mathematics education research for decades in order to study the specific objects or processes for which they are developed. This gives the framework a sensitivity toward the particularity of the given innovation in question. Moreover, innovation-specific frameworks have often been informed by a substantial body of knowledge, such as common misunderstandings among students trying to grasp a mathematical concept. These are all good reasons to maintain diversity in research objects, illustrating the benefits of integrating existing domain-specific theories into implementation research.

This level of diversity might make it difficult to build a coherent body of knowledge in implementation research as an independent sub-field in mathematics education research. How do findings from studies driven by different aims, theoretical frameworks, and methods relate?

On a smaller scale, this is also an issue that needs to be addressed in the context of this thesis. How do studies of the organizational and the practical level relate? To what extent do the studies across the two levels contribute to building coherent research findings? In relation to Nilsen's (2015) different aims of implementation research, the papers in my thesis indeed all aim to describe and understand the implementation process. Beside this common denominator, it is not immediately obvious how the papers qualify as implementation research. In order to clearly articulate how the papers contribute to studying the *implementation* of digital learning platforms, I use Century and Cassata's (2016) definition of implementation research as a starting point. This definition describes implementation research as a scientific endeavor that includes a perspective on four different elements (enactment, innovation, factors of influence, and outcome). It is key that these elements are generic and that implementation research studies interpret and conceptualize them differently according to the aim and theory they use. Century and Cassata's (2016) definition of implementation research functions as the foundation for explaining how the individual papers in this thesis have interpreted these four elements. The ultimate goal of this exercise is to better describe how the conclusions generated from the different findings relate.

Towards a Definition of Implementation Research

As mentioned above, I draw on Century and Cassata's (2016) definition of implementation research:

“(...) the systematic inquiry regarding innovations enacted in controlled settings or in ordinary practice, the factors that influence innovation enactment, and the relationships between innovations, influential factors, and outcomes” (Century & Cassata, 2016, 170, underlining added).

The term *innovation* in this definition is considered in a broad sense and may include “. . . programs, interventions, technologies, processes, approaches, methods, strategies, or policies that involve a change (e.g., in behavior or practice) for the individuals (end users) enacting them” (Century & Cassata, 2016, p. 170). It is also important to note that the term *innovation* in this context is neutral in that it refers to the envisioned *change* brought about by the program, intervention, technology, process, approach, method, strategy, or policy—not to a presupposed *quality* of that change.

Before I describe how I interpret and conceptualize this definition at the two levels, I detail the context in which it was developed, as it has significance for how I use it. The above definition stems from a comprehensive literature review of implementation research in the field of educational research that Century and Cassata (2016) conducted. One of the difficulties they encountered in conducting such a review was that implementation research studies were typically not declared as such. As they noted, this makes implementation research poorly suited for conducting a traditional review that identifies, evaluates, or synthesizes the body’s empirical results, as it “involves more than a single set of methodologies, and it includes many different theoretical approaches” (Century & Cassata, 2016, p. 171). The working definition of implementation research the authors developed was therefore constructed with the purpose of creating a

“(...) conceptual clarity and common (or at least clearly communicated and understood) language so that those working under the broad umbrella of implementation research can understand one another and how their various bodies of work relate” (Century & Cassata, 2016, p. 170).

As implementation research seldom declares itself as such, it is not straightforward to conduct a literature review of such a field. What key words

should be used, and on what basis should papers be included or excluded? In this respect, Century and Cassata's (2016) definition functioned to guide their selection of paper to include in their review. If the study applied to their generic definition, they included it in the review. This purpose of the definition makes it beneficial for this context, as it specifies a set of generic concepts (enactment, factors of influence, innovation, and outcome) that support communicating how different implementation studies relate to one another. According to Century and Cassata (2016), the interpretation and conceptualization of the concepts in the definition are shaped by the aim, context, research question, theoretical frameworks, and methodological approaches being used. On the one hand, this was caused because they developed the definition to guide the selection of papers to be included in the review. On the other hand, the generic nature of the definition has prospective potentials, as it allows researchers to interpret and conceptualize the definition according to a wide range of theoretical frameworks and research aims while simultaneously building and preserving an overarching vocabulary that enables articulating the relation among different forms of research designs and aims. As the two levels of implementation represented in this thesis draw on different theoretical frameworks and have different research aims, this definition works well as the foundation for describing how the levels approach the implementation of learning platforms and how they relate. In the following section, I describe how the papers at these two levels have interpreted *enactment, innovation, influential factors, and outcomes*.

Two Levels of Implementation

The two levels of implementation represented in this thesis are the *organizational level* and the *practical pedagogical level*.

In the *organizational level* of the implementation, I investigated how the actor groups involved in the implementation viewed the learning platforms, what they considered to be the main issues and potentials of the learning platforms, and to what extent they succeeded in successfully implementing the learning platforms. This aspect of the implementation was of particular relevance in the Danish situation, as the platforms formed part of a national digitalization strategy requiring Danish municipalities to purchase and implement a digital platform. Often, local schools in the municipalities had some degree of autonomy in deciding how, to what extent, with what aims, etc. the teachers should use the platforms. These circumstances placed schools in the peculiar situation of having to identify aims and strategies for the implementation of a technology that they had not chosen.

The *practical pedagogical level* regarded teachers' pedagogical usage of the learning platform in different contexts. The need for this level firstly reflects, as illustrated in Paper 1, that this aspect of research about platforms has been under-exposed in the literature. While many studies have examined what affects teachers' usage of platforms (Underwood & Stiller, 2014; De Smet, Bourgonjon, De Wever, Schellens, & Valcke, 2012; Nokelainen, 2006), few studies have investigated how teachers' use of digital platforms are related to or affect their pedagogical practices. Even fewer studies investigate this from a subject-specific point of view. Moreover, and as already illustrated, the Danish platforms integrate a heavily debated recent curriculum reform. The practical pedagogical level sheds light on how this affects teachers' use of the platforms for lesson planning and teaching mathematics.

The Interpretation and Conceptualization of Implementation Research at The Two Levels of Implementation

To provide a conceptual account for the essential differences between the two contexts, I will take a point of departure in Century & Cassata's (2016)

definition of implementation research. As previously mentioned, this definition involve key elements, namely *enactment, innovation, factors of influence* and *outcomes*. I will begin the following sections by specifying the two levels of the implementation, and how the papers of the thesis have investigated the implementation process at each level.

The Practical Pedagogical Level

The practical pedagogical level addressed mathematics teachers' enactment of digital platforms in their work in and outside the classroom. I empirically investigated this aspect of the implementation in Paper 2 and Paper 6; I investigated it theoretically in Paper 5. I drew on the instrumental and documentational genesis in the studies at the practical pedagogical level. To briefly review, the instrumental genesis framework distinguishes between artifacts and instruments. An artifact is defined as a cultural social construct that offers mediations of human activity, and an instrument is defined as the product of a subject's use of the artifact for certain activities with a certain objective (Gueudet & Trouche, 2009). An artifact therefore *becomes* an instrument when a subject uses the artifact; the instrument is considered to be a psychological construct. This process is called instrumental genesis; it results in a change in the mediating artifact and in the activity mediated by the artifact. These two opposite processes (the shaping and the being shaped) are referred to as instrumentation and instrumentalization (Haspekian, 2005; Drijvers et al., 2010). Instrumentation is the process in which the subject's use of an artifact shapes the artifact, while instrumentalization is the process in which the artifact shapes the subject's activity (Gueudet & Trouche, 2009). Teachers' work with artifacts is considered a dialectic process, where teachers' usages on the one side and resources on the other side mutually affect each other (Gueudet & Trouche, 2009). A *document* is defined as the product of combined resources, usages, and knowledge.

Century and Cassata's (2016) definition of implementation involves enactment, innovation, influential factors, and outcomes. As the instrumental approach considers the implications of implementing new artifacts among mathematics teachers, this framework is well suited to studying the implementation of digital learning platforms. This is also evident in that the framework falls under Century and Cassata's (2016) definition of implementation. In this approach, mathematics teachers' *enactment* of digital learning platforms can be considered a goal-oriented usage of an artifact. In particular, the object of study in analyses when using this framework is how the characteristics of the artifact shape its usage and vice versa. The innovation (the platforms) can thus be considered the artifact that a mathematics teacher uses. As the instrumental genesis is based on the assumption that the relation between designs is dialectic rather than one-sided (Haspekian, 2005), this framework implies a dialectical perspective on the relation between enactment and innovation. The influential factors involve how the actor enacts the innovation and with what objective he or she has in mind. It may also involve the functional characteristics and design features of the specific innovation being enacted. In this respect, the outcome is the instrument and a construct of the enacted innovation. In contrast, instrumental genesis frequently described this as instrument = artifact + usage. I rephrase this with Century and Cassata (2016) as outcome = enactment + innovation.

The other framework I used at the practical pedagogical level is documentational genesis (Gueudet & Trouche, 2009; Gueudet, Pepin, Sabra, & Trouche, 2016; Gueudet, Pepin, & Trouche, 2013; Gueudet & Parra, 2017). As already mentioned, instrumental and documentational genesis share many foundational assumptions, but they have slightly different vocabularies and foci. Documentational genesis introduces a distinction between resources and documents (Gueudet & Trouche, 2009). Whereas a resource is broadly defined

to include human, material, cultural, or social things used for teaching, a document is, similarly to an instrument, considered to be a psychological product of a teacher's goal-directed usage (Gueudet & Trouche, 2009). Like the instrumental approach, the documentational approach also investigates the instrumentations and instrumentalizations that emerge with teachers' resource usage. Gueudet and Trouche (2009) emphasized that resources are never isolated, but that they are related to each other; this indicates resource systems. Within this framework, the innovation is the digital platforms, but here, the framework helps me to analyze how the platforms might have significance for teacher practices, their resource systems, and the documents that emerge. Enactment is, as in instrumental genesis, considered to be a dialectical process, with the outcome measured as the document emerging from teachers' usage of the platforms.

A central characteristic of both types of genesis is that they approach the implementation of platforms from a psychological point of view. This is evident by their study of the cognitive processes emerging in the relation between teachers' use of artifacts/resources and their pedagogical work: the enactment of the innovation is essentially examined in isolation from the organizational and political contexts. The framework thereby takes a highly locally situated perspective to study platform implementation. Neither the instrumental nor the documentational approaches have a vocabulary to account for the systemic levels of the implementation process outside the classroom, such as the political level and the organizational level. In the context of the implementation of digital platforms in Denmark, this is a shortcoming, as the implementation process is interwoven with political issues. Moreover, it represents an organizational challenge for Danish compulsory schools. Introducing the organizational level of implementation in this thesis is a direct consequence of the lack of the instrumental and

documentational genesis in this context. As I argue later, introducing this level extends the scope of the thesis by integrating investigations of the enactment process at the organizational level. My colleagues and I have also sought to extend the documentational genesis with a concept that allowed us to study the implications of the close relation between teachers' interpretation of the recent curriculum reform and their perception and usage of the platforms (see Paper 4). In the following section, I describe the origin of the instrumental and documentational approach and explain how this origin has led to a shortcoming of the frameworks in relation to the current Danish situation.

Encountering the Limitations of the Instrumental and Documentational Genesis

Mathematics education research has a long tradition of studying the relationship between technology and mathematics learning and teaching (Dreyfus, 1993); the topic continues to be widely researched (Clark-Wilson et al., 2016). Generally, it is acknowledged that digital tools make a difference for mathematics teaching and learning (Laborde & Sträßer, 2010; Dreyfus, 1993; Tabach, 2013; Winsløw, 2003), and perhaps for this reason, teaching mathematics with technology has long been considered a subject that requires distinct theoretical frameworks (Guin, Ruthven, & Trouche, 2005, p. 3). One of the most widespread theoretical approaches to accomplish this is so-called *instrumental genesis* (Guin & Trouche, 1998), which I use in this thesis, originating in 1998 and described above. Verillon and Rabardel (1995) originally developed this approach in educational psychology and cognitive ergonomics; mathematics education researchers later adopted, complemented, and transformed it. Despite dramatic changes in types of technologies, the ways in which they are used, and the extent of their use in educational contexts, many of Verillon and Rabardel's (1995) basic assumptions and key

foci remain. As I illustrate here, the Danish learning platforms in particular have characteristics that the instrumental genesis cannot account for.

The Origin of Instrumental Genesis

The instrumental genesis framework originates from the ideas of Verillon and Rabardel (1995), as described in a paper entitled “Cognition and Artifacts: A Contribution to the Study of Thought in Relation to Instrumented Activity.” In this paper, Verillon and Rabardel (1995) sought to develop a theoretical framework within the realm of psychology to describe the human cognition and knowledge-building in activities mediated by artifacts. According to the authors, previous theoretical approaches to the study of artifact-mediated activities had either failed to acknowledge the distinction between natural and artificial objects or had focused on anthropological aspects rather than cognition and knowledge-building. Their goal was to develop a theory capable of studying the micro processes of how cognition was related to human beings’ use of artifacts. According to Verillon and Rabardel (1995), previous scholars’ work on artifact-mediated activities had suffered a number of shortcomings. In the following, I briefly summarize Verillon and Rabardel’s (1995) critiques of these theories.

Piaget was one of the most prominent researchers in the field; the author had previously worked with developing a theory capable of describing the relation between artifacts and human activity. Within Piaget’s framework, the main property of artifacts was that physical laws structured them. The specific design of an artifact was thus not considered relevant, and artifacts were essentially considered non-historical and non-cultural objects (Verillon & Rabardel, 1995). Though a Piagetian psychology was able to study how tools (and the environment) are related to thought, Verillon and Rabardel (1995) argued that this theory did not distinguish between natural and artificial

objects. Verillon and Rabardel (1995) considered this problematic, arguing that artifacts (as opposed to natural objects) possessed cultural and historical dimensions because they were constructed with a particular purpose, and because researchers had a particular way of fulfilling this purpose in mind. For this reason, the design of an object is associated with inherent possibilities and limitations related to conducting a task. Therefore, Verillon and Rabardel (1995) argued that artifact-mediated activities could only be fully understood by considering their culturally and historically conditioned factors. Verillon and Rabardel (1995) also stressed that Piaget focused too heavily on the assimilatory process related to the properties of an artifact, whereas they argued for the need for a more dialectical view of the relation between artifacts and the subjects using them.

Another attempt to develop a theory accounting for the relation between human activities mentioned by Verillon and Rabardel (1995) was the work of Leontiev and Wallon. In these scholars' work, an artifact was characterized by not only its physical properties, but also its "operating method," which they linked to a cultural and intellectual tradition. Within this framework, an artifact was only valuable to a subject who was able to decode and understand the cultural and intellectual tradition within which the artifact was produced (Verillon & Rabardel, 1995, p. 81). Though Leontiev and Wallon included cultural aspects of artifacts, Verillon and Rabardel (1995) claimed that their solutions remained *anthropological* rather than psychological, as the focus was to understand the relation between artifacts and culture and not between artifacts and cognition. Thus, according to Verillon and Rabardel (1995), Leontiev's work still failed to approach a theory capable of studying *cognition* in artifact-mediated activities.

To address these limitations, Verillon and Rabardel (1995) sought to build a framework for understanding how thought related to the use of artifacts, and in so doing, close the gap in the theories available within psychology. Their contribution was entitled *instrumented activity situations* and was built to study situations in which a subject engaged in an activity with a specific purpose in mind and then deliberately used an artifact to solve the task at hand (Verillon & Rabardel, 1995). One key tenet of instrumented activity situations is that certain possible ways of solving a task emerge when a specific artifact is used; however, this is not a deterministic process—the intentions of the subject using the artifact are also significant (Verillon & Rabardel, 1995). Thus, Verillon and Rabardel (1995) distinguished between *artifacts* and *instruments*. While they conceptualized of an artifact as a man-made object, they defined an instrument as a psychological construct that emerged when a subject appropriated an artifact and “subordinate[d] it as a means to his ends” (Verillon & Rabardel, 1995, pp. 85–86). An instrument, therefore, emerges partly from the subject’s intentions and partly from the artifact’s specific properties. Further, Verillon and Rabardel (1995) suggested that an analysis of cognition and knowledge-building in instrumented activities should consider 1) the constraint management and the required activity, 2) the expansion of the field of possible actions afforded by the artifact, and 3) the social schemes of artifact utilization (Verillon & Rabardel, 1995, p. 86). Knowledge-building in instrumented activity situations should thus be studied by analyzing the origin of the instrument, arising partly from the subject and partly from the artifact’s properties.

This framework is based on an epistemological assumption that artifact-mediated activities occur in situations in which a subject deliberately uses an artifact to solve tasks *in accordance with his or her intentions*. This assumption might be associated with the main purpose of the contribution of

the paper (i.e., to fill the gap in available theory), but the authors nonetheless took for granted that subjects using an artifact did so deliberately and with a particular purpose in mind. Verillon and Rabardel (1995, p. 77) suggested that their framework could support analyzing how a subject's intentions shape and were shaped by the artifact that mediated a given activity.

Verillon and Rabardel (1995) developed their theory primarily to describe and better understand the relationship between knowledge-building and artifact-mediated activities; thus, the nature of the outcome of their analysis was mainly descriptive. As I demonstrate in the following sections, several modifications of these aspects of the framework can be identified in instrumental genesis.

Instrumental Genesis: Adoption into Mathematics Education Research

Instrumental genesis first appeared in mathematics education research in a paper by Guin and Trouche (1998) entitled “The Complex Process of Converting Tools into Mathematical Instruments: The Case of Calculators,” which was published in the *International Journal of Computers for Mathematical Learning*. The situation in French mathematics education at that point was crucial to understanding the integration of Verillon and Rabardel’s work.

In 1998, calculators became part of the upper secondary high school curriculum in France, but relatively few teachers (15%) integrated calculators into their teaching of mathematics (Guin & Trouche, 1998, p. 195). As a result, students were often required to learn calculator skills on their own, which, according to the authors, led to confusion and misunderstandings concerning the relationship between mathematical objects and the ways in which they were represented in calculator technology (Guin & Trouche, 1998, p. 197). These misconceptions led Guin and Trouche to argue for the need for teachers

to become aware of the potential gap between a mathematical object and its representation by a specific tool or artifact. They emphasized that teachers should support students in making appropriate links and connections between mediated mathematical content and “reality” by drawing their attention in “the right direction(s)” (Guin & Trouche, 1999, p. 200). To accomplish this, the authors argued the need to understand the relation between cognition and artifacts—a need that Verillon and Rabardel (1995) fulfilled.

In its adoption into mathematics education, minor adjustments to the framework were made, but many of the key epistemological assumptions were maintained. Guin and Trouche’s (1999) analysis of instrumented activities had two foci: “the constraints and potential” (in this case, of symbolic calculators) (Guin & Trouche, 1999, p. 202), which corresponded to what Verillon and Rabardel (1995, p. 86) had earlier called “constraints management and required activity” and “expansion of the field of possible actions.” This analysis of calculators’ constraints and potentials was used to design an intervention to foster activities in which the use of symbolic calculators could enrich students’ opportunities to learn (Guin & Trouche, 1998, p. 208).

In instrumental genesis, the distinction between artifacts and instruments was also maintained from an instrumented activity situation perspective as well as from the general idea that artifacts were able to support students in learning mathematics. The focus on the relationship between intentions and artifact-mediated activities was also maintained. However, a minor transformation regarding the nature of the outcome of the analysis can be identified. While Rabardel and Verillon sought to *describe* cognition in artifact-mediated activities from a psychological perspective, Guin and Trouche sought to explore how mathematics education could be *improved*. In general, Verillon and Rabardel conceived of artifacts as beneficial for the knowledge-building

process and advocated for the exploitation of artifacts as part of the educational context (Verillon & Rabardel, 1995, p. 96). Guin and Trouche, however, took this a step further, suggesting designs for lessons and using the framework to qualify such uses. Further, Guin and Trouche's suggestions for using artifacts were done according to the potentials (and limitations) of the artifacts being used (Guin & Trouche, 1998, p. 207).

This origin of the framework illustrates that within the instrumental genesis, the core cause of instrumentalization processes can be explained from the design and functionality of the *artifact* being used; indeed, it may shape the usage of this artifact. As documented in Paper 4, the design and functionality was only one aspect of teachers' perceived limitations of the platforms. In addition, the teachers considered the inherent pedagogics in the curriculum, which the platforms mediated, to be another central cause of instrumentalizations that were poorly aligned with their pedagogical values and beliefs. Paper 4 showed that by mediating a curriculum, digital learning platforms could simultaneously mediate a certain voice of the curriculum that enforced a set of rules that teachers felt obligated to comply with. Instead of expanding and supporting teacher agency, as a tool is often developed to do, it can also constrain teacher agency. In documentational genesis, this is encapsulated in the concept of instrumentation. As argued in Paper 4, instrumentation is considered to be caused by the product of the artifact's properties—not the subject's interpretation of them. According to Century and Cassata (2016), implementation research can either focus on the *actual* attributes of an innovation or on the actors' *perceived* attributes of the innovation. One way of describing Paper 4's contribution is that it enabled me to better account for the latter by integrating the concept of curriculum voice in documentational genesis.

With respect to Century and Cassata's (2016) four elements of implementation research, this extension of the documentational approach considerably reframed my understanding of influential factors. The previous version of the documentational approach argued that influential factors involved the actors' enactment of the innovation, the objective they had in mind, and the functional characteristics and design features of the specific innovation. By integrating Remillard's (2005) notion of curriculum voice, Paper 4 reframed enactment to also include the actors' *interpretation and perception* of the rules that the innovation integrated and enforced, and not only its material properties.

The Organizational Level

At this level, I investigated how the actor groups involved in the implementation viewed the learning platforms, what they considered to be the main issues and potentials of the learning platforms, and to what extent they succeeded in implementing the learning platforms. I studied this level of the implementation in Paper 3 and Paper 4. Besides sharing a focus on this level, these papers also shared the characteristic that they were written in the context of a larger research project entitled "Use of Digital Learning Platforms and Resources." Both papers had an empirical outset in future workshops that were held in the project, which I partook in as a facilitator and researcher. I elaborate on this context in Chapter 6. As described in both Papers 2 and 3, these workshops were held with the purpose of supporting the actors involved in the implementation process in articulating their perspectives on the problems and visions related to using the platforms and in developing and testing new ways of using them that were better aligned with their visions. As indicated by the research questions at the organizational level, these papers addressed the mutual relation between actor groups' perspectives of digital platforms, the effect of this on the opportunities of a successful

implementation, and the pedagogical staff's possibilities of overcoming their perceived limitations of the platforms.

Paper 3 addressed this issue by using Nielsen's (2012) concept of cultural logics as a starting point; it mapped the relation of stakeholders' perspectives on the platforms and the implications of these interrelations for the opportunities of implementing the platforms. Paper 4 focused more specifically on teachers' experienced shortcomings of the platforms and discussed to what extent and how teachers' were able to succeed in spite of these perceived shortcomings. Paper 4 was not theoretically rooted in the concepts of cultural logics, but it offered a perspective on how the pedagogical staff perceived the platforms and their underlying reasons for these perceptions. Papers 3 and 4 thereby shared an understanding of *enactment* as stakeholders' interpretations and perspectives of the digital learning platforms. Moreover, they considered enactment as efforts in aligning the usage of the platforms with pedagogical values. In Paper 3, these efforts take the form of negotiation between stakeholder groups of how to use the learning platforms, whereas in Paper 4, they appear as experiments in designing platform usages that are aligned with the pedagogical staff's values.

In this respect, the *innovation* (the learning platform) can be considered as an artifact that the stakeholders *relate to* and which they shape discursively in negotiations. In Papers 2 and 3, the platforms are not as such materially present as research objects, but we investigate them through the actors' articulated experiences of how the platforms affect their pedagogical practices. At the organizational level, the analyses are driven by the assumption that the inherent properties of the innovations are of less interest than how the proposed users perceive them. The particular stakeholders' perception of the innovation may depend on aspects such as his or her beliefs

about good education, values, and priorities. Within Nielsen's (2012) framework, this is affected by the particular actor's cultural logic. Though cultural logics are generally considered to be difficult to change, an essential characteristic of the papers at the organizational level is that the interpretations of innovation are open for re-interpretation. This is possible to the extent that actors are able to re-interpret the innovations and develop usages that correspond to their cultural logics. *The influential factors* at the organizational level are considered to be the stakeholders' perceptions and interpretations of the platforms' properties. The influential factors are therefore, as the innovation, not considered static, but are dynamic, as they depend on the user's perception of the innovation, which may change over time. Lastly, the organizational perspective considers the *outcome* as both the interrelation between cultural logics and the result of pedagogical staff's efforts to align their cultural logics with concrete ways of using the digital platforms.

As apparent from the above, the organizational and practical pedagogical levels of implementation operate with different perspectives on the implementation process. Using Century and Cassata's (2016) generic definition of implementation has enabled me to describe how the two levels approach studying the implementation of digital learning platforms. Their work helped me to identify the need for investigations that were conceptualized and situated in broader contexts than what happens between mathematics teachers and the platform. By pinpointing this shortcoming in relation to the Danish context, I could specify the need to extend the documentational genesis and operate with two levels of implementation.

Due to the two levels' different paths, I have approached the data collection, processing, and formatting differently at the practical pedagogical and organizational levels. In Chapter 6, I describe how the questions I addressed

and the concepts I used on the two levels have led to concrete data collection strategies.

Chapter 6: Method

This thesis consists of six individual research papers that investigate different aspects of the implementation of digital platforms in Danish compulsory schools. Together, these papers can be viewed as what Yin (2002) refers to as an embedded multiple case study—a case study featuring several units of analysis. Generally, Yin (2002, p. 13) defines a case study as “*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*” (Yin, 2002, p. 13). The cases in this thesis originate from three different investigations covered in the six papers: 1) a pilot study focusing on teachers’ lesson planning using platforms, 2) a large-scale research project focusing on supporting schools and teachers in implementing the platforms, and 3) a long-term ethnographic study of teachers’ usage of platforms for classroom teaching. I conducted the pilot study reported in Paper 2 at an early stage of my PhD project; here, I focused on investigating mathematics teachers’ lesson planning with learning platforms. I drew on a descriptive approach to the research practice based on video observations and interviews with three teachers. The study reported in Papers 3 and 4 was based on a large-scale interventionist research project that sought to support stakeholders in schools to implement a learning platform in ways that aligned with their desires. The third study, found in Paper 6, was based on long-term observations of four mathematics teachers working at three different schools. Finally, Paper 1 was a literature review using a different type of method and Paper 5 were primarily a theoretical paper based on a single case.

This thesis thus consists of projects in which I have studied the implementation of digital platforms from various approaches to research: partly from ethnographic descriptive approaches and partly from contexts in

which I was actively engaged in facilitating workshops that sought to support schools in implementing platforms. Here, I will thus focus on describing the methods I deployed in these contexts. The scheme presented in Table 1 provides an overview of these studies, including their informants, research sites, and the data they draw on.

Investigation Context	Informants	Research Site	Data
The pilot study (reported in Paper 2)	Three mathematics teachers	A room at the school in which the three teachers jointly planned lessons	Observation of the teachers' joint planning; interviews
The platform project (reported in Papers 3 and 4)	Teachers, school leaders, local supervisors, and municipal consultants	Future workshops held at the participating schools	Observations from the future workshops
The ethnographic study (reported in Paper 6)	Four mathematics teachers working at two different schools	Classrooms at two schools (Parkview and Hillside)	Two interviews with each of the teachers; observations of classroom practices for a period of six weeks for each teacher

Table 1. An overview of the data in the project.

As previously described, this thesis applied an analytical strategic approach to philosophy of science. This approach operated with a central distinction between methodology and method: whereas methodology refers to the foundational philosophical underpinnings of a given research project, method refers to the concrete and practical ways of collecting, formatting, and processing data (Esmark, Laustsen, & Andersen, 2014). In the following section, I address these practical matters regarding the method of the work described in this thesis. As described previously, I have chosen to separate the papers of my thesis into two levels of implementation, which corresponds to two theoretical approaches. As my data collection strategies (in line with an analytical strategic approach) correspond to the concepts used at the two levels, I will describe the strategies for the two levels of implementation separately.

The Organizational Level

Determining the Research Object

As previously specified, the research question at the organizational level is phrased as follows:

What are the mutual relations between actor groups' perspectives on digital platforms, how does this affect the chance of a successful implementation, and to what extent can the pedagogical staff overcome their perceived limitations of the platforms?

All the data collected and analyzed to address this question were collected in the context of future workshops conducted in a larger intervention-based research project that I partook in from September 2016–April 2017. The overall aim of this project was to support and investigate the implementation of the digital learning platforms at 16 different schools across Denmark.

The workshops were therefore chosen and designed according to the overall aim of the project. In the context of this thesis, the workshops were a conditioned site for data collection and were not directly linked to the aim of my own project. One of the central advantages of applying an analytical strategic approach in this context is that it not only supports researchers in making decisions about what data to *collect* but also what *parts* of data to focus on when researchers are left with data sources that come in a format they have not chosen (or only partly chosen). A central reason for including data from this context in spite of the apparent limitation was that the workshops constituted a unique opportunity for accessing data sources that would otherwise be difficult to access. The workshops gathered together many different actor groups involved in the implementation process; they gave a close-up view of how these groups related differently to the platforms and the significance of this for the implementation process. Collecting data in a context defined more or less independently from the aim of my own project required reflections on how I worked with collecting and processing the data in line with my own objectives.

As described earlier, the research question at the organizational level is informed by the concept of cultural logics (Nielsen, 2012). As the concept of cultural logics refers to the stable underlying priorities, orientations, and values in actor groups' utterances, the aim of collecting and processing the data was to get information about

- how teachers and other stakeholders involved in the platform implementation perceived the platforms,
- the reasons why they felt a particular way about the platforms and to what extent they were able to overcome any negative perceptions of the platforms,

- how the stakeholders' perceptions of the platforms related to one another, and
- the significance of the relation of their perceptions for the success of the implementation.

Before I describe the data and how I processed it in line with these requirements, I describe how the workshops were conducted.

Future Workshops

Both the papers addressing the organizational level (Papers 2 and 3) draw on data collected at future workshops. Future workshops represent a participatory method developed with the aim of actively and democratically involving participants in changing and bettering the circumstances in which they live or work (Jungk & Müllert, 1984). Future workshops typically involve five phases: a preparations phase, a critique phase, a phantasy phase, a realization phase, and a follow-up phase (Jungk & Müller, 1984). Participants are mainly actively involved in the critique phase, phantasy phase, and realization phase, as the preparation phase concerns the facilitators' planning of the workshop, and the follow-up phase involve investigating any changes initiated by the workshops.

The purpose and aim of the critique phase is to enable participants to articulate what they experience as unsatisfactory in their current situation. In the phantasy phase, the aim is to support participants in expressing their visions for what a new and better future in their given context should look like. Finally, the realization phase helps the participants to convert their fantasies into concrete initiatives and strategies that allow them to change their current situation in ways that align with their visions and wishes.

These workshops were held at 16 schools that had all been recruited by the commissioners of the project (the Ministry of Education and Local

Government Denmark). The future workshops held at these schools underwent some adjustments from their original form, as we found this beneficial for meeting the aims of our particular research project. We maintained the three phases as an essential element, but we chose to inform the realization phase with inspiration from the method called rapid prototyping.²⁴ Rapid prototyping is an approach that quickly and at low cost seeks to fabricate a prototype of an idea that can later be up-scaled. In the realization phase, we drew on this inspiration by providing the participants with templates to quickly convert the vision they had chosen into a concrete pitch. The pitch should address a specification of the problem the design aims to solve, a specification of why this is a problem, for whom it is a problem, and how the idea solves the problem. The participants delivered this pitch to their colleagues, who then gave immediate feedback to qualify the idea. The groups then refined their design according to the feedback. An integrated part of refining the design was to make a time schedule of the activities and/or experiments to be carried out after the workshops had ended. The workshops did not set any constraints on what types of visions or problems the designs should address, except that they should somehow be related to the digital learning platforms. After the realization phase, the participants implemented the interventions/experiments on their own.

Navigating Future Workshops as a site for Data Collection

The political landscape surrounding the implementation of the digital platforms meant that many teachers had doubts about the real intentions behind the governmental decision to implement the learning platforms. Among Danish teachers, this resulted in resentment toward using the platforms, which at many schools had caused a deadlock where teachers

²⁴ http://www.efunda.com/processes/rapid_prototyping/intro.cfm

collectively insisted on not using the platforms. This was a challenge we were aware of in the research project, and it was related to our choice to use future workshops as a method.

We considered the future workshops to be a tool to end the deadlock by empowering schools to take charge of how and for what they would use the learning platforms. The rationale was that giving teachers a space to articulate the current problems and their future visions would enable them to view the platforms from new perspectives. The rationale was also that the future workshops would create an opening for the participants to make use of the platforms on their own terms and thereby create a sense of ownership. As illustrated in both Papers 2 and 3, the future workshops to some extent fulfilled this aim.

In spite of our intentions of empowerment and ownership, the future workshops had other implications for the type of data collected at these sites. Naturally, the then-current deadlock was a consequence of teachers' resentment of the platforms. By engaging the participants in future workshops, the project simultaneously bypassed the participants' opportunity to consider whether or not to use the platforms by instead having them relate to *how* to use them. In this sense, the workshops introduced a shift in which the *question* of whether to use the platforms was transformed into a *premise*. As described in Paper 4, this shift was deliberate and reflected that we sought to support teachers navigating the current situation on their own terms. Such an approach allowed schools to take control of the current situations in which they found themselves.

One of the potential disadvantages of applying the future workshops as a method in this context was that they provided limited access to the reasons why some teachers resented the platforms. This disadvantage was partly

balanced in the critique phase. The aim of the critique phase was to support the participants in articulating their dissatisfaction with the current situation, including why they previously had chosen to use the platform if this was the case. In this respect, the critique phase had the additional benefit that they provided an insight into the perceived dissatisfaction of the current situation from the perspective of multiple stakeholders (school leader, teachers, local supervisors, and municipal consultants). The simultaneous participation of these different stakeholders had several disadvantages. As mentioned, the digital learning platforms entered a political landscape characterized by significant conflicts between teachers and their employers. The outset of the workshops was that teachers and school managers in each other's presence should specify their critique of the current situation in the critique phase and their visions for the future in the phantasy phase. Due to the unequal relation between teachers and school leaders, it would be naïve to think of this space as neutral, in which both parties had the freedom to articulate their viewpoints without being concerned about the consequences of doing so. We addressed this issue by asking the participants to write their critiques and visions anonymously on small pieces of cardboard and put them on the table with the statements facing downward. After each participant had written their statement, we as facilitators picked a card and read it aloud to the entire group. Their job was to then place the statements in categories. Subsequently, in the phantasy phase, they had to agree on a ranking of the importance of the visions in order to choose a final vision to address in the realization phase. In this manner, we attempted to create a space where anonymous statements could be made and where individuals were not held accountable for these views.

Collecting Data at the Workshops

Every future workshop was held over the course of two days approximately one week apart. Each day was scheduled to last for five hours. On the first

day, the participants were taken through the critique and phantasy phase—the second workshop focused on the realization phase. Workshops can be used for several different purposes and can be considered a means, a practice, or a research methodology depending on their aim and design (Ørnsgreen & Levinsen, 2017). We thought of the future workshops held in this context as a means, as they provided the facilitators and participants with guidelines on how to “orchestrate, conduct, and facilitate workshops” (Ørnsgreen & Levinsen, 2017, p. 72) with the purpose of achieving a goal—in this case, to support the local implementation of platforms. The workshops were conducted in the context of a research project and served an additional aim of providing data that would allow us to study the processes taking place at the workshops. Two researchers who were also responsible for collecting data facilitated the future workshops. These data were partly collected during the workshops and partly afterward in the form of 1) an evaluation meeting with all the participants, and 2) interviews with the school leader.

During the workshops, the researchers collected data via video-recordings, photo documentation of the utterances made by the practitioners in the different phases, and observations documented in field notes. The observations focused on capturing the participants’ utterances that displayed their 1) dissatisfaction with the platforms and reasons for this, and 2) their visions for the future usage of the platforms and how the different actor groups’ visions related to one another.

One challenge of conducting observations in the context of future workshops is navigating between being a participant observer and a workshop facilitator. Whereas facilitating requires a high degree of direct active engagement, the term “participant” in participant observation often merely involves being present (Kristiansen & Krogstrup, 2015). As there were two researchers

present at each workshop, we handled this issue by taking turns facilitating and observing the workshops. In this way, we devoted our full attention to either facilitating or collecting data. This strategy was occasionally challenged, as some schools required more than what one facilitator could accommodate. In these cases, the video-recordings provided an opportunity to revisit the situations if necessary.



Figure 10. A photo taken in of a teacher working in the phantasy phase. This teacher is working with an idea of making *MinUddannelse* “the natural choice” for the pedagogical staff at the school.

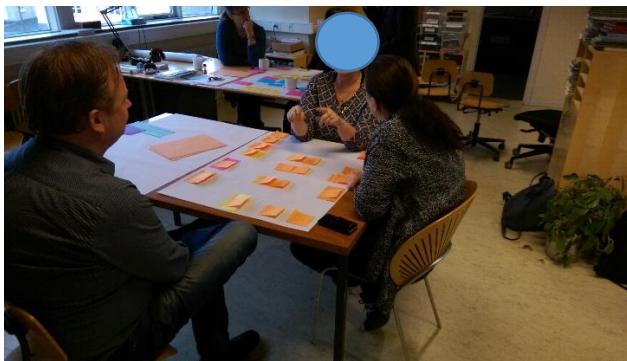


Figure 11. Group collaboration in the realization phase.



Figure 12. A group (seated) working in the realization and getting support from a facilitator (standing).



Figure 13. *The picture shows the initial stage of the realization phase; the participants are deciding on what visions to address.*

Processing the Data

One of the immediate challenges of using the concept of cultural logics to analyze data collected in the context of future workshops was the issue of identifying and interpreting stable priorities among stakeholders from many utterances made during the course of two days. This was in particular a challenge in Paper 3 that had a specific focus on identifying the logics. The co-author of Paper 3 (Benjamin Brink Allsopp) and I handled this issue mapping the utterances in statements in order to synthesize and represent the data (see Paper 3). To do this, we used Arcform, which is a map-like and non-linear notation (Allsopp, 2013). As described in Paper 3, Arcform is a network notation system, in which nodes can be used to represent objects, and arcs can be used to relate objects to other objects. Arcform allows all forms of subjects and object to appear in the map and map both objects and subjects as acting actors. This does not imply that Arcform is built on the assumption that objects and subject have the same level of agency. This feature of the notation however provide the maker of the map with the freedom to incorporate assumptions that human and non-human actors in principle are symmetric. As stated in chapter 5, the object of the analysis at the practical pedagogical levels regards how stakeholders relate to the digital platforms. Of this reason, we concentrate the perspectives of these stakeholders.

Arcform is different from most network notations in that it allow for more flexible arcs that for example can point from or to other arcs. This enable meanings to use other meanings recursively. Nodes and arcs have labels that can be read in sequence as grammatically normal English sentences, but

meanings are always represented by a single token. Figure 14 below shows an example of a how we used Arcform to map stakeholder beliefs.

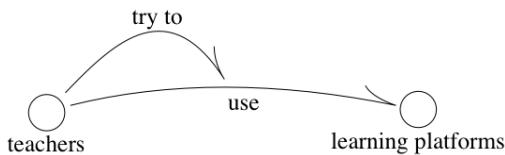


Figure 14. A map of the Arcform expression “teachers try to use learning platforms” (see Paper 3 for a more elaborate description of Arcform).

We used the Arcform notation to map the stakeholders, their relations to each other, the platforms and non-human actors, which helped us identifying stabilities in the actors’ utterances. We began the mapping process by watching the video recordings from the future workshops. In these recordings, we investigated the stakeholders’ utterances regarding the platforms (whether positive or negative) to identify their underlying priorities (cultural logics). This process consisted in discussing and negotiating adequate interpretations of the stakeholder beliefs over many iterations until we arrived at a stable map, on which we (the authors) could agree. As many other analytical approaches, creating an Arcform map is a process that involves interpretation. The object of this interpretation consisted in identifying and mapping viewpoints among the stakeholder that came as close as possible to representing the utterances made by the stakeholders at the workshops. During the process of mapping the stakeholder beliefs, we constructed preliminary versions of a map. This occasionally led to disagreements on how to adequately represent the stakeholders’ beliefs. We handled these situations by returning to the data material (the video recordings), which caused us to refine and occasionally more radically to amend our map to more adequately represent the utterances of the stakeholders. In this respect, it is important to note that the maps included in Paper 3 represents the final maps.

The advantage of Arcform in this context is that is allowed all forms of subjects and objects to be included in the map and to let actions and points of view to be being from both subjects and object. This does not imply that Arcform as a tool for mapping inhabits the assumption that objects possess the same agency as humans. Arcform does however provide the mapmaker the freedom to construct a map based on such assumptions. Drawing on the concept of cultural logics, the primary concern on the analysis was to investigate the stable underlying priorities, orientations and values among actor groups' perspectives regarding learning platforms.

Limitations of the Method

As previously stated, the studies at the organizational level predominantly considered enactment of the platform as how stakeholders in schools discursively related to the platforms. As illustrated in Paper 4, this approach proved to be valuable in both exposing and being able to address stakeholders' conceptions of the problems and shortcomings of the platforms. In this paper, we found that stakeholder' perceived shortcomings of the platforms was a result that they discursively associated the platforms with inherent values, to which they did not subscribe. In this respect, the workshops proved able to create a space that allowed the stakeholder in re-interpreting the platforms. Paper 4 however also identified that the opportunities of such re-interpretations were limited by the compatibility between the concrete aims of the stakeholder and the material properties of the given platform. This issue could not be described or explained from a perspective on enactment as merely discursive. Contrary, this phenomenon called for analyses similar to those at the practical pedagogical level, that considered enactment a dialectical process, in which the properties of a given artifact shape and are shaped by the particular task for which it is used. This illustrates that an imminent risk associated with a too narrow theoretical foundation research design is

overlooking important aspects that lies outside the scope of the given analytical strategic frame. As I will return to later, I encountered similar shortcomings of instrumental and documentational genesis at the practical pedagogical level.

The Practical Pedagogical Level

Determining the Research Object

The overall research question at the practical pedagogical level is informed by the concepts of instrumental and documentational genesis and is phrased as follows:

How do mathematics teachers pedagogically enact digital learning platforms, what are the underlying reasons for these, and what are the implications for their pedagogical work?

As described in Chapter 5, the instrumental and documentational approaches were developed within mathematics education research and share a focus on studying a subject's goal-directed use of an artifact/resource (Haspekian, 2005). To collect data that would allow me to answer the research question informed by these frameworks, I needed data that would provide me information about

- situations in which the teachers were using the platform;
- how, with what goals, and for what reasons they were using the platform; and
- other resources that the platform usage was combined with.

I chose ethnographic observations and interviews as my primary research methods. I introduce my description of the data collection strategy at this level by describing how and on what criteria I chose the respondents, as this choice had significance for the type of data I collected.

Choosing the Research sites and Recruiting Respondents

It had proven difficult to recruit informants from the beginning. The political landscape surrounding the implementation of both the then-recent lockout, the new curriculum, and the learning platforms had had critical implications for the level of trust between teachers and their employers. It is likely that these circumstances made it less appealing for teachers to let a foreign researcher into their classrooms to study how they were using these mandated digital platforms.

My initial strategy in recruiting respondents was to contact teachers by email. For the pilot study, the three most significant requirements for recruiting informants was that they were mathematics teachers, that they worked at a school that had implemented a platform, and that they used a platform, if not daily, then on a weekly basis. These relatively modest requirements reflected that only a few schools at this point had implemented the learning platforms, and that one of the aims of the study was to explore how to collect data about teachers' lesson planning with the platforms.

During February and March of 2016, I contacted between 12 and 15 teachers by email, but I only got one response. The teacher who responded was a female teacher, who I refer to as "Gina" in Paper 2. Gina worked at a school that at this time had been using Meebook for more than a year; it had adopted the platform on its own initiative, as it believed the platform would help it to collaborate and share its work. At an initial meeting with Gina, she told me that she did most of her planning in Meebook in collaboration with two of her colleagues. I therefore decided to investigate their collaborative process of planning with the platforms. Though this context was far from representative of the situation at other schools, it provided an opportunity to research the process of mathematics teachers' planning with learning platforms (see Paper 2 for reflections on the implications of the collaborative element of their

planning). At this stage of the project, Gina, her colleagues, and the school they worked at lived up to the requirements for the data site and the informants. As described in Paper 2, I video-recorded all their planning sessions. As indicated in Figure 15 and Figure 16, I alternated between zooming in and out on the computer screen during the sessions I recorded. This strategy reflected the theoretical assumption in instrumental genesis that both the practice and the aim of the practitioner as well as the artifact in itself may shape the activity. For this reason, I considered it important for the subsequent data processing and analysis to be able to see which interfaces the teachers were using in Meebook.



Figure 15. A screenshot of the video recordings presented in Paper 2.



Figure 16. Another screenshot of the video recording of the three teachers' planning (close zoom on the screen).

The inclusion criteria for respondents in Paper 6 followed more strict guidelines than those in Paper 2. This was because this study was on a larger scale and provided deeper and richer insight into mathematics teachers' work with platforms over a longer period of time.

As there were multiple platforms available, one priority was to recruit respondents who were working in municipalities that had chosen different platforms. The choice of studying the implementation of different platforms was not an attempt to carry out a comparative study of the pros and cons of two different platforms. According to Yin (2002), drawing on single cases from one context is a vulnerable approach, as a case from a single context substantially minimizes the opportunity of generating generalizable findings. In line with this argument, I sought to include schools working with different platforms to minimize the risk that my findings would only apply to a particular platform. If one is able to generate a common analytical conclusion across varied circumstances, this considerably increases the generalizability of the results (Yin, 2002).

Another key consideration in recruiting respondents was to include teachers from schools that had all the required material resources to use the platforms in their classroom teaching. My participation in the large-scale research project, in which we conducted the future workshops, revealed there were substantial material differences across schools, and that this had significance for teachers' opportunities to use the platforms. At some schools, students had a device available to them at all times, and the classrooms were equipped with well-functioning smartboards or something similar. These material resources enabled teachers to project their screens in the classroom so that students could view the lessons they had planned in the platform. At other schools, teachers might have access to a computer, but the classroom was not equipped with the technology required for teachers to display the content in the learning platform in the classroom. Another critical aspect was whether students had access to a device that could be trusted to work. Such conditions had significant implications for teachers' opportunities to distribute material to students in the platforms. As indicated by the research question at the practical pedagogical level, a central aim was to investigate mathematics teachers' pedagogical enactment of platforms and the underlying reasons for doing so. To maintain this focus, it was important to recruit respondents in contexts that provided teachers with the material resources required to use the platforms. Otherwise, I risked studying teachers whose choice to not use the platforms was a consequence of not having access to the needed technology. Recruiting respondents from well-equipped contexts as an attempt to avoid the practices of the teachers I was studying was conditioned by material constraints rather than being a product of their deliberate choice. In this respect, my choice of research site resembled that of critical cases. Flyvbjerg (2006) defined a critical case as "having strategic importance in relation to the general problem" (Flyvbjerg, 2006, p. 230). Critical cases are often chosen for

representing either particularly favorable or disadvantageous contexts in relation to a given phenomenon. In this case, I chose schools with all the material and technological opportunities necessary to use the digital platforms to their full potential. According to Flyvbjerg (2006), a central benefit of conducting research at such sites is that it allows for generalizations: “if it is valid for this case, it is valid for all (or many) cases” (Flyvbjerg, 2006, p. 231). By minimizing the material and technological constraints, the results generated in these contexts provided insights into challenges that were still challenges even in optimal material conditions.

To recruit teachers who lived up to these requirements, I approached two teachers by email whom I knew were working at schools that had the sufficient technological resources to make full use of the platforms. Here, every teacher had a computer or a tablet; every classroom had a projector, a whiteboard, or something similar that a device could be connected to; and the students had a computer or a tablet to use daily. To make sure that the teachers I approached lived up to this, I asked for help from my colleagues at both University College Copenhagen and Aalborg University. A colleague from each institution had previously collaborated with teachers fitting these requirements, who were mathematics teachers, and who worked in municipalities that used two different platforms. Two of the teachers from two different schools that I contacted responded quickly, and they put me in contact with an additional mathematics teacher from the same school. I then had my choice of four teachers working in two schools located in each municipality. For ethical reasons, I have anonymized the two schools and the four teachers. I refer to the two schools as Parkview and Hillside and to the teachers as Ralph, Dylan, Michael, and Jacob.

Data Collection

At both schools, I collected data through classroom observations and interviews with the four teachers between August and mid-December of 2018. I chose to conduct the data collection one school at a time, beginning with Hillside. I observed each teacher for a period of six weeks.

The research question at the practical pedagogical level sought to explore teachers' pedagogical enactment of the digital platforms, the implications of this, *and* the underlying reasons for this enactment. Observation is a data collection technique that allows the researcher to gain information about what people *do*, *how* they do it, and *when* they do it (Jorgensen, 2008). Therefore, this approach fit my purpose of gaining insight into how teachers enacted the platforms, and to some extent, the implications this had on their pedagogical practices. Interviews, in contrast, can provide researchers with respondents' *accounts* of *what* they do, *how* they do it, and *when* they do it (Kvale & Brinkmann, 2008). More importantly for this context, interviews give the researcher insights into respondents' accounts of *why* they acted as they did in a given situation—that is, their underlying *reasons*. Such an integration of multiple data sources is a frequent characteristic of ethnographic studies (Hammersley & Atkinson, 2010; O'Reilly, 2013), but it nonetheless obliges the researcher to address two central questions: 1) How and with what purpose are the data sources integrated/combined? 2) What is the time order of the data source collection?

In this case, the time order was closely related to integrating the two different data sources. Johnson and Onwuegbuzie (2004) distinguished between a concurrent and a sequential data collection. Whereas a concurrent strategy involves a simultaneous collection of data from different sources, a sequential approach begins by collecting data from one source and then collects data from another source afterward (see Table 2).

Concurrent Time Order	Sequential Time Order
Observations + Interview	Observations → Interviews or Interviews → Observations

Table 2. A scheme displaying two approaches to the timely order of data collection strategies (Johnson & Onwuegbuzie, 2004, p. 19).

At the practical pedagogical level, I approached the data collection by applying a sequential time order. I began with an initial informal interview with each of the teachers I had planned to observe. The purpose of this meeting was for me to gain an overview of their weekly schedules in order to plan when to observe their classroom teaching. As previously described, both Parkview and Hillside only provided students in Grade 4 and above with devices. To the widest extent possible, I sought to observe the teachers' mathematics teaching in grade levels where students were equipped with a device. This was an attempt to minimize the material constraints of their usage of the platforms; the meeting gave me this information and shaped my aims.

At the meetings, I also informed the teachers that my role as an observer in the classroom meant that I would not participate in any activities as a resource person, but that I to the greatest possible extent would be a passive observer. Moreover, we discussed and finally agreed upon how I should be introduced to the class, and we discussed whether the individual teacher had any preferences for my physical placement in the classroom. Shortly after these meetings, I began observing the teachers' classroom teaching. Approximately halfway into the observations (after four weeks), I interviewed the individual teacher I had been observing. I then completed the last two weeks of observations. The time order of my data collection strategy for each teacher is summarized in Table 3.

The Time Order of the Data Collection for Each Teacher
Initial meeting →
Observations of classroom teaching →
Interview →
Observations of classroom teaching

Table 3. A scheme displaying the time order of the data collection strategy deployed in this thesis.

Whether a concurrent or sequential time order strategy is applied in the data collection, there can be several rationales and purposes for combining multiple data sources. In this regard, Johnson and Onwuegbuzie (2004, p. 15) argued that combining data sources can be directed to one of the following five purposes:

Triangulation (convergence and corroboration of results from different methods)

Complementarity (seeking elaboration, enhancement, illustration, and clarification of the results from one method with results from the other method)

Initiation (discovering paradoxes and contradictions that lead to a reframing of the research question)

Development (using the findings from one method to inform the other method)

Expansion (seeking to expand the breadth and range of the research by using different methods for different inquiry components)

As illustrated in Table 3, my study at the practical pedagogical level involved four sequences. In all the sequences, the purpose was to inform and qualify the following data collection method. The initial meeting with the teachers was directed toward clarifying and agreeing upon the practical arrangements of my observations. The meeting thereby provided me with an informed foundation for choosing which of their classes to observe in order to collect data that would constitute the best conditions for answering my research question. This meeting followed a loosely structure agenda that I had sent to the teachers in advance. The agenda specified that I wished to make the practical arrangements for the observations and clarify my role as an observer in the classroom. The data collected from these meetings consisted of a written memorandum of what the teacher and I had agreed upon.

Similarly, the subsequent observations had a dual purpose; firstly, and most importantly, I aimed at collecting data that would grant me insight into how and when the mathematics teachers' were using the digital platforms. During the observation, I collected data through field notes typed on a computer, pictures, and short video-recordings. Each lesson I observed resulted in 3–6 typed pages. Figure 19 below is a photo taken at Hillside.



Figure 19. A photo taken in the classroom at Hillside. The photo documents how Michael began the majority of his lessons: by projecting his own or a

student's screen on the Apple TV to go through the learning objectives for the day's lessons, which were written in Meebook.

The video-recordings I made sought to document frequently recurring practices with or without the digital platforms so that I could take a closer look at the situation afterward.

A secondary aim of the observations was to inform an interview I would hold with the teacher after having observed him or her for four weeks. After four weeks of observations, I identified what seemed to be recurrent practices among the four mathematics teachers' classroom teaching with or without the use of the digital platforms. From these, I developed an interview guide in which I asked the teachers why they had chosen to use or not use the platforms in the situations in question and what priorities these choices reflected.

This approach led to slight differences among the interviews with the four teachers, which is not uncommon in studies involving more than one interview unless a highly structured interview guide is used (Kvale & Brinkmann, 2008). For the sake of comparison, I made an effort to streamline the interview guides to the extent that I found it productive to answer the research question without compromising the quality of the individual interviews. These efforts included initiating the interviews by asking the participants questions about

- background information such as seniority, education, age, etc.;
- their perception of the implementation of platforms; and
- their view of the learning platforms and of using them.

Moreover, in the questions addressing their particular practices in the classroom, I aimed to glean information about both why they did or did not chose to use the platforms and their accounts of the underlying reasons for these choices.

The interviews provided a deeper insight into the individual mathematics teachers' reasoning and rationales of their practices, which once again informed the focus of the remaining observations. In some cases, the interviews informed me that the teachers had particular aims of, for example, beginning every lesson by introducing the students to the learning objectives for the lesson. This information helped me focus the observations to get an increased insight into the particular teacher's effort in obtaining these goals. Being aware of each teacher's intentions of doing what he or she did made it possible to identify both efforts and obstacles in obtaining this objective that otherwise could have remained hidden. Table 4 illustrates the relation between the data collection strategies, including how and with what information they helped me to develop my subsequent method.

The Time Order and Purpose of the Data Collection
Initial interview/meeting →
(Development: logistics, agreement of my role as a researcher in the classroom, physical placement in the room, etc.)
Observations of classroom teaching →
(Development: selection of episodes and stable practices to be discussed in the interviews)
Interview →
(Development: new information about the teachers' rationales behind their practices)
Observations of classroom teaching →
(Development: Nuancing and enriching existing results)

Table 4. *An overview of the time order and purpose of the components of the data collection.*

The data collected at the practical pedagogical level include observations of four teaching hours and interviews with three mathematics teachers from one school regarding their planning with platforms; in total, I conducted eight interviews and observed 64 lessons among a total of four teachers from two different schools. Table 5 provides an overview of the entire empirical material collected at the practical pedagogical level.

Teacher	School	Focus	Observations	Interview
Gina	B	Planning	2 x 2 hours	1
Karen	B	Planning	2 x 2 hours	1
Miriam	B	Planning	2 x 2 hours	1
Total:	1 school		4 hours	3 interviews
Ralph	Parkview	Classroom teaching	14 lessons	2
Dylan	Parkview	Classroom teaching	16 lessons	2
Jacob	Hillside	Classroom teaching	18	2
Michael	Hillside	Classroom teaching	16	2
Total	2 schools		64 lessons	8 interviews

Table 5. An overview of the data in the practical pedagogical level.

Processing the Data

The ethnographical data collection at Parkview and Hillside conducted over the course of a total of 12 weeks provided me with a relatively large amount of data. To process this data systematically, I began coding it before proceeding to analyze it according to the theoretical concepts (in this case, the documentational genesis). In the coding process, I took an outset in the second interview (held during the observations). As mentioned, the research question at the practical pedagogical level regarded mathematics teachers' pedagogical enactment of the platforms, the underlying reasons for this, and the implications for their pedagogical work. As evident, a central aspect of answering this question was to identify teachers' underlying reasons of their ways of using the platforms. Whereas the observations of the teachers' practices primarily concerned *what* they did, the errand of the interviews was to investigate their underlying reasons (*why*) of these practices. The interview data thus seemed as an obvious starting point for coding the data.

As described in Paper 6, I conducted the coding of the interview transcripts in Excel. The coding process followed a combination of theoretically generated thematic codes and empirically types of these codes. Concretely, this consisted in that I defined five thematic and theoretically informed thematic codes a priori. These were informed by the documentational genesis and included:

- Instances of instrumentations (the teacher shapes usage of the platform)
- Instances of instrumentalizations (the teacher's practice is shaped by the platform)
- Conditional factor (what was causing the instrumentation or instrumentalization according to the teacher)
- A specification of the activity (for example teaching, planning, communication etc.)

- A specification of the actor being talked about (sometimes the teachers were referring to other teachers or to hypothetical situations)

I imported the transcripts into Excel, assigning each sentence separated by a dot their own row and added the five coding themes as columns. I began the coding by reading the transcripts line by line, adding an empirical type of the thematic code when an instance of an instrumentation appeared in the data etc.

		Utterance	Coding																							
			Instrumentation	Teacher structures	Teacher communication/cooperative with other teachers	Instrumentalization	Platform	Activity	Teaching	Planning	Assessment	Communication	Conditional factor	Low ICT skills	High ICT skills	ICT infrastructure	Regulation	1	2	3	4	5	6	7	8	
Respondent	Speaker	Text	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1762																										
1763	L4	B	På den måde har det ikke nogen betydning, om jeg ligger det ind i det ene eller andet system, fordi det ikke har nogen betydning for, hvordan jeg gør det.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1764	ALT4	B	IV: Og hvornår bruger du så Minitjeddelnet?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1765	L4	B	I: Det er som regels i starten og i slutningen af et forlæb	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1766	L4	B	Det kommer på, hvor langt det er, nu i de her små geometrisforlæb vi har haft, der laver jeg ikke nogen mittejsevaluering	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1767	L4	B	Det ville jeg typisk gøre i forlæb, der var lidt længere	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	L4	B	Og så er det jo også sådan, at i de kompender, de har, der står der også hele tiden oppe i højre hjørne, hvad det er for nogle mål, der arbejder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 20. A screenshot of the coding in Excel.

I conducted the coding in a binary manner, adding a 1 if the code appeared in the line (see Paper 6 for a more elaborate description of this process). After having completed this coding with the interviews of all four teachers, I decided to conduct a principal component analysis (PCA) of the coding. PCA is a statistical method that allow reducing a large number of variables into fewer variables by grouping them into cluster that correlate. This method thus allowed me to explore which of the empirical codes that most frequently co-occurred. As briefly mentioned in Paper 6, a PCA (conducted with codes that are not weighed) provide results that assign importance factors (co-occurrence of codes) based on the frequency of their co-occurrence. Although the result of the PCA only identified two factors as significant for explaining the variance in the data, a statistical less important factor emerged had importance

for answering the research question posed in the paper. This factor consisted of a single code, namely “requirements from parents”. In the interview in which this code emerged, it had importance for the relation between this teacher’s usage of the platform and his documentation work. In spite of its little statistical importance, I therefore decided to include it in the paper. In this respect, my approach to coding and processing the data was therefore both informed by quantitative and qualitative considerations.

Limitations of the Method

As in the case of the organizational level, I also encountered limitations regarding the theoretical frame informing the data collection at the practical pedagogical level. Whereas the organizational level predominantly conceptualized enactment as discursive ways of *relating* to the platform, I considered enactment and a dialectical process emerging between an artifact or resource and its usage. Paper 5 and 6 both document the necessity of broadening this conceptualization to fully understand teachers’ usage, non-usages and experiences of using the platforms. In this case, my colleagues and I acted upon this shortcoming by developing a theoretical extension of the documentational genesis to account for the mathematics teachers’ ways of *relating* to the curriculum as it was mediated by the platforms.

Chapter 7: Conclusion

In this thesis, I have sought to address the following research questions:

How do stakeholders in schools engage in the organizational implementation of digital learning platforms, and what are the implications of the implementation of the platforms for mathematics pedagogical teachers' work?

- *What are the mutual relation between actor groups' perspectives on digital platforms, how does this affect the opportunities of a successful implementation, and to what extent can the pedagogical staff overcome their perceived limitations of the platforms?*
- *How do mathematics teachers pedagogically enact digital learning platforms, what are the underlying reasons for these, and what are the pedagogical implications for their work?*

I have investigated these questions by engaging in a combination of descriptive, ethnographical research studies that have sought to explore mathematics teachers' usage of digital platforms and intervention based research studies, in which I actively have sought to support schools in implementing digital platforms. I have reported these research studies in 6 individual papers, that have contributed in addressing the research questions by providing empirical as well as theoretical results.

At the organizational level, this thesis identifies that implementing learning platforms is a process that requires negotiations among the actors that are affected by the platforms and involved in the implementation. The actor groups' involved in the implementation have highly different perceptions of the platforms, and reaching to negotiated and agreed upon reasons for using them are necessary if the platforms are to support teachers in their pedagogical

work. Otherwise, the different ways of viewing the platforms represents a substantial threat that may hinder a successful implementation process.

The papers addressing the organizational level have identified Future and Design Workshops as effective tools to facilitate such negotiations. These workshops provide a space where the actor groups are able to express their concerns and visions about using platforms, which is a key foundation for negotiating the platforms. When agreed upon vision have been defined, design workshops provide support for developing ways of using the platforms that are aligned with teachers' values and beliefs about good teaching.

The central new insights brought by this thesis are thus that implementation of new technology requires that stakeholders in schools are actively involved in negotiating and renegotiating of in what situations, how, to what extent and not least for what reasons these technologies should be used. If this does not happen, teachers are likely to experience that the technology compromise their professional autonomy. In such situations, a best scenario is perhaps that teachers choose not to use the platforms, as the alternative is that they do use the platforms in ways that have negative implications for their teaching. Involving teachers actively in negotiating the technology may however open for new perspectives on the platforms and how they *could* be used beneficially. As described above, this can result in usage of platforms that support teachers in pursuing their pedagogical aims.

In this respect, implementing new technology such as digital platforms are not only associated with potentials of improving teaching and learning, but also *risks* of alienating teachers' from the core of their pedagogical work. This is a challenge that is likely to be increasingly important for both school managers, municipalities, the Ministry of Education and technology developers to be aware of. For people working with implementing technology in school

contexts, the work therefore lies in understanding how users can be supported in tapping into, influencing and aligning their usage of aspects of the technology with their core values. In some cases, this aspect of the organizational implementation of a technology is as determining for the success the implementation as the quality of the technology in itself.

At the practical pedagogical level, this thesis have illustrated that digital platforms have implications for the core of mathematics teachers' pedagogical work. The implementation of digital platforms result in a complex interplay between teachers' pedagogical work and their usage of platforms. In particular, the platforms' integration of learning objectives have proven to be a central aspect of how teachers' use and experience using the platforms in their work. This thesis identifies how the platforms' integration of learning objectives in some cases may support teachers in making qualified decisions when planning and teaching lessons. In other cases, this feature of the platforms lead to the experience of being forced to worked in constraining and rigid templates that are not able encompass the complexities of teaching and learning mathematics. Whereas these findings provide new empirical insights into teachers' work with platforms in their own right, they also illustrate that the same technology may have a number of different implications depending on the teaching practice with which it is combined. For mathematics teachers' to successfully use the platforms to improve their teaching is thus a complex process in which the individual mathematics teacher need to navigate in aligning pedagogical practice, goal, visions and the need of students. This highly complex endeavor requires continuous experimentation and professional reflection of the teacher. Implementing digital platforms is thus far from an easy "quick-fix" to improve the efficiency of teachers, the quality of their teaching and their students' learning.

Across the two levels of implementation, a recurrent phenomenon described in this thesis is teachers' resistance towards using the platforms. The underlying reason of not using the platforms may both regard teachers' interpretations of the platforms' inherent values and teachers' experiences of the concrete implications and constraints the platforms have for their practices. This thesis have however also revealed more tacit and less obvious reasons of not using the platforms, which at first glance may look appear conservative and reactionary. This regard the unpredictable results of using the platforms. This unpredictability are found at both the practical pedagogical and organizational level of implementation.

At the organizational level, Paper 4 illustrated this in that the teachers' *did not know* whether the platforms were able to support them in their pursuing their pedagogical visions; thus the need of developing experiments during the workshops to test this. At the practical pedagogical level, this unpredictability was illustrated in Paper 6 where the teachers from Parkview were surprised that using the platform provided them an overview of their lessons, which supported them in improving their teaching.

As argued in Paper 6, this unpredictability occasionally results in situations that are not desirable. This point thus shows that there are *risks* involved in using a platform; it might end up compromising the quality of the teaching. This issue is of a scale that is beyond of what is reasonable for the individual teacher to cope with. It needs to be addressed in close and continuous communication between teachers and to involve the managers and other relevant authorities at schools. This point illustrates the need for teachers' to share how their experiences of using the platforms in fora where school managers, local supervisors and other local authorities and capacities can

support them in creating the best possible ways of doing their job: developing excellent teaching.

Towards Better Usage of Platforms

As argued in the introduction of this thesis, the requirement for schools to continually implement new technology is likely to be the future norm. This thesis both identifies challenges related to navigate in such contexts and describes strategies that schools may deploy therein. A central challenge related to the implementation of digital platform have proven to be balancing between gaining the benefits of new technology while at the same time maintaining what works and avoiding unforeseen and undesired implications of using the new technology. This is a complex endeavor that occasionally appear contradictory and paradoxical; why risk reducing the quality of teaching that already work? This thesis have showed that one way of balancing the development of new practices with maintaining what works is to engage in small-scale experiments driven by the visions of teachers themselves. A potential benefit of having to relate to new technology is that the considerations of whether to use it or not requires teachers to reflect on *what already works*. What are the underlying characteristics of these practices that makes them good? How would the technology change these practices? What would the effects of this change be? As described in this thesis, the answers to these questions are far from obvious and may be difficult to anticipate. Of this reason, it is key that schools and teachers' collectively investigate and discuss these matters carefully.

Limitations of the Study

The research findings in this dissertation have been generated during a period where the platforms have not been fully implemented in the everyday life of schools. The papers of the thesis thereby study implementation in the midst of

the process where few schools yet have reached a stable state. At the one side, this provide the results of this thesis the strength of providing valuable insights into implementation *processes* and how schools and teachers navigate in such contexts. Although the papers in this thesis study the implementation of a specific innovation, namely digital platforms, the complexity of the process described in the papers illustrates the many aspects of school life that are affected by implementing a new technology. As argued for in the introduction to this thesis, this is valuable as the implementation of technology in schools are likely to increase. A central contribution of the thesis is thereby to provide deep and rich descriptions of how teachers' and other stakeholders engage in such implementation processes of technology, and in identifying the challenges this bring along with it for their everyday work and how these challenges can be addressed. As of 2019, the majority of the Danish schools have however been engaged in the implementing the platforms for several years. It is therefore likely that schools have reached some level of stability in their implementation of the platforms, which would be worth exploring. This thesis have focused on investigating the implementation process at relatively few schools and in among relatively few teachers. Considering the scale of the national implementation of the platforms, an obvious next step would be to generate a more comprehensive overview of how schools and teachers of different topics are using the platforms, to what extent and with what purposes. Such research could perhaps inform a revision of the 64 functional requirements for the platforms, so that the specification of the platforms reflect how they are being used.

The mathematics teachers that are represented in the practical pedagogical level work at schools with favorable material context; they and their students had access to computers and they taught their lessons in classroom with a stable internet connection and with smartboard, to which both teachers and

students easily could connect. As argued in chapter 6, I deliberately chose to study such schools to avoid encountering teachers who were not using the platforms due to local material insufficiencies. By following this approach, I thus sought to isolate teachers' pedagogical reasons of using and not using the platforms as this was a core aspect of the research questions I sought to answer. The advantage of this approach is that it allowed me to explore the full potential of the platforms and identifying the non-material factors that makes it complicated and even unnecessary to use the platforms in spite of having all the technical equipment available. Many schools across the country however find themselves in contexts that are less privileged than what is the case for the schools represented in this thesis. For these schools, the potentials of using the platforms identified in this thesis may therefore not be within reach due to their lack of access to technical equipment. Moreover, they are likely to face challenges of a different kind from the ones described in this thesis. This situation is therefore likely to bring challenges related to using the platforms that are of an entirely different kind than the ones identified in this thesis. Oddly, the requirement specifications for the platforms and the policy documents seldom include reflections on such local material and technological limitations. On the contrary, as described in paper 4, these documents tend to argue for the need of having the platforms "fully implemented" by 2018. This situation calls for research that seeks to investigate what technological devices less privileged Danish schools have available, and in what ways platforms can be used in such contexts.

Although this thesis provides the initial answers related to the organizational and pedagogical implications of implementing digital platforms, there is thus need of future research in this field.

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