Designing for Transformational Change in School

To my family

Örebro Studies in Informatics 18

ANNIKA AGÉLII GENLOTT

Designing for Transformational Change in School
Digitalizing the Digitized

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Digitalizing the Digitized

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Abstract

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Digital technologies have gained a prominent role in education and schools, but research concerning how digital technologies can create better conditions for improved teaching and enhanced learning for students is scarce and inconclusive. Successful use of digital technologies requires a complex combination of interacting factors, including integrating technology and pedagogy as well as organizing and leading a structured transformation process. The capability of school organizations to lead and support the digitalization process is an under-researched field compared to the well-established focus on individual stakeholders.

This thesis examines how experimentation and innovation processes in school can be designed and pursued to support and enhance digitalization across an entire school organization by using a Design Science Research (DSR) approach to answer the question: *How can a school organization at municipal level lead digital transformation through the digitalization of teaching and learning processes in an organized, professional, and, as far as possible, scientifically based way?*

The findings show that the design and use of the Information System Artifact model (ISA) together with a DSR development method can support both improved teaching and enhanced learning *within* and *across* a school organization. Effective use of digital technologies to improve teaching and learning across the school organization requires fundamental changes of ordinary practices and engagement as well as commitment from school authorities and school leaders.

This thesis contributes with empirically and theoretically based insights from leading (digital) transformational change in school through the iterative design of IS artifacts used as a driver and quality control for the shift from digitization towards digitalization aiming at improved teaching and enhanced learning.

Keywords: Design Science Research, Digitalization, Information Systems artifact, School organization, School leadership

Annika Agélii Genlott, Örebro University School of Business
Örebro University, SE-70182 Örebro, Sweden,
annika.ageliigenlott@oru.se

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List of studies

Study 1

Agélii Genlott. A., & Grönlund, Å. (2013). Improving literacy skills through learning reading by writing: The iWTR method presented and tested. *Computers & Education, 67*, 98-104. https://doi.org/10.1016/j.compedu.2013.03.007.

Study 2

Agélii Genlott. A., & Grönlund, Å. (2016). Closing the gaps - Improving literacy and mathematics by ict-enhanced collaboration. *Computers & Education, 99*, 68-80. https://doi.org/10.1016/j.compedu.2016.04.004.

Study 3

Agélii Genlott. A., Grönlund, Å., & Viberg, O. (2019). Disseminating digital innovation in school - leading second-order educational change. *Educ Inf Technol 24*, 3021-3039. https://doi.org/10.1007/s10639-019-09908-0.

Study 4

Agélii Genlott. A., Grönlund, Å., & Viberg, O. Disseminating digital, science-based innovation in education – a leadership challenge. (Submitted to a journal – under review)

Abbreviations

AI	Artificial Intelligence
CAI	Computer-Assisted Instruction
CAL	Computer-Assisted Learning
CMI	Computer-Managed Instruction
DOI	Diffusion of Innovations
DSR	Design Science Research
EdTech	Educational Technologies
EU	European Union
ICT	Information and Communication Technologies
ITiS	Information Technology in School
IS	Information Systems
ISA	Information Systems Artifact
IT	Information Technology
iWTR	integrated Write To Read
LA	Learning Analytics
LDP	Least Developed Countries
Lgr 11	Curriculum for compulsory school 2011
Lgr 80	Curriculum for compulsory school 1980
Lpo 94	Curriculum for compulsory school 1994
OER	Open Educational Resources
OLPC	One Laptop Per Child
PC	Personal Computer
PIM	Practical IT and Media
PISA	Programme for International Student Achievements
PLATO	Programmed Logic for Automatic Teaching Operations
PLC	Professional Learning Community
TEL	Technology-Enhanced Learning
TFAL	Teachers Formative Assessment Learning (STL-kursen)
WTL	Write to Learn (Skriva sig till lärande (STL))
ZPD	Zone of Proximal Development

Terms and definitions

Diffusion: "Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas" (Rogers, 2003 p. 5).

Digitalization: "the adoption or increase in use of digital or computer technology by an organization, industry, country etc." Oxford English Dictionary (OED, 2020).

Digitization: "the action or process of digitizing; the conversion of analogue data (esp. in later use images, video and text) into digital form" (OED, 2020).

Digital Transformation: "a marked change in form, nature or appearance" (OED, 2020).

First-order-change: "is incremental. It can be thought of as the next most obvious step to take in a school or a district" (Marzano, 2005 p. 66).

Information artifact: "an instantiation of information, where the instantiation occurs through a human act either directly (as could happen through a person's verbal or written statement of a fact) or indirectly (as could happen through a person's running of a computer program to produce a quarterly report)" (Lee et al., 2015, p.8).

IS artifact/ Information system artifact: "a system, itself consisting of subsystems that are (1) a technology artifact, (2) an information artifact, and (3) a social artifact, where the whole (the IS artifact) is greater than the sum of its parts." Lee et al., (2015, p. 6).

Municipal organizer of school: the organizer of communal schools within a municipality.

Organizer of the independent school: the organizer of independent school/schools.

Second-order-change: "Second order change is anything but incremental. It involves dramatic departures from the expected, both in defining a given problem and in finding a solution" (Marzano, 2005 p. 66).

Social artifact: "an artifact that consists of, or incorporates, relationships or interactions between or among individuals through which an individual attempts to solve one of his or her problems, achieve one of his or her goals, or serve one of his or her purposes. We describe this artifact as social because relationships and interactions involve more than just one person; hence, they involve the social, not just the individual"(Lee et al., 2015, p. 9).

Technology artifact: a human-created tool, created for the purpose to either; "solve a problem, achieve a goal or serve a purpose that is human defined, human perceived or human felt" (Lee et al., 2015, p. 8).

Table of Contents

1. Introduction

This thesis concerns the use of digital technologies in schools to improve teaching and enhance learning. The topic has been on the agenda for several decades, but it is really only during the 2000s that the widespread availability of digital tools and resources over the Internet has soared. The increased use of technology has been largely experimental and lacks research-based pedagogical methods. This lack is deplorable but quite understandable as the use is emergent. There has not been a large empirical base of users, and technology develops rapidly – which means the conditions for teaching and learning change.

There is a gap between the widespread use of digital technologies and the lack of knowledge about how to make its use effective.

To help address this gap, this thesis reports an attempt at developing, testing and disseminating a method for literacy development at early school stages. The method is based on research on teaching and learning, it uses digital technologies to improve teaching and enhance learning, and the learning effects are evaluated using the Swedish national tests in grade 3. During the process positive learning effects were not only found for literacy but also for mathematics.

The thesis describes the development, evaluation and dissemination of the "Write to Learn" (WTL) ("Skriva sig till lärande" (STL)) method and discusses it in the general framework of "Technology-Enhanced Learning", currently one of the most popular term for use of digital technologies in education.

1.1 Digital Technologies in school

Increased access to – and use of – Information and Communication Technology (ICT), both within the societal context and in the personal sphere, has today more or less become the "new normal" and has various implications worldwide for many aspects of, and processes in, modern society. This also applies to education and the school sector which, although tangible differences still prevail between schools and classrooms, is largely influenced by investments in, and access to, technological hard- and software (Grönlund, 2014; Tallvid, 2015; Håkansson Lindqvist, 2015) but less concerned with understanding how digital technologies can best be used to improve work processes and teaching methods. Improving work processes brings with it a need for changed conditions for teaching and learning (Willermark, 2018) as well as complexity to the school organization (Pettersson,

2018) and calls for leaders to focus upon leading the change needed for making the best of the new technologies provided (Grönlund & Wiklund, 2018; Håkansson Lindquist & Pettersson, 2019). School organizations and their capability of leading and supporting digitalization is, however, an under-researched field compared to the focus on individual actors (Pettersson, 2018; Håkansson Lindquist & Pettersson, 2019).

Technology-enhanced education is an emergent field where trials, experimentation, and evaluation are important. Beyond this, dissemination of innovation is problematic in school due to the distributed organization model. This thesis therefore seeks to learn how experimentation- and innovation processes in school can be designed to support and enhance digitalization within and across a school organization and how municipal organizers of schools can lead and support this complex and challenging digital transformation.

Access to digital technologies has increased markedly over the past few years and according to the Organisation for Economic Co-operation and Development (OECD) "on average across OECD countries, there is almost one computer for educational purposes available at school for every 15-year old student (the computer-student ratio is equal to 0.8)" (OECD, 2020 p. 5). However, technology use has shown to vary to a large extent (McKinsey & Company, 2017), and existing research on the impacts of digital technologies in teaching-learning contexts has, to date, been limited, rarely sustainable (Toh, 2016) and often used only to replicate already existing practices in school (Glover, Hepplestone, Parkin, Rodger & Irwin, 2016). Hence, the debate and uncertainty around the use of digital technologies in school and their effect on teaching and learning over the years has brought with it disparate attitudes and beliefs, all the way from eager supporters to confident critics.

Despite that digital technologies are increasingly present in schools today and discussions where digital technologies are perceived as disrupting daily practices in school have been extensive (Selwyn, 2016), disruption and changes of teaching practices on a deeper level do not appear to have taken place on a larger scale as yet. The potential for digital technologies to improve teaching and enhance learning in general has not yet delivered on the desire to transform the very learning and teaching practices (Glover et al., 2016), despite investments in digital technologies, great expectations and, as stressed by Selwyn (2016), the "hype" of digital technologies in school.

1.2 A Productivity Paradox in Education?

The productivity paradox was highlighted by Brynjolfsson (1993) in a widely cited article and refers to the decrease of productivity growth in the USA during the 1970s and 1980s despite huge expectations, dramatic advances of computer power and large investments in digital technologies over the same period of time.

Is education today facing the same productivity paradox as industry did during the 1990s? Peslak (2005), when analyzing test scores in a study of 2,500 schools in Pennsylvania, found no positive benefits accrued to schools having invested more in digital technologies. A report from McKinsey & Company (2017), evaluating results from the PISA tests, the world's deepest and broadest education dataset, shows that the impact on student results of technology use in schools varies from +12 to -16 points. This means technology can have both positive and negative effects and illuminates the necessity to learn more about how digital technology can be used so that it becomes conducive for teaching and learning. Argued in the report from McKinsey & Company (2017) is that;

> Given the evidence of the negligible or even negative impact of much student-centered technology, school systems might be tempted to abandon their ICT efforts. Not so fast. The PISA survey describes the impact of education technology as currently implemented, not its long-term potential. First, the results tell us only about hardware, not software or specific interventions like well-executed personalized learning. Second, education technology is evolving rapidly, and it is possible that specific interventions, including software and implementation strategies, can raise achievement at the system level. (McKinsey & Company, 2017, p. 51)

McKinsey & Company (2017) also stress that improving learning requires instruction of high quality and investigates two different types of instruction: (i) "teacher-directed instruction" – where the teacher explains, demonstrates and leads discussions, and (ii) "inquiry-based teaching" – which rather is characterized by students using digital technologies individually. The findings in the McKinsey & Company (2017) report show that the highest student learning results come from a mix of teacher- and inquiry-directed instruction. Hence, learning more about how to design blended learning methods in school through using digital technologies effectively for improved teaching and enhanced learning is important and also one of the main focuses of this thesis.

Even though schools today are increasingly equipped with digital technologies, the way we teach and think about the use of new technology is often relatively unchanged, and so far, what we associate with digital technologies is often more self-regulated and learner-autonomous work. According to the OECD (2016), overall the most frequently performed task in school in relation to digital technologies was to browse and search the Internet, with 42% of students on average doing so at least once a week. The report from McKinsey & Company (2017) finds that over half of the students in Europe have too little teacher-directed instruction and suggest that if all students have a blend of teacher-directed and inquiry-directed instruction, the average PISA scores would be around 4% higher, which according to the report is equivalent to around half a school year of learning (McKinsey & Company, 2017).

1.3 Integrating Digital Technology in Practice

Digital technologies can bring possibilities for both the advancement as well as the improvement of teaching and learning, but in order to do so the technology needs to be thoroughly integrated into the planning, implementation and analysis of teaching practices (Makki, O'Neal, Cotten, and Rikard, 2018). This has in turn, by Willermark (2018), shown to be both a complex and time-consuming process that requires long-term comprehensive efforts characterized by both challenges and frustration among the teachers involved in the process. Also, according to Willermark (2018), 50% of the Swedish teachers in primary and secondary schools express an urgent need for educational training in how to use and integrate digital technologies in practical schoolwork. In 2019 the Swedish Schools Inspectorate (Skolinspektionen) finds that digital tools are still largely unconnected with subject content, principals' support to teachers regarding digitalization is limited, school organizers have strategies but lack implementation and pedagogical focus, and that pedagogical support for teaching with technology is lacking (Swedish Schools Inspectorate, 2019).

This suggests that the important and sometimes complex process of learning how to improve teaching and enhance learning through the integration of digital technologies is not subject to strategic school development but is rather left for the teachers to attempt to solve by themselves. Argued by Koehler and Mishra (2009) there is a need for teachers to learn and practice how to integrate digital technologies into the pedagogy and practical teaching practice, which in turn requires more long-term and continuous teacher training. The effectiveness of teacher training, educational programs

and reforms though varies and stressed by Stoll, Bolam, McMahon, Wallace, and Thomas (2006), as critical for progress is the capacity of individuals and organizations;

> International evidence suggests that educational reform's progress depends on teachers' individual and collective capacity and its link with school-wide capacity for promoting pupils' learning. Building capacity is therefore critical. Capacity is a complex blend of motivation, skill, positive learning, organisational conditions and culture, and infrastructure of support. (Stoll et al., 2006, p. 221)

Consequently, in order to build individual and organizational capacity for improved technology use in school there is a need for; well-grounded incentives for the use of digital technologies in daily practice, improved digital competences, positive social systems and networks and last but not least a supportive organization promoting long-term improvement. Whereas supplementary technology use often requires relatively small changes in the pedagogy or organizational strategies, integrated use of digital technologies places greater demands on classroom culture and teachers' adaptability to new conditions (Ertmer, Addison, Lane, Ross, & Woods, 1999) as well as on the school organization level (Vanderline, Aesaert, & Van Braak, 2015).

External as well as internal factors have shown to have an impact on teachers' adaptability towards the use of digital technologies and can serve as barriers to the change of educational practices (Ertmer et al., 1999) and are related to each other (Erdogan, 2011). External factors relate to factors outside the teacher's control, e.g., access to support, digital hard- and software and overall infrastructure whilst internal factors are intrinsic and include beliefs and willingness or unwillingness to change teaching practices (Ertmer et al., 1999; Erdogan, 2011).

Thus, in order to be able to address both internal and external factors affecting teachers' adaptability towards integration of digital technologies into practice, there is a need to address and focus not merely on individual actors but rather on the leadership on different levels within the school organization.

Leadership on different levels has shown to be important for the success of a technology initiative (Grönlund, 2014), but requires digitally competent school organizations (Pettersson, 2018), and includes challenges at different levels of the organization (Håkansson Lindquist & Pettersson, 2019).

Successful integration of digital technologies in teaching and learning processes is more than just applying digital technologies into ordinary practice. It is instead a complex and long-term process, that involves different developmental changes of both internal and external characteristics, that need to be supported and consciously led from leaders on different levels within the school organization. In order to support these developmental changes towards successful, long-term integration of digital technologies it is useful to separate conversion of analogue data into digital form, replicating already existing practices from thorough implementation where digital technologies are intertwined in – and supportive to – pedagogic activities and processes. Therefore, in the nest section (1.4), I discuss the concepts of Digitization, Digitalization and Digital Transformation.

1.4 Digitization, Digitalization and Digital Transformation

The concepts of digitization, digitalization and digital transformation are frequent in both public debate and in research. They are often used interchangeably, but they have different definitions and aim at different aspects of technology use. The three concepts; Digitization, Digitalization and Digital Transformation is explained by the Oxford English Dictionary (OED) as;

Digitization; "the action or process of digitizing; the conversion of analogue data (esp. in later use images, video and text) into digital form".

Digitalization; "the adoption or increase in use of digital or computer technology by an organization, industry, country etc".

Digital Transformation; "a marked change in form, nature or appearance". (OED, 2020)

The terms digitization and digitalization have over the years been extensively used by the private sector in order to try and separate the differences for the business between converting analogue data into digital form and changing the very practice of business processes.

Digitization is in this thesis defined as the *process of converting analogue material into a digital/numerical format*. This means that digitization requires access to, and use of, digital technology but does not include a view of how this material is used in teaching and learning. It may be used for replicating already existing practices or for something that turns the practice up-side down.

Digitalization is in this thesis interpreted as *using digital technologies to enhance teaching and learning processes*. It is important to highlight here that digitalization is not turning existing processes, instructions and schoolwork, into digital replications, but rather enhancing them, adding values in

some way, as enabled by digital technologies. Digitalization in school then is when teaching and learning processes, due to the use of digital technologies, take on new forms, and, to different extents, improve the ordinary practice. While the level of change may vary, the main point is that digitalization involves rethinking existing practices in view of new opportunities – including considering the risks involved.

Added value can be achieved in many different ways, for example by enabling direct and global digital cooperation with peers all over the world, by production of different multimedia products that can also be globally published, or by increased digital and social interaction in learning activities. On the teaching side, beyond new kinds of material and presentation tools the use of learning analytics – collection and analysis of data about students' learning activities, contexts and results and using that analysis to improve teaching – can be an important part of digitalization. Finally,

Digital transformation in this thesis is, following the OED, used to mean *a marked change in form, nature or appearance*. But before that change actually takes place there will have to be a process of defining and implementing such change. Therefore, digital transformation in this thesis refers to the process of organizational change added to the use of digital technologies in the form of the overall political decision of a municipal (or independent) organizer of school.

1.5 Increased Access but Differences in Use

Increased access to – and use of - digital technologies can bring with it positive, none, or even negative effects on teaching and learning. According to OECD (2020);

> On average across OECD countries, one additional computer per student in a school was associated with a 12-point decline in reading scores before accounting for other factors, and with a 6-point decline after accounting for students' and schools' socio-economic profile. While this negative association between computers-per-student and students' test scores may have many reasons, it does suggest that it takes more than providing technology to reap benefits in terms of better learning. (OECD, 2020 p. 5)

A focus on digitization here means putting efforts into achieving a high device-to-student ratio. Providing digital technologies and infrastructure to schools has up until today been the focus in many countries, including Sweden.

It may be that the focus on access – equipping and connecting schools with digital technology (digitization) – has led to less focus on the use, i.e.,

how to support the developmental change and integration of digital technologies that can enable new learning processes (digitalization). This in turn resulting in an increasingly digitized school suffering from some form of productivity paradox (see 1.2).

Digitalization in school can bring improvements to schools (Makki et al., 2018), but requires developmental changes, professional development in teaching- and learning practices (Koehler & Mishra, 2009) as well as adaptability to new conditions (Ertmer et al., 1999; Vanderline et al., 2015). Sustainable developmental improvement in a broader sense, beyond digitization and towards digitalization, does not occur by itself but has to be led by leaders in school, is suggested to target improved student results instead of the change process getting there and has a direct impact on the success of a technology initiative (Beycioglu & Kondakci, 2014). Leaders as the key to successful digitalization has earlier been stressed by e.g., Grönlund (2014); Pettersson (2018); Håkansson Lindquist and Pettersson (2019) and the focus of this thesis is to learn how school organizations can design and lead sustainable developmental change – moving from digitization towards digitalization.

1.6 Thesis Scope

Since the digitization of school, e.g., the purchase, installation and maintenance of digital technologies, is costly but does not lead to a real improvement of teaching and learning in school per se, there is a need to learn more about how to achieve digitalization and what needs to be performed to get there.

Beyond investment in digital infrastructure, digitalization also requires changes of processes both in administration, teaching and learning practice, which in turn requires digital competence and leadership on different levels within the school-organization. But since the everyday management of students' learning in school is in the hands of the teacher, leadership in the context of school is complex. School leaders cannot, and should not, interfere with how teachers plan or execute their lessons to an undue extent. On the other hand, school leaders are responsible for delivering equal education to all students in their school whereas the organizer of the school (within the municipality or private sector) then has an overall responsibility for all schools within the organization. Digitalization concerns all levels – from the students and teachers in the classrooms to the school leaders, the municipal or independent organizer of school as well as on a national level.

This means that leading change towards digitalization has to include all levels at the same time. Moreover, the use of digital technologies in school

is still quite a new phenomenon, and there is still a lack of research to build upon. In order to learn more about this subject – how to *digitalize rather than only digitize* – there is a need to innovate, test and analyze the outcomes of attempts to truly integrate digital technologies into the teaching- and learning practice. In order to be able to test and analyze the integration of digital technologies there is also a need for scaling up the innovation efforts and for the entire school organization to be involved.

This thesis concerns how experimentation and innovation processes in school can be designed to support digital transformation; that is to say, make sure successful innovation does not stay in the classroom of origin but is disseminated to enhance digitalization within and across the entire school organization, and how municipal or independent organizers of schools can lead and support this complex and challenging transformation.

1.7 Problem Statement and Research Questions

Leading digitalization in school requires action at several levels, at national as well as municipal and school level, and from both actors within the political and administrative systems' bodies and from individual professionals, including school leaders, teachers and students. Because digitalization is emergent, there is no blueprint regarding how to do it and how to measure the results of it; careful experimentation and innovation are thus needed. Research has as yet only provided limited support for how to integrate digital technologies into teaching- and learning processes, and new findings can be expected. As digitalization is emerging everywhere, there is great uncertainty about best practices. All these factors contribute to making leading digitalization a matter of learning and pursuing an effective and efficient digital transformation process. It is not simply a top-down process where "solutions" are "implemented".

This thesis investigates the struggle of digitalization by asking:

> *How can a school organization at municipal level lead digital transformation through the digitalization of teaching and learning processes in an organized, professional, and, as far as possible, scientifically based way?*

Because it is a complicated question and because both technology, research and experiences from technology use in school continue to develop

and bring new input to the change process, there is obviously no simple straightforward answer. There may also not be just one specific way to do it, but rather several options are more likely possible.

However, there are certain criteria that have to be met in order for changes to teaching- and learning processes to be accepted by people other than those who invented it. Such criteria include there being some credible measure of success, the new methods being described in sufficient clarity in order to be possible to be learned by others than the inventors, and to be sufficiently economical, i.e., possible to implement within available resources. Most conspicuously, as the technology to a large extent is already in place, resources here means teachers.

Digitalization in school regards the improvement of teaching- and learning processes through the integration of digital technologies. Such improvement begins and ends in the classroom, but because digitalization of school concerns not just individual classrooms or schools but is a concerted action within and across all schools, there is need for management of this change. This thesis investigates the process of digitalization using a design science research approach to understand:

1. *How can technology-enhanced teaching and learning methods be designed and implemented?*
   Testing of new teaching- and learning methods must initially be performed on a small scale. We need to learn how to best harness technology so it fits well into, and improves, classroom work, and we need to adjust teaching and classroom work in order to smoothly engage technology in ways conducive to improving learning. This thesis takes a design science perspective, which means I investigate the issue by means of a case study with no intention to cover all the possible ways in which it can be achieved.
2. *How can we measure the result of the use of such a method outside the classrooms of origin?*
   In order to be confident in the effectiveness and usability of the method we need to be able to display some convincing results.
3. *How can such a method, if successful, be disseminated to other schools, beyond both the school and the municipality of origin?*
   Once we have convincing results, what does it take to make other teachers and schools adopt the method? Dissemination of innovations is a complicated process which is not only dependent on the innovation itself but also on the social contexts in which it is to be disseminated (Rogers, 2003)

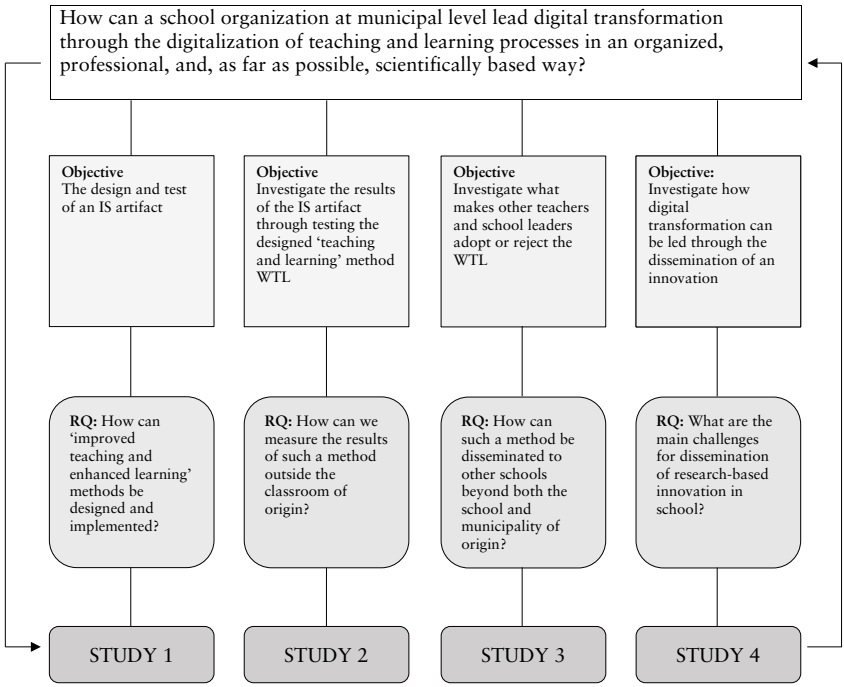

Figure 1. Research map

1.8 Thesis Structure

Chapter 1 has given an introduction to the research area, defined central concepts and presented the research questions guiding this thesis.
Chapter 2 presents the research context, the Swedish development towards integrating digital technologies in school, and the development in the research field concerned with educational technologies.
Chapter 3 presents the theoretical foundations and frameworks underpinning the research.
Chapter 4 presents the research design and approach that guided my research as well as the methods utilized.
Chapter 5 presents both the process and results of the research by the use of Design Science research (DSR).
Chapter 6 summarizes the findings from the four studies conducted.
Chapter 7 discusses the main contributions of this research.
Chapter 8 presents the conclusions and discusses implications.

2. Research Context

This chapter presents the study context from a national as well as a municipal perspective in which the empirical evidence for this research was also collected. In this chapter, with the aim of further situating my research in its context and settings, I link together educational perspectives contemporary with the global evolution of digital technologies.

2.1 ICT and the Swedish school

Sweden is a parliamentary representative democracy under a constitutional monarchy, it is one of the five Nordic countries (Denmark, Finland, Iceland, Norway, Sweden), has an area of 450,295 square kilometers and is the third largest in Northern Europe and the fifth largest in Europe. The capital of Sweden is Stockholm and the country has a low population density of 22 inhabitants per square kilometer. The highest urban concentration in the country is in the south and central parts, and the total population in the country is, in 2020 according to Statistics Sweden (Statistiska centralbyrån (SCB)), 10.3 million people (Statistics Sweden, 2020). Geographically, Sweden is connected to Denmark by a bridge-tunnel across Öresund in the south west, borders Finland to the north and east, and Norway to the north and west.

There are 21 regions and 290 municipalities in Sweden. All regions and municipalities are self-governed by local authorities that are responsible for different sectors and activities, which is why there are no hierarchical relations between regions and municipalities.

The main industries of Sweden today include telecommunications, industrial machines, motor vehicles, pharmaceuticals, etc. Sweden develops engineering, steel, and mining, as well as industries – e.g., Ericsson, ASEA/ABB, Alfa Laval, AGA – that are competitive on an international market. Sweden has also become known as a country with a large proportion of incubators and accelerators motivating entrepreneurs and tech startups and is also the home of unicorns and tech giants such as Skype, Spotify, Klarna, etc.

Sweden together with the Nordic countries have been early adopters of innovation and digital technologies and share, together with the Baltic countries, common goals concerning digitalization of which one objective is "a digital single market" (Nordic Co-operation, 2020). Sweden are by the European Commission (Europakommissionen) considered being one of the most digital economies in the European Union (EU) (European Commission, 2020). According to the Swedish Internet Foundation (Internetstiftelsen) Sweden is among the top three countries regarding advanced digital

economies, and among citizens of Sweden 98% have Internet connectivity at home, of which 91% use it on a daily basis (Swedish Internet Foundation, 2019).

The school system of Sweden is decentralized – thus there is a shared responsibility between national and local authorities concerning school where most responsibilities and decisions are taken on a local and school level. Not only decentralization but also different administrative systems on national levels affect how decisions concerning schools are taken and policies run.

School is compulsory up until grade 9, even though the majority of Swedish students continue through grades 10-12. There is a large proportion of both public funding, as well as public realization of education in the country. Compulsory school is free of charge, as are educational materials. The national administrative system of Sweden is similar to other Nordic countries in the sense of the relatively small size of the ministries primarily involved in strategic issues, complemented with semi-independent government agencies that carry out the plans and programs decided by the ministries.

The Swedish National Agency for Education and its equivalents in the Nordic countries have been instrumental in implementing different ICT policies and programs initiated by the government.

Since 1991, the school system of Sweden has been decentralized, and the national government responsibility for operation of schools is replaced with municipal responsibility. Nonetheless, of course, there is national legislation and inspection, and sometimes direct interventions, which results in a shared responsibility between national and local authorities concerning schools where most decisions are taken on municipal level and in many by delegation to school level. Sweden shares this decentralization and structure of shared responsibility between national and local authorities with other Nordic countries, where the role of the local authorities is to run school with state grants.

Norway was the first Nordic country to, in 2006, adopt digital competence as a basic skill in the national curriculum. Finland, Denmark and Iceland to various extents implemented national policies with the same objective. In Sweden "adequate digital competence", integrated into almost all subjects and consisting of four aspects, was implemented by the Swedish National Agency for Education (Skolverket) as a basic skill in the curriculum in 2016 (Swedish National Agency for Education, 2016). Just after, in October 2017, the Swedish Government decided on a national strategy for digitalization of the schools in Sweden. The strategy includes the notion of

"adequate digital competence", implying that this type of competence changes in relation to technology advancement and over time. According to Fransson, Lindberg and Olofsson, (2018);

> [I]t seems possible to describe the notion of 'adequate digital competence' as being both multi-layered and somewhat stretchable. It can be understood in relation to almost all aspects of education, and it offers a position that is not easy to contest. As such, 'adequate' places the enacting of a policy in the hands of different actors in the K-12 school system – the local school authorities, the school leaders, the teachers, and all other staff members who are involved in education. (Fransson, Lindberg & Olofsson, 2018 pp.225)

Sweden, together with the Nordic countries, have been some sort of forerunners concerning interest in - and use of ICT – in school. Still, despite different types of attempts, strategies and national initiatives schools in Sweden are still struggling to make digital technologies conducive for improved teaching and enhanced learning.

2.2 Evolution of ICT use in Swedish schools

Even though the first computers had already entered Swedish schools by the 1970s, the dissemination process within education and school was considerably slower in relation to the societal effects that the entrance of computers had on society overall (Hylén, 2011). Despite that very few schools had access to computers in the1970s, ideas of how the technology were expected to contribute to more individualized and independent learning arose and was also shown in research projects (Lindh, 1993).

The 1980 Swedish curriculum for grades 1-9 (Läroplan för grundskolan 1980 (Lgr 80)), marks the introduction of computer science. According to Söderlund (2000) the introduction of computer science in the curriculum was associated with individualized work for students but, as stressed by Hylén (2011), did not presuppose access to digital technologies in school. The addition of computer science in the 1980 curriculum was then not learning by using computers but rather learning about computers, as a result of only rarely having them at hand.

During the 1980s several initiatives from the Swedish Ministry of Education were made, reflecting an increased interest in how digital technology could and should affect education and schools in Sweden. The initiatives generally concerned the constellation of different groups working on behalf of the Ministry of Education but also at one time the initiative of producing a computer designed for school, namely the COMPIS, COMPuter In School,

which survived the competition from large international brands for only a few years (Hylén, 2011). In 1988 the Swedish Parliament decided on a three-year-long initiative called; computer and the school (Datorn och skolan (DOS)), which came to consist of: (i) centralized developmental work, (ii) regional developmental and experimental work, and (iii) co-operation between the Nordic countries in order to exchange pedagogical software between the countries (Hylén, 2011).

The project DOS, according to (Riis, 2000), despite a substantial amount of state and municipal funds did not have any specific impact on the actual teaching practice, to a large extent having been characterized by top-down thinking and not enough taking into account the teachers' experiences. One reason for this, stressed by Hylén (2011), was that digital technologies were merely used for traditional and ordinary teaching practice and not for changing or bringing efficiency to either the teaching- or learning processes. Despite governmental and municipal financial investments in IT during the 1980s, and despite a number of national initiatives from the Swedish Ministry of Education (Utbildningsdepartementet) in ICT during the 1980s the integration of digital technologies in pedagogy and transformation of teaching practice in the 1990s was still quite low (Riis, 2000).

In 1991, a decision in the Swedish Parliament (Riksdagen), stemming from a 20-year political discussion, was taken regarding decentralizing the school system. This significantly increased the responsibility of all municipal or independent organizer of school (municipal or private), small or large but also strengthened the possibilities for decision-making on a local level regarding school. In the same year the Swedish national agency (Skolöverstyrelsen) responsible for pre-, primary-, secondary- and upper secondary school, on behalf of the Swedish Ministry of Education (Utbildningsdepartementet) was replaced by a semi-independent government agency, namely the Swedish National Agency for Education (Skolverket). This new agency was to carry out the plans and programs decided by the Swedish Ministry of Education and was responsible for school-related issues, including ICT policies, on a public level but interfered less in school-related issues on local levels than its antecedent.

The decentralization increased the responsibility for school-related issues overall for municipal- and private organizers of schools in Sweden, but the Swedish National Agency for Education (Skolverket) was still to ensure that Swedish education held a good standard of quality. The Swedish National Agency for Education acts on behalf of the Ministry of Education (Utbild-

ningsdepartementet) and is, among other things, responsible for the establishment and revision of the curriculum, and for issuing certificates to preschool teachers and teachers. In order to maintain a high level of quality the Agency is to establish different national school development programs as well as in-service training of teachers. In 1992, a new school reform decided by the government opened up for so-called "charter schools". The reform, called the Independent school reform (Friskolereformen) meant that private, "independent" schools not owned by the state, county or municipality were allowed to conduct business in Sweden and enjoy financing by the municipality on the same terms as municipal schools. In the beginning the independent schools were not, in principle, bound to the curriculum, but this was changed in the 2000s.

Just a few years after the decentralization, in 1994, a new curriculum for compulsory school (1994 års läroplan för det obligatoriska skolväsendet, förskoleklassen och fritidshemmet (Swedish National Agency for Education, 1994). was launched by the Swedish National Agency for Education (Skolverket). This new curriculum was different from former ones, being significantly less explicit in its methodology and design, permitting teachers to decide the content of the teaching to a higher degree whilst aiming towards the objectives in the curriculum. In other words, the new Swedish curriculum of 1994 was different from previous ones and required a different kind of analysis of objectives as well as planning from the teachers.

This new situation of a decentralized school in 1991 and a new type of curriculum in 1994 affected the overall management from the principal organizer of schools, school leaders at each school, but also teachers at different schools, since the teachers now had the opportunity to more freely choose what content to put into the planning of the teaching but also responsibility to correctly interpret the curriculum. This also coincided with the beginning of the Internet era and an overall movement towards individualization, i.e., letting students plan their own time to a larger extent when learning, formalizing a development that had been ongoing since the curriculum in 1980 (Söderlund, 2000).

In 1995, around 2% of the Swedish population had Internet access in their home whereas 17% of the primary schools and 59% of the upper secondary schools had Internet access.

Stressed by Riis (2000) is that initiatives from the national policy level during the 1980s and 1990s was characterized by a top-down technology push, was costly and did not succeed to improve practice and use of digital technologies in pedagogy.

2.3 Teacher Training Programs

In 1999, a national policy-level project called "information technology in school" (ITiS, Informationsteknologi i Skolan), was initiated from the Swedish National Agency of Education (Skolverket) together with the Swedish Municipal Workers' Union (Svenska kommunalarbetareförbundet, popularly "Kommunal"). The objective was to increase teachers' digital competence and the pedagogical know-how to use the digital technologies in teaching practice. All participants in ITiS were equipped with a computer of their own, and 75,000 teachers were included in the training program, which continued for two years. The cost for equipping each teacher with a computer became the most controversial part of the ITiS (Hylén, 2011) but it marks a change as, for many teachers in Sweden, this was the first time they had access to a computer at work. In the ITiS program, teachers attended sessions arranged at each school together with their colleagues, discussing ICT and possible pedagogical use in teaching practice. The fact that a large proportion of students at this time still did not have access to digital technologies made it complicated for the teachers to practice what they theoretically discussed during the ITiS sessions.

Education policy of Sweden since the mid-1990s had been characterized by both the decentralization, the start-up of independent schools, i.e., private school financed by the Government, opportunities for students to apply to any school, and new approaches to evaluation and accountability. This all coincided with increased availability and use of the Internet as well as improved digital technologies in schools of Sweden (OECD, 2015b).

In the wake of the decentralization, decisions on how to address the increased need and use of digital technologies in school were now in the hands of municipal organizers of school/organizers of the independent schools and school leaders at each school. This opened up for companies such as Apple, Microsoft and Google to become impelling actors, now more actively approaching education and schools as potential customers. Other drivers for digital technologies entering schools in Sweden during these times were trade shows such as the British Educational Training and Technology Show (BETT) organized by ITE Group and first held in London, England in 1985. BETT became well-attended during the years by school leaders, teachers and politicians within the Swedish school sector. The Scandinavian Educational Technology Transformation (SETT) exhibition held in Kista, a Stockholm suburb and a center for Swedish IT industry, was held for the first

time in 2012. Educational trade shows and EdTech business became an integral part of ICT development in school during the beginning of the 2000s.

During the summer of 2001, the Swedish Ministry of Education (Utbildningsdepartementet) assigned an internal group to further develop, broaden and deepen the knowledge concerning ICT strategies in the Swedish school system (Swedish Ministry of Education, 2001). The report, submitted in May 2002, stressed the importance for Sweden to now move on from temporary ICT policies carried out in the form of projects towards continuous and regular activity, including in-service training and organizational change. A challenge, however, according to the report, would be for the decentralized municipalities to introduce necessary major organizational changes and locally make clear the costs and profits associated with, for example, investments in both digital technologies but also in-service training. The strategy proposed in the report to the Ministry of Education was therefore to support the municipalities in developing methods for describing costs and profits associated with the change. This support was to be given to municipalities and schools through the Swedish National Financial Management Authority called Ekonomistyrningsverket (ESV) together with the Swedish Association of Local Authorities and Regions (SALAR) and the Swedish National Agency for Education. The suggestions from the report, however, were never implemented.

One year after the report from the Ministry of Education was delivered, in 2003, a national authority for school development entitled "the Agency for school development" (Myndigheten för skolutveckling (MSU)) with the responsibility of supporting developmental work in the school-sector was initiated by the Swedish Government.

In 2006, four years after the last ICT project ITiS had ended, the MSU launched a national training program concerning the practical use of IT and digital media Practical Media and IT competence (Praktisk IT och Mediekompetens PIM) with the aim of strengthening IT competence among teachers in the country. PIM was a mandatory program for all teachers. Even though it was in line with the report from the Swedish Ministry of Education in 2002, suggesting the continuation of in-service training for teachers, the PIM program was (as the name reveals) more about the practical use of digital software than about pedagogical use and the integration of digital technologies into daily teaching practice. The PIM program was designed as course materials made available on a website where teachers could access texts, tutorials and assignments that, when complete, were sent

to PIM examiners. These PIM examiners were selected teachers from schools all over Sweden. Unlike ITiS, where teachers together in groups at each school discussed issues of teachers using their computers and other Internet-based resources in teaching practice, in PIM there was no collaboration taking place between the participating teachers. Instead, PIM focused on how to use e-mail, Windows, Excel, PowerPoint, and different types of multimedia. In order for local authorities to be able to sign up for the national PIM program they had to organize and pay for local examiners (often teachers trained by the national agency) but also decide on a reasonable schedule for the program to run in the municipality. The local authorities thereby had to show some kind of engagement, organization and local vision when signing up to PIM.

In 2008, the Swedish Parliament decided on a new organizational structure for the school sector where MSU, which had been responsible for PIM, was now no longer an authority but incorporated into the Swedish National Agency for Education.

By 2014, when the PIM project was finished, 150,000 teachers from 230 out of the 290 municipalities in Sweden had been registered in the training program – at that time, together with ITiS, one of the larger teacher training programs in Sweden.

2.4 One to one (1:1) in Sweden

The non-profit global initiative One Laptop per Child (OLPC) of Nicholas Negroponte, or 1:1, was announced in 2006 and aimed at producing educational, digital devices and software for the least developed countries (LDCs). The primary goal of OLPC was to enable children in LDCs to have access to content, media and computer-programming environments. The OLPC was praised for pioneering low-cost computers, and the original OLPC computer was later followed by commercial products such as Chromebooks, but criticized in regard to ignoring the high total costs, a lack of focus on maintaining the digital devices, not emphasizing training and finally its limited success.

During approximately the same period as PIM (2009-2014) the OLPC had become well-known and frequently discussed in Sweden and, by 2013, schools in as many as 250 out of 290 Swedish municipalities had already started or at least planned for OLPC (Grönlund, 2014), or as it came to be known as, one-to-one computing (1:1 for short). Even though Sweden already had a relatively high computer-to-student ratio compared to other European countries, 1:1 demanded twice as many computers in secondary

school (school years 10-12), four times as many in K12, upgraded Wi-Fi, as well as the support of digital systems and structures, etc. (Grönlund, 2014). Håkansson Lindquist (2015) shows that in 1:1 initiatives, clear policy directives – i.e., explicitly expressed directions in the curriculum – are of importance, as is the continuous professional development for teachers and school leaders. This aligns with the results from the Swedish collaboration project "Unos Uno" (Latin for one-to-one) aiming to study the challenges with 1:1, which involved the Swedish association for local authorities and regions, 11 municipalities, and one university. The results of the Unos Uno, published by Grönlund (2014), showed that five areas had to be approached and developed in order to gain improved learning and results among students involved in 1:1. The areas concerned: digital literacy among teachers; shared pedagogical resources; digital, unitary platforms for learning; that computers were used for enhanced learning and not as a substitute for teachers; and competent school leadership with a clear vision and a long-term perspective.

Initiatives such as 1:1 led to some municipalities and some schools quickly increasing their access to digital technologies. This, however, was not the case for all of them, and Sweden still had no overall national policy or strategy clearly pointing out the direction for the digitalization of school. The result was that some of the municipal organizer of school (as well as independent ones) established regional and/or local action plans for managing the purchase, implementation and technological support of the technology, whilst others did not.

2.5 Swedish Policies Guiding ICT Use in Schools

As mentioned in this chapter, the Swedish Government (Regeringen), from the 1970s up until the 2000s, through both the Parliament (Riksdagen) and the Ministry of Education (Utbildningsdepartementet), introduced a number of ICT policy initiatives on a national level, of which the largest in terms of the number of participating teachers were ITiS and PIM. Up until the 2000s Sweden, along with the Nordic Countries, the Netherlands and the UK, was a European frontrunner concerning the amount of ICT use in school (digitization). At that time, however, this was not the effect of a national effort, but rather a number of local ones. The Swedish decentralization of the school sector in the 1990s, together with a lack of alignment between overall Swedish national ICT strategies and plans for ICT in education resulted in local authorities – by that time municipal and independent organizer of school – and sometimes individual schools taking action by

themselves. Overall, this opened up new business opportunities for the IT industry in Sweden, which expanded their business idea from a focus on selling digital hard- and software to also offering training for teachers and school leaders. Differences regarding financial conditions but also concerning digital competence among municipal organizers of schools in the 290 different municipalities, among organizers of independent schools but also among school leaders at each school and among the increasing numbers, led to increased inequality within- and across schools all over Sweden (Samuelsson, 2014).

In around the same period of time when schools in Sweden rapidly became increasingly digitized, the OECD's Programme for International Student Achievements (PISA) report, measuring literacy, math and natural science among 15-year-old students, showed declining results among Swedish students.

PISA is the world's largest study regularly measuring the results from both students within and outside the OECD. The PISA tests have been questioned for not being theoretically based on any explicit, systematic or documented framework. Still, they can serve as some point of reference and also as suggested by Håkansson & Sundberg (2016) for comparing one school system with another. PISA has certainly gained considerable attention from politicians and the media and has been an authoritative input in the Swedish school debate over the years. The declining PISA results for Swedish students, especially in the 2009 and 2012 measurements (Swedish National Agency for Education, 2020; OECD, 2010; OECD, 2012) left few of those active in the school sector unaffected and there was great national concern regarding possible underlying factors to the decreasing results. Or as put by OECD (2015a) in the report; Improving schools in Sweden: An OECD Perspective;

> Education is a public priority in Sweden. The country is committed to a school system that promotes development and learning for all students and nurtures their desire for lifelong learning. But student performance on the Programme for International Student Assessment (PISA) has declined dramatically, from near the OECD average in 2000 to significantly below the average in 2012. No other country participating in PISA saw a steeper decline than Sweden over that period. These disappointing results fuelled a national debate on the quality of school education, leading to a broad consensus on the need for change. (OECD, 2015a p. 7)

In 2015 the results improved somewhat, back to the level of 2009, but still it was clear that there was a need for research-based knowledge regarding how digital technology in school could affect student learning and results. Even though there are some existing research-based studies of the effects from using ICT in the context of school and learning, most of these are on a small-scale basis (Cuban, 2013), seldom sustainable (Toh, 2016), and only used in order to replicate existing practice in school (Glover et al., 2016). The comprehensive analysis of the PISA results by McKinsey (2017) show, unsurprisingly to researchers but challenging to the strongly pro-technology public debate, that the effect of technology in school on PISA results is not straightforward but can yield widely differing results depending on how it is aligned with teaching processes.

In June 2017 the Swedish Government decided on a national digital strategy named; For sustainable digital transformation in Sweden – a Digital Strategy (För ett hållbart digitaliserat Sverige – en digitaliseringsstrategi). (Government Offices of Sweden, 2017a). The strategy outlines the government's vision for sustainable digital transformation in Sweden and the overall objective is that Sweden is to become world-leading in harnessing the opportunities of digital transformation.

Four months later, in October 2017, the Government also published a digital strategy for the school sector named; A national strategy for digitalization in the school sector (Nationell strategi för digitalisering av skolväsendet). (Government Offices of Sweden, 2017b), since the non-equivalence between schools, students and teachers all over the country was now both a fact and an increasing problem. The national digital strategy for school comprised three focus areas: Digital competence; Digital infrastructure and use; and Research and development, and included overall goals to be reached at the latest by 2022. Moreover, the national curricula for compulsory and secondary school were revised to include digital aspects and specific goals in certain subjects such as programming and coding, mandatory to start in 2018 (Swedish National Agency for Education, 2011). In a following report from 2019, the Swedish Schools Inspectorate (Skolinspektionen/SSI), reported schools' compliance with the new revised curriculum in (2018) according to the goals for digitalization in mathematics and technology. The results showed that only a minority of the inspected schools fulfilled the requirements for digitalization. For the majority of the schools the SSI reported a lack, often even an absence, of use of digital tools in the classroom as well as a lack of digital competence among both teachers and

school leaders. The most striking finding was a lack of digital competence and overall leadership of digitalization among the municipal and independent organizers of school (Swedish Schools Inspectorate, 2019).

The SSI findings confirm that, aside from the two national efforts regarding teacher training, ITiS and PIM, the focus of municipal organizers of school/organizers of the independent Swedish schools has mostly been on the hardware itself – that is to say, digitization – and less on the use and least on a systematic implementation process among users and in work procedures, that is digit*al*ization.

This lack of focus on digitalization is, according to the OECD (2018), an issue of the lack of national leadership. Despite the good access to digital technologies in Sweden and the national strategy of digitalization in 2017, according to the OECD (2018), Sweden suffers from a lack of coordination and national leadership. The OECD (2018) report therefore calls for stronger leadership and, as stated by the Director at the OECD Directorate for Science, Technology and Innovation, Andrew Wycoff in an interview in Computer Sweden; "It is now time for the Swedish Government to begin conduct the orchestra" (Computer Sweden, 2018).

2.6 Educational perspectives and Digital Technologies

Over more than half a century, different paradigms, learning theories, assumptions and perceptions, together with the inception of digital technologies in school, have influenced the development of software and programs but also notions, debates, educational policies, pedagogical practice and expectations of technology use in school. This section serves to situate the thesis work within the context of learning paradigms, different educational perspectives, and practices contemporary with the development and increased use of digital technologies in education.

Nicholson (2007) provides an overview of the evolution of educational technology between the years 1975 and 2005, as shown in (Table 1).

Table 1 The changing focus of educational technology (Nicholson, 2007)

Period	Focus	Educational characteristics
1975-1985	Programming; Drill and practice; Use of educational software, e.g., Computer-Assisted Learning (CAL)	Behaviorist approaches to learning and instruction; programming to build tools and solve problems: local user-computer interaction
1983-1990	Computer-Based Training; Multimedia	Use of older CAL models with interactive multimedia courseware: Passive learner models dominant: Constructivist influences begin to appear in educational software design and use
1990-1995	Web-based training	Internet-based content delivery; Active learner models developed; Constructivist perspectives common; Limited end-user interactions
1995-2005	E-learning	Internet-based flexible courseware delivery; Online multimedia courseware; Increased interactivity; Distributed and constructivist and cognitivist models common; Remote user-user interaction

In order to include the starting period of educational digital technologies in the 1960s and the evolution from 2005 up until 2020 I extend the table of Nicholson (2007) in time based on other research in the field, including among others Cooper (1993); Charp (1997); Schunk (2012); and Bottino (2020), to broadly describe over time changing focus in learning paradigms and educational technology from the 1960s until 2020. Table 2 provides an overview, which is explained in the following four subsections.

Table 2 Educational technologies and learning paradigms

Era	Focus	Educational characteristics
1960s and 70s **Technologies for drill and practice**	Programming; Drill and practice; Programmed Instruction (PI); Use of educational software, e.g., Computer-Assisted Instruction (CAI); Arrival of the Personal Computer (PC); Computer-Assisted Learning (CAL);	Behaviorism, drill and practice; Conditioning theories; Programming to build tools and solve problems; A movement towards cognitivism and constructionism (a constructivist theory and theory of instruction)
1980s **Technologies for cognitive learning**	Computer-Based Training; Multimedia; Artificial Intelligence (AI) in educational software	Cognitivism, opening of the 'black box'; Focus on internal information processes; Constructivist ideas starts to appear in educational software
1990s-2010s **Technologies for constructive learning**	Web-based training; Open Educational Resources (OER), open source and free sharing E-learning Mobile learning/M-learning comprises learning through multiple contexts and social interactions;	Constructivist approaches more common. Development of social constructivism and active learner models; Internet-based content delivery; Limited end-user interaction Distributed constructivist and cognitivist models common; Increased interactivity; Remote user-user interaction; Online multimedia courseware
2010s-2020 **Technologies for Enhanced Learning**	Gamification; Learning Analytics (LA); Technology-Enhanced Learning (TEL)	Social constructivism common; Participatory Environments including most modern educational technologies referring to constructionist principles

Overall, educational paradigms and learning theories have shaped pedagogical practices (Schunk, 2012), but also the focus and development of a number of software instruction and learning programs (Nicholson, 2007). Educational software was originally intended to describe educational material for teachers or as tutorials for students and is also called 'courseware'. Around 60 years ago, when computers were first introduced into the field of education, a computer was more an object to study than a tool for education. It was primarily used to learn algorithmic languages and programming and the teaching material often did not require access to a computer (Charp, 1997). Companies such as IBM and Hewlett-Packard soon foresaw the potential market of education and, for example, introduced the IBM 1500 in 1966, involving a computer, a film projector and an audio recorder. The first production was sent to Stanford University in 1967, but as a result of it being too expensive and with less developed courseware it was not a success and was taken off the market only a few years later. A number of early attempts at using computers for instruction in education failed due to reasons such as: the computers were too expensive; the projects were conceived as research and mostly ignored by the education community; the existing hard- and software did not allow for quality designed courseware, which resulted in teachers not being interested in using it; a fear of that computers would replace teachers antagonized the teaching profession; support from the education community was more or less non-existent; and innovators received no or little attention from the faculty members of education (Charp, 1997). The development of both hard- and software has, since the inception of computers in education, been shaped by both time and different learning theories, but several of the obstacles stressed by Charp in 1997 are unfortunately still relevant today.

A variety of concepts for describing digital technologies developed and used for educational purposes have over the years been extensively used, although differences in how they are defined complicates the understanding of what they mean and include. There is, for example, no single agreed-upon definition of the concept of E-learning, which is widely used within different areas and has evolved differently in the fields of, for example, education, business and the military.

2.6.1 Technologies for "drill and practice"

Patrick Suppes and Don Bitzer, two pioneers of E-learning had, already by the 1960s, situated the use of digital technologies within an educational agenda (Nicholson, 2007) and Suppes (1966) predicted that all students, in

the future, and by the use of digital technologies would have their own individual tutor. This expectation – and fear – of disruption and replacement of teachers in favor of digital technologies has since it emerged in the 1960s influenced the discussion and is apparent still today. Don Bitzer created the timesharing system Programmed Logic for Automatic Teaching Operations (PLATO), used in the US and Europe (Charp, 1997) that was discontinued relatively soon but became an ancestor of today's E-learning platforms and the forerunner of today's conference systems (Nicolson, 2007). Suppes developed a Computer Managed Instruction (CMI) system that was used in higher education but also provided elementary school with individual CMI tutorials, used as a supplement to teacher instruction.

The work of Suppes, Bitzer and contemporaries was influenced by prevailing psychological paradigms of its time, e.g., behaviorism, primarily based on "drill and practice" defined by Lim, Tang, and Kor (2012) in the Encyclopedia of the Sciences of Learning as;

> The term *drill and practice* is defined as a method of instruction characterized by *systematic repetition* of concepts, examples, and practice problems. Drill and practice is a *disciplined* and repetitious *exercise,* used as a mean of teaching and *perfecting* a *skill* or *procedure*. As an instructional strategy, it promotes the acquisition of knowledge or skill through systematic training by multiple repetitions, *rehearse*, practice, and engages in a rehearsal in order to learn or become proficient. Similar to *memorization*, drill and practice involves repetition of specific skills, such as spelling or multiplication. (Lim et al., 2012 p.1)

Argued by Suppes was that individualized education through computers was the future but also the challenge. The results of Suppes' software program Computer Assisted Instruction (CAI) can according to Cooper (1993) briefly be described as instructing a learner on a one-to-one basis with interaction and turned out to be inconclusive and contested but led to suggestions for improved teaching. Contemporary critiques, stressed by Nicholson (2007), however, overlooked the lack of viable alternative paradigms and argue Suppes' awareness of the limitations, since he predicted that the impediments for CAI were not technical but pedagogical. Today, sixty years later, this early prediction of challenges associated with technology use in pedagogical settings are still relevant.

The arrival of personal computers (PCs) in 1975 changed the field of software since, before this, users were primarily dependent upon computers owned by universities or governments. The availability of PCs, e.g., the

Commodore PET in 1977, opened up for EdTech (Educational Technologies) business, which also in turn had implications for the development of educational software. Main challenges, according to Cooper (1993) though was challenges in improving the quality of the software alongside with implementing the EdTech educational software into teaching- and learning practice. This, partly stressed already by Suppes (1966) and later argued by Cooper (1993), aligns with Riis (2000) stressing that teachers and school leaders in Sweden during the 1980s and 1990s did not think digital technologies improved or changed the teaching practice in any other way than moving practice towards increased individualization.

During the era of the 1960s until the 1980s, behaviorism was the prevailing paradigm (Table 2), e.g., CAI, Computer Assisted Learning (CAL) and other similar software and programs thus applied to a behavioristic approach to learning and instruction based upon the assumption of stimuli and response applying "drill and practice" (Nicholson, 2007). During this time conditioning theories, based on the assumption of behavioristic ideas dominated the psychology of learning, explained learning in terms of external, environmental activities and through associations between stimuli and responses (Schunk, 2012). Skinner's learning theory, operant conditioning is well known in the area of education since its inception in 1938 and holds the assumption that "features of the environment (stimuli, situations, events) serve as cues for responding" (Schunk, 2012 p. 114). Behaviorism explains behavior as a response (behavior) to external stimuli (inputs), which in turn is related to either reward or punishment. Principles from behavioristic ideas and operant conditioning models have been, and still are, applied in different contexts of teaching and learning, and thereto in different EdTech software (Nicholson, 2007). In terms of software applications of today, used either for entertainment or for learning purposes, these types of behavioristic ideas is operationalized e.g., through activities of the type where the correct answer gives the learner access to the next and desirable higher level or are given some sort of reward in the form of applause, stars or similar.

The generality of the behavioristic principles started to be challenged already in the late 1960s by cognitive theorists, arguing that ignoring cognitive processes – e.g., viewing minds and thoughts like Skinner's the 'black box' (1974) – offers an incomplete explanation of human learning (Schunk, 2012). Early software-based technology instructional programs, e.g., Programmed Instruction (PI) derived from a behavioristic approach and were used to teach segmented content based on tasks aiming to develop stimulus-

response behavior. Numerous studies have shown the effectiveness of instructional software based on behavioristic assumptions in general but particularly the use of feedback. The quality of the feedback is, however, crucial and feedback only providing scarce indications of correct/incorrect response performs fairly poorly (Cooper, 1993).

The criticism towards behavioristic ideas and a shift towards new theories with assumptions of cognitivism and constructivism came to influence practice in both instruction and learning in many ways and today major theoretical perspectives stem from the view of cognitivism and constructivism (Schunk, 2012).

To different extents, and contested by some, cognitivism and foremost social constructivism have come to influence the design of software. Still, fundamental behavioristic attributes of stimuli and response, operationalized through activities promoting "drill and practice" and characterized by repetition until learning is mastered today often influence both the design and use of EdTech software in schools.

2.6.2 Technologies for cognitive learning

Unlike behaviorism, cognitivism focuses on internal processes involved in learning, arguing for the "black box" to be opened. Social cognitive learning theory has the assumption that learning can be described as some sort of information-processing activity. According to social cognitive theory individuals can learn to set goals and, by self-regulation of behaviors, emotions, cognitions and environments, promote achieving the set goals. Unlike conditioning theories arguing that cognitions could accompany, but not influence, behavioral change, cognitivism views learning as an information-processing activity where behaviors resulting in positive consequences are retained (and vice versa).

Alternative approaches to behaviorism, first cognitivism and later constructivism, emerged during the 1980s (Table 2). From the perspective of social cognitive theory, cognitions (e.g., the mental process of learning through the mind, experience and senses), more than consequences affect learning (Schunk, 2012).

According to Cooper (1993), along with the movement from behaviorism towards cognitivism (from an external to an internal view) in designed instruction a need to include individual differences emerged. This in turn required extensive development of existing software, e.g., intuitive interface pushing the development towards graphical user interfaces leading to, among other things, increased hardware capacity (Cooper, 1993). During

the 1980s, artificial intelligence (AI) in educational software systems, was used for the development of educational software systems in digital courseware. Early attempts to create cognitively based designed instruction, however, used non-sufficient tools (Cooper, 1993; Charp, 1997;) and only later would programming and EdTech instructional design make possible the development of tools more in line with a cognitive view of learning (Cooper, 1993).

Thus, the shift towards increasing interest in cognitivism and constructivism seems to have included not only an acceptance of the assumptions of the new learning theories, but also pushed the development of technology to the more complex development of both hard- and software.

The era of cognitivism and internal views of learning is also traceable in the Swedish curriculum 1994 (Swedish National Agency for Education, 1994), which is much less explicit in its methodology and design than its predecessors. Rather than strictly prescribing, it allowed teachers to a greater degree decide the content of the teaching whilst aiming towards the objectives in the curriculum. This period also coincides with the Internet era, increased use of digital technologies in school and an overall movement towards individualization, which meant giving students greater autonomy to plan their own time when learning (irrespective of access to - and/or use of - digital technologies). This revised curriculum reflected a development in pedagogical thinking that had been ongoing since the curriculum in 1980 (Söderlund, 2000). Computer based training (CBT), is a type of Computer based instruction where the primary source of delivery is a computer. The use of CBT increased during the 1980s, delivered either by EdTech software installed on the computer or increasingly over the Internet as a Web based training. The use of Multimedia, in the form of text, audio, images or video increased during this time which e.g., came to form the content in teacher training programs like the Swedish PIM (see 2.4).

Viewing learning as an internal information-processing activity entailed changes in instructional design methodology as well as appropriate programming tools to accompany the theory of cognitivism.

2.6.3 Technologies for constructive learning

The 1990s included a shift towards constructivism in pedagogical focus and coincides with increased interest and access to digital technologies and resources such as; Web based training, Internet based Multimedia resources, Open Educational Resources (OER). Further development of EdTech software influenced the use of digital technologies in education. The concept

"E-learning", is during this time increasingly used and interpreted in various ways. According to Andersson (2010); "The term e-learning has become an overall term covering most forms of education where ICT is involved and where there is a distance between the learner and the teacher" (Andersson, 2010 p. 22).

The access to mobile devices now also becomes more common and 'mobile learning' more commonly used. Mobile learning, in the same way as E-learning, comprises learning in multiple contexts but with the involvement of mobile techniques, or as put by Traxler (2005);

> Mobile learning can perhaps be defined as 'any educational provision where the sole or dominant technologies are handheld or palmtop devices'. This definition may mean that mobile learning could include mobile 'phones, smartphones, personal digital assistants (PDAs) and their peripherals, perhaps tablet PCs and perhaps laptop PCs, but not desktops in carts and other similar solutions. (Traxler, 2005 pp. 262)

As stated by Viberg (2015) " The meaning of mobile learning has evolved during the last years" and "As yet, there is no definite and widely accepted definition of mobile learning" (Viberg, 2015 p.23).

In the 1990s constructivist perspectives became more common and in the beginning of the 21st century the dominant educational schools of thought were the constructivist and social constructivist paradigms of learning, focusing on processes together with interactions (Hung, 2001; Schunk, 2012).

The assumptions of constructivism are that reality is personally constructed, rather than acquired and that personal experiences determine reality instead of the other way around. As put by Cooper (1993);

> The move from behaviorism through cognitivism to constructivism represents shifts in emphasis away from an external view to an internal view. To the behaviorist, the internal processing is of no interest; to the cognitivist, the internal processing is only of importance to the extent to which it explains how external reality is understood. In contrast, the constructivist views the mind as a builder of symbols – the tools used to represent the knower's reality. (Cooper, 1993, p. 16)

In Sweden constructivist perspectives not only affected curriculum or practice in schools but also the national policy-level project concerning information technology in school "Informationsteknologi i Skolan" (ITiS) with the objective of increasing teachers' digital competence and the peda-

gogical know-how to use the digital technologies in teaching practice. Unlike PIM, focusing on increasing teachers' skills in practical use of Multimedia resources through individual, web-based assignments, ITiS more in line with constructivism focused on learning processes involving collaboration among peers. In ITiS teachers attended sessions arranged at each school together with their colleagues, discussing ICT and pedagogical use in teaching practice although with limited possibilities to practice what they learnt, since only the teachers and rarely the students had access to digital technologies.

2.6.4 Technologies for Enhanced Learning

The development of hardware and online multimedia courseware, in combination with increased interactivity, remote interaction and increasing integration of AI since the millennium has affected the notion and focus of digital technologies in educational settings. Gamification, here referred to as when using educational games as tools for learning, becomes an emerging trend in the early (Dicheva, Dichev, Agre and Angelova, 2015). During around the same period of time the development of e.g., online multimedia courseware opened up for collecting and processing data and an emerging field of "Learning analytics" (LA) in education which is defined by the Society for Learning Analytics Research (SOLAR) as, "Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (SOLAR, 2020).

The concept of "Technology-Enhanced Learning" (TEL) increasingly subsumes the older concept of E-learning (Table 2) but, in the same way as E-learning, TEL does not have one universally agreed upon definition or explicit statements of what it is understood to mean. Instead, both concepts are differently interpreted and widely used in a variety of meanings and settings, and, as argued by Kirkwood, A. and Price, L. (2014), it is not evident that a shared understanding of what *enhancement* of the learning constitutes. Clearly, it is not tied to any one specific pedagogic theory.

Concepts used for describing technology are often formed based on characteristics of the technology itself. "Multimedia" is one such example, where there is no link to the field of application. It is used in educational context, but also in any other context. One of the positive aspects of the concept of TEL, for the purposes of this thesis, is that it is technology-neutral and clearly states a purpose related to teaching and learning. Evidently, "enhancement" is not clearly defined, but that is also a positive characteristic

because it means it is up to professionals in the education sector to discuss and define progress and enhancement. This is arguably an improvement compared to the earlier commonly used "E-learning" which can be interpreted as an undue technological imperative – it may give the impression of there being some difference between "learning" and "E-learning". In the view of this thesis, learning takes place within people, alone or in interaction with other people, and with or without technology.

The movement from the learning paradigm of behaviorism in the 1960s, towards cognitivism and further on constructivism brings during the 1990s and 2000s, according to Nicholson (2007), with it increased adoption of constructivist paradigms in the fields of educational and software training applications. This alleged relationship between constructivism and more newly developed software is though contested and argued by e.g., Gance (2002) arguing that the call for increased use of digital technologies is often justified by the potential to support constructivist approaches but that "the facile association of computer based educational technologies as inherently constructivist cannot be sustained" stressing that a large proportion of educational software rather is "retrograde in the sense that they largely incorporate behaviorist or information transfer strategies that are antithetical to a constructivist philosophy" (Gance, 2002, p. 1).

The expectations from – and fear of – digital technologies to revolutionize teaching and learning through individualization and even replacement of the teacher emerged early on and has surrounded the debate around technology use in education. This discussion has been fairly constant and ongoing during the same time as the increased attention of, and interest in, constructivism. Despite the alleged trends in EdTech educational software towards constructivism, behaviorist attributes are still common in different software based instructional applications, either in the form of small parts of material or more obvious. Since numerous studies have shown the effectiveness of instructional software based on behavioristic assumptions (Cooper, 1993), this is neither surprising nor a problem so long as the teacher has consciously selected the courseware with a certain purpose. A conscious use of digital technologies for improved teaching and learning thus requires knowledge of which type of learning assumptions (e.g., behavioral, cognitivist, constructivist) and instructional design the software applications in question are based upon, thus if, how and when to use it when designing TEL environments.

Argued by Kirkwood et al. (2014), is that the potential for digital technologies and TEL to transform both teaching and learning "does not appear to have achieved substantial uptake, as the majority of studies focused on reproducing or reinforcing existing practices" (Kirkwood et al., 2014, p. 24). This lack of using the potential of digital technologies by merely adding it to already existing practice without transforming ordinary work is also stressed by, for instance, Glover et al. (2016).

2.7 My research and Educational Technologies

It is my belief that teaching and learning are crucial components of one another. Therefore, my research addresses both of them through the design of a scientifically based ICT-supported pedagogical model used by teachers to (according to the objectives in the curriculum) plan, carry out and evaluate both their design of instruction and learning activities as well as the learning results among their students.

In order to make the best use of existing digital technologies in school it is important for digital technologies to support both teaching and learning. However, in my view, the use of digital technologies in education, in the same way as analogue teaching material and other practical tools for learning, deserves to be thoroughly planned, designed, used and evaluated by the teacher. Hence, the teacher needs to possess knowledge of how to apply digital technologies according to the purpose and design of different teaching and learning activities.

With the historical backdrop of different educational perspectives and practices contemporary with the development and increased use of digital technologies in education, this research has a starting point in the ideas of constructivism. The concept of technology-enhanced learning fits well with constructivism as the constructivist teacher prefers to use different technologies as necessary to enhance learning in different ways during the course of student progress in learning. This means technology is considered as not just enhancing learning, but also teaching.

The artifact designed in this research is intended to improve teaching and enhance learning among younger students through using different digital technologies in order to create learning environments where technology fits in smoothly and purposefully with the physical activities in the classrooms. The method I constructed and tested, the "Write to Learn" (WTL), is based on social constructivism. It draws on the idea that we learn together in a social context, and uses technology to enhance that learning context in cer-

tain ways. WTL aims to support teachers in how to apply digital technologies in both instruction and design of practice but also in how to specifically design learning environments for improved teaching and enhanced learning.

3. Theoretical foundations

In this thesis a number of theoretical frameworks and models have been used in different stages of the research process. The overarching theoretical perspective is framed within the field of information systems (IS) and uses the concept of the IS artifact of Lee, Thomas, and Baskerville, (2015) as the conceptual background. Methodologically it follows the Design Science Research (DSR) approach (Vaishnavi & Kuechler, 2008) to design, disseminate and test the IS artifacts of this thesis. For analysis of the dissemination, Rogers (2003) theory of Diffusion of Innovations (DOI) is used.

Since the IS artifacts designed, used, tested and disseminated in school aims to learn more about how to improve the use of digital technologies in the complex context of teaching and learning, this thesis is underpinned by social constructivism and draws on socio-cultural theory (SCT) developed from the work of Vygotsky (1962; 1978). In this chapter I provide an overview of the theories used in the research and how they are used in the different parts of this thesis.

3.1 IS artifact theory

Central to the IS field is design, where the outputs are defined as artifacts of some sort (March & Storey, 2008). In order to bring design activities into science, Simon (1996) distinguishes between natural science and the "science of the artificial". The first is the body of knowledge of natural objects or phenomena and how they interact, whereas the science of the artificial is the body of knowledge of artificial phenomena, artifacts, designed for certain goals. More specifically, Simon (1996) divides sciences of the artificial into an inner/outer environment and the interface between meeting both desired goals. The outer environment refers to the various factors in the use situations that affect the artifact whereas the inner environment is the different parts, and relationships between these parts, constituting the artifact. Therefore, the behavior of the artifact depends upon both the relationships and organization within itself and its outer environment. Considering design as the very crafting of an interface between inner and outer environments Vaishnavi and Kuechler (2008) propose that design research can be looked upon as the know-how for implementing an artifact satisfying a set of functional requirements.

This thesis utilizes the Information Systems Artifact (ISA) theory, advanced by Lee et al., (2015). The ISA is based on the theory; The Sciences of the Artificial by (Simon, 1996) and hence focuses on artifacts and their

designs. The addition made by ISA concerns the view of information and communication technology as comprising three separate but intrinsically interlinked subsystems: (i) the technology artifact, (ii) the information artifact, and (iii) the social artifact. The IS artifact is greater than the sum of its parts and where the technology artifact no more than any of the other predominates the design of the IS artifact. The three subsystems can be analyzed separately but in order to fully understand the role of IT use in processes where it is applied, they must also be analyzed together.

As defined by Lee et al. (2015, p. 5);

1. The technology artifact (also called IT artifact) is a tool, created for the purpose to either "…solve a problem, achieve a goal or serve a purpose that is human defined…".
2. The information artifact is "… an instantiation of information, where the instantiation occurs through a human act […] either directly or indirectly".
3. The social artifact "consists of, or incorporates, relationships or interactions between or among individuals through which an individual attempts to solve one of his or her problems, achieve one of his or her goals or serve one of his or her purposes. We describe this artifact as social because relationships and interactions involve more than just one person; hence, they involve the social, not just the individual."

Aiming to promote a broader use of the DSR methodology and in order to be able to study different kinds of artifacts, Lee et al. (2015) seek to "liberate IS design from the IT artifact-centric perspective" (p.25) and suggest that design within IS should not only focus on the technology artifact but also on the design of the entire IS artifact. The division of the IS artifact into subsystems of technology, information and social aspects does not imply any hierarchy between the subsystems. The ISA conceptualization matches the situation in schools well, as digital technologies need to be thoroughly integrated into, and support, different information and social learning contexts that occur during different phases in education. Moreover, as stressed by Lee et al. (2015) and important to this thesis is that distinguishing the subsystems from each other according to the definitions in the IS artifact theory enables both clearer descriptions of each artifact and analysis of the interdependence and interaction between them in together forming the IS artifact.

3.1.1 The IS artifacts within this research

Here, an overview is provided of how the IS artifacts Write To Learn (WTL) and Teachers' Formative Assessment Learning (TFAL) within this research is comprised and theoretically applied to the definition of IS artifacts defined by Lee et al. (2015) whilst a more in-depth and practical description of the elements of the artifacts and iterative DSR process is presented in chapters 4 and 5.

Both IS artifacts in this research, in accordance with the definition of Lee et al. (2015), comprises the three subsystems; technology, information and social, all equal to and interdependent on, each other. Hence, the IS artifacts designed within this research are a mix of the following;

- A set of technological components used by teachers, school leaders and students in different teaching and learning contexts
- A system for handling information and documentation related to different learning activities
- A social system, comprising different parts and activities used for enhanced teaching and learning

Table 3 summarizes how the IS artifacts, WTL and TFAL, within this thesis applies to Information Systems (IS) artifact theory by (Lee et al., 2015), (3.1) and to the elements of diffusion according to Diffusion of Innovations theory (Rogers, 2003), (see 3.4).

Table 3 IS artifacts of this thesis and their relation to DOI

Artifact	WTL	TFAL
Technology artifact	An effective educational setup of digital technologies for student and teacher use (computers, tablets and cloud based digital environments	Teachers' digital technologies (computers and tablets), discussion forums, website
Information artifact	Templates for digital classrooms, websites, documents, checklists for formative assessment	TFAL course site, digital information documents, digital templates used for analyses, etc.
Social artifact	The WTL teaching process method	TFAL process design, including learning goals and methods and providing an extended social system
Element of DOI	The Innovation	The Channel and the Social system

3.1.2 The Write to Learn artifact

The technological, informational and social artifacts are comprised and designed so that they all interact with, and contribute to, each other – thus together contributing to the fulfilment of the IS artifact Write To Learn (WTL).

The set of technical components, defined as the *technological artifact* in the IS artifact WTL, is represented by an effective educational setup of digital technologies for student and teacher use (computers, tablets and cloud based digital environments) in the form of: i) hardware – e.g., computers, tablets and interactive whiteboards, but also ii) cloud-based software – at that time Google Apps For Education (GAFE), later on named G Suite and today known as Google Workspace. The cloud-based resources included different digital spaces and arenas for interaction, collaboration and feedback among teachers, students and school leaders.

The system for handling information and documentation, defined as *the informational artifact* in the IS artifact WTL, is represented by the structured design of teacher instruction and different types of assignments and work by the use of templates for digital classrooms, websites, documents, checklists for formative assessment.

The WTL cycle/teaching process, defined as the *social artifact* in the IS artifact WTL (also the WTL pedagogical method) is designed with the backdrop of the socio-cultural theory of Vygotsky (1962; 1978) and represented through a pedagogical teaching- and learning methodology comprising different parts and activities supported by digital technologies for technology enhanced teaching and learning. WTL is designed by the concept that learning is an active process which is also not just an individual matter but also develops within a social context. The social artifact, in the form of WTL, seeks to increase the effect of key factors for learning, e.g., socio-cultural learning and formative feedback through deeply integrating a set of technical components, i.e., the technology artifact and structured learning contexts and environment, i.e., the informational artifact and by that making the best possible use of digital technologies in school. The WTL cycle (Figure 2) supports teachers integrating digital technologies in pedagogy by comprising six parts; starting from thorough information to students concerning which objectives in the curriculum chosen by the teacher to reach by following instruction and assignments, thereafter going through each step in the cycle. The WTL cycle and teaching process comprises both physical and digital; information, instruction, assignments, social interaction formative feedback both between teachers and students as well as between peers and publish of final products on digital class

sites. The WTL cycle (Figure 2), and teaching process, is used as a supportive method by teachers before, under and after lessons and learning activities, further on elaborated in 5.1.4.

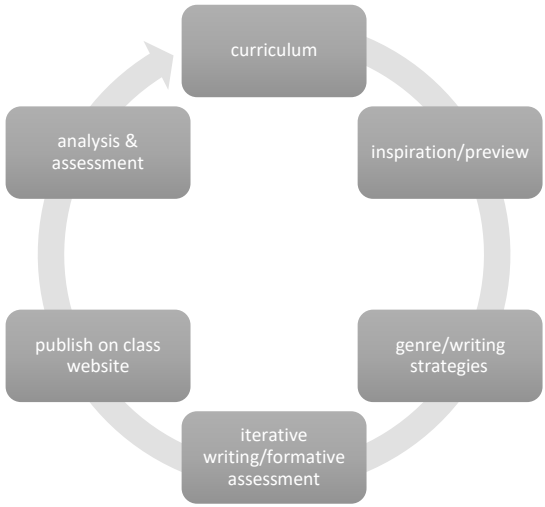

Figure 2. *The Write To Learn (WTL) method*

3.1.3 The Teachers Formative Assessment Learning artifact

The technological, informational and social artifacts are (in the same way as in the IS artifact WTL) comprised and designed so that they all interact with, and contribute to, each other – all together contributing to the fulfilment of the IS artifact TFAL.

The set of technical components, defined as the *technological artifact* in the IS artifact TFAL, is represented by the teachers' digital technologies (computers and tablets), discussion forums and websites today known as Google Workspace. The cloud-based resources included different digital environments for interaction, collaboration and feedback among teachers, course leaders and school leaders.

The system for handling information and documentation, defined as the *informational artifact* in the IS artifact TFAL, is represented by the uniquely designed TFAL course site, digital information documents, digital templates used for course instruction and different types of assignments, frameworks, analyses and documentations.

The TFAL **process design,** defined as the *social artifact* in the IS artifact TFAL (also the TFAL course), includes learning goals and methods, underpinned by socio-cultural theory of Vygotsky (1962; 1978), providing an extended social system formed as a Professional learning community (PLC) as defined by Stoll et al. (2006) and with the backdrop of the seven key elements for professional learning by Timperley, Wilson, Barrar, and Fung (2007). This further described in (5.2).

The TFAL process design, in the form of a teachers training course, comprises teacher activities concerning; planning, conducting and analyzing the outcomes of using the WTL cycle in teaching practice. The TFAL includes physical and digital seminars comprising both theoretical and practical use of the WTL cycle together with formative assessment between participants, course-leaders and school leaders. TFAL is designed by the concept that professional learning is an active process which is also not just an individual matter but also develops within a social context. The social artifact, in the form of TFAL, aims to enhance professional learning, through the integration of technical components, i.e., the technology artifact and structured learning contexts and environment, i.e., the informational artifact. TFAL supports teachers integrating digital technologies in pedagogy by e.g., the theoretical and practical use of the WTL cycle in different learning contexts together, formative assess and analyze the effects of using WTL together with participants, course leaders and school leaders.

3.2 Social constructivism

The social artifacts in this thesis, the WTL and the TFAL, is designed with the backdrop of social constructivism and the ideas of Vygotsky (1962; 1978) suggesting that learning is an active process which is not just an individual matter but develops within a social context. The social artifact is intertwined with the informational- and the technology artifact, together acting to support social interaction and enhanced teaching and learning in different learning contexts and environments.

Social constructivism, belonging to the overall concept of constructivism, stresses the collaborative nature of learning. It views human reality as socially constructed and has since its inception been the focus of many educational psychologists. Social constructivism is an underlying epistemological perspective of this thesis and a sociological as well as a learning theory with the perspective that each learner constructs their own knowledge in different ways depending on both internal and external factors but also depending on how the learner interpret and organize information (Adams, 2006).

The assumptions of constructivism include that reality is personally constructed and that personal experiences determine reality instead of the other way around (Cooper, 1993), thus postulating that knowledge is not acquired automatically but rather constructed by the learner (Schunk, 2012).

> The constructive paradigm, as advocated by Piaget (1960) and Bruner (1990), stress the notion that whatever gets into the mind has to be constructed by the individual through knowledge discovery (Piaget 1960/1981) with a focus on the process of assimilation and accommodation of knowledge. (Hung, 2001 p. 282)

Vygotsky (1962) expands on the view of Piaget, stressing that learning takes place in the interaction with the environment and that interpersonal social interaction between peers and the teacher is the key to facilitate learning (Gance, 2002).

Social constructivism from the perspective of Vygotsky emphasizes the importance of building knowledge of concepts and skills in a social context. This knowledge building is, according to Vygotsky, acquired in, for example, what is called 'scaffolding' processes where students develop their potential through (in the right time) obtaining knowledge both from teachers and peers and according to the zone of proximal development (ZPD). The ZPD is defined by Vygotsky (1978) and can briefly be described as the level of potential development that the learner reaches by the guidance of the teacher and in collaboration with peers. Or as put by Chaiklin (2003);

> If instruction is not viewed as an end in itself, then a theory about the relationship between specific subject-matter instruction and its consequences for psychological development is also needed. This last problem was the main tension against which Vygotsky developed his well-known concept of zone of proximal development, where the zone was meant to focus attention on the relation between instruction and development, while being relevant to many of these other problems. (Chaiklin, 2003 p. 1)

Socio-cultural perspectives on learning emphasizing the social, cultural and historic situation where language is central for the learning process is stressed by Barton (2001) and are important for the social artifacts of this thesis. With the backdrop of social constructivism, the perspective that learning develops in social-cultural contexts of language and, together with scaffolding processes increasing the ZPD among students, the IS artifacts comprising the social artifacts WTL and TFAL (further described in 5.1.4 and 5.2) is designed for technology-enhanced teaching and learning.

3.3 Design Science Research (DSR)

Design Science Research (DSR) (Hevner, March, Park, & Ram, 2004), specifically the definition by Vaishnavi and Kuechler (2008), is in this thesis used as a theoretical foundation for the research design as well as the lens and framework. DSR derives from the sciences of the artificial (Simon, 1996) and is a problem-solving paradigm that, in IS research, often concerns the design and implementation of an IS artifact into an organization, and where the focus is to seek and understand phenomena, for instance usefulness or impacts related to the use of the artifact (Hevner et al., 2004). Research can be defined as an activity, or process, that contributes to the understanding of a phenomenon. In DSR all parts of a phenomenon may be created, as opposed to naturally occurring, and the phenomenon is often a set of behaviors of some entity found interesting by a researcher and/or a community (Vaishnavi & Kuechler, 2008). DSR activities concerns both the design and evaluation of artifacts and include iterative refinement through different cycles.

The three-cycle view (Figure 3) by Hevner (2007) gives an overview of the DSR idea, refining the artifact through intertwined design, relevance and rigor cycles. The relevance cycle concerns the research problem, requirements and acceptance criteria for the utility of the artifact. The rigor cycle concerns how the design of the artifact is based in knowledge that includes scientific theories and experience. The design cycle concerns the iteration between building and evaluating and is dependent on the two other cycles.

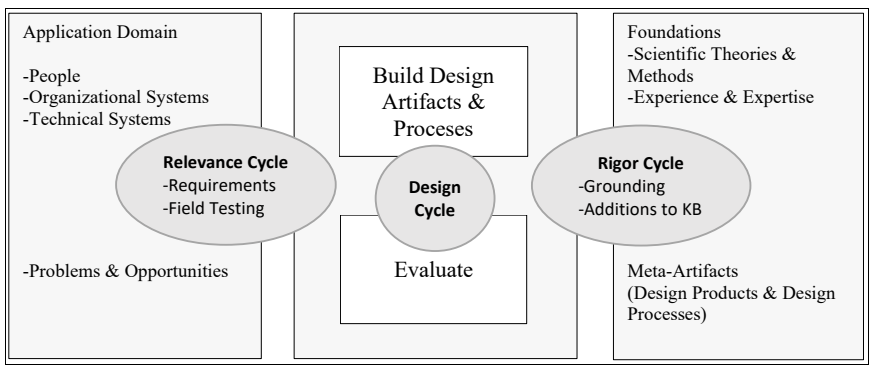

Figure 3. *Design science research cycles (Hevner, 2007)*

With the aim of more effectively capturing the nature of artifact in real-world contexts Drechsler and Hevner (2016) include a fourth "change and impact cycle" into the DSR model (Figure 4). This fourth cycle captures the long-term effects in a broader organizational and societal context. As the aim of the present research is to disseminate the designed artifact beyond the initial internal environment of individual schools across an entire school organization, and in the long run beyond the municipality, it reaches beyond the three-cycle view. Even if the fourth cycle is not yet totally completed within the scope of this thesis, it is my view that it more accurately describes the purpose and outcomes of this thesis.

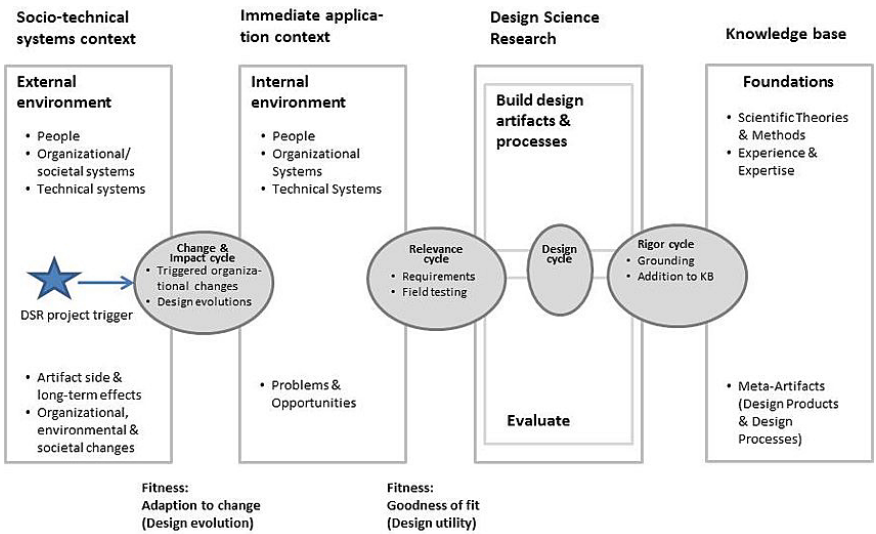

Figure 4. *Change and Impact cycle (Drechsler & Hevner, 2016)*

Emphasized by Vaishnavi and Kuechler (2008) are the four general outputs in DSR proposed by March and Smith (1995): (i) constructs, (ii) models, (iii) methods, and (iv) instantiations. Constructs form the vocabulary of a domain and are used to both describe problems and specify their solutions, a model is a set of statements explaining relations among the constructs, a method is a "set of steps" – e.g., a guideline used to perform something, and an instantiation operationalizes the constructs, models and methods (March & Smith, 1995). The instantiation thus is "the realization of the artifact in an environment" (Vaishnavi & Kuechler, 2008 p. 13).

According to Gregor and Hevner (2013) "The goal of DSR in the improvement quadrant is to create better solutions in the form of more efficient and effective products, processes, services, technologies, or ideas" (Gregor & Hevner, 2013 p. 346). DSR is sometimes also called "improvement research" which clarifies the performance-improving and problem-solving nature of the methodology (Vaishnavi & Kuechler, 2008). This research comprises the design and test of an IS artifact which is disseminated and evaluated over a school organization in order to improve teaching and enhance learning.

The IS artifact consists of the four general outputs through: (i) Constructs, i.e., the common vocabulary communicated over the school organization aiming for digitalization and second-order change; (ii) A model, i.e., the training model and also the TFAL course used for disseminating the method; (iii) A method, i.e., the social artifact, and also the WTL used as a guideline for teaching and learning practice, and (iv) The instantiation of the IS artifact, i.e., the transformation from supplementary use of digital technology in teaching practice to conscious implementation of digital technologies used for improved teaching and enhanced learning as implemented in the City of Sollentuna.

Much of behavioral research has, according to Hevner et al. (2004), focused on only one side of the artifact, i.e., evaluating the constructs or instantiation whilst "Relatively little behavioral research has focused on evaluating models, a major focus of research in the management science literature" (Hevner et al., 2004 p. 77).

This research contributes by both testing the designed IS artifact through studies 1 and 2 and by evaluating the designed training model TFAL used for disseminating the WTL method (study 3, study 4) and leading transformational change.

The focus of this thesis is to improve the use of digital technologies in teaching and learning practice through the design, evaluation and dissemination of an IS artifact. The research process follows Vaishnavi and Kuehler (2008), who describe the DSR process in terms of five steps: (i) awareness of a problem, (ii) suggestion (iii) development, (iv) evaluation, and (v) conclusion (Figure 5.) The details of the research process are presented in chapter 5.

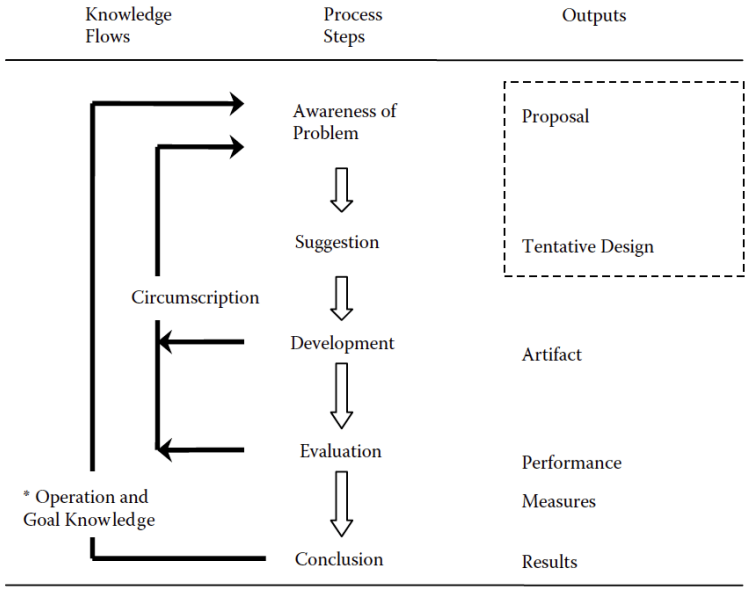

Figure 5. *General methodology of design science research (Vaishnavi & Kuechler, 2008)*

3.4 Diffusion of Innovations

The theory Diffusion of Innovations (DOI) by Rogers (2003) is the theory used in this thesis for the analysis of the dissemination of the WTL. The theory has commonly been used within a broad variety of research areas but has also been used for investigating the adoption of technology within the education. DOI presents crucial factors for the dissemination of innovations, including properties of the innovation, the adopters, the communication channels by which the innovation is disseminated, time, and the social system in which the adopter lives and works. The theory has been used in educational research, e.g., to; determine the degree to which institutional strategy, structure, and support decisions facilitate or impede blended learning adoption among faculty (Porter & Graham, 2015); to understand preservice teachers' perspectives of the diffusion of ICTs in elementary education (Sahin, 2012), and to understand factors affecting teachers' adoption of game-based learning in elementary schools (Li & Huang, 2012). DOI concerns regularities and patterns found across both cultures, innovations and the people that adopt or reject the innovation. Of particular interest for

this study, trying to learn how an innovation can be disseminated among teachers and school leaders within and across a school organization, is that "Diffusion of innovations explains social change, one of the most fundamental of human processes" (Rogers, 2003 p.17)

The DOI is used in this thesis to study the dissemination process of the WTL over 5 years through a teacher training course, entitled Teachers Formative Assessment Learning (TFAL), organized from the local school authority for teachers and school leaders across the municipality one academic year at a time. The reason for using DOI in this thesis is to learn how an innovation can be disseminated through an organized way of constructing a teacher-training course. Since adoption can be volatile, and, according to Borman (2003) five years is a critical time in this respect, it was also important to study the sustainability of the dissemination effort during the course of five years.

Diffusion research has made important contributions for understanding human behavior change during the past few decades but has also been criticized for shortcomings and biases. Four main criticisms are identified by Rogers (2003) and concern: (i) a pro-innovation bias, (ii) the individual blame bias, (iii) recall problem, and (iv) the issue of equality. The pro-innovation bias concerns the implication in DOI research that the innovation should not only be diffused and adopted by all members of a social system but also that the diffusion process should be more rapid and the innovation neither rejected nor re-invented. The individual blame bias concerns a tendency to hold individuals, instead of the system of which the individual is part, responsible for shortcomings. The recall problem concerns the time variable and since diffusion occurs over time it is difficult not to include time as an aspect. Thus, the respondents are asked to recall their experiences of the innovation which is sometimes hard. The issue of equality concerns that the DOI has been criticized for widening the socio-economic gap between segments within a system (Rogers, 2003).

These four main criticisms should, according to Rogers be addressed and have, in this research, been considered as far as possible. This research takes into account not only the adopters, but also discusses the re-inventers and what re-invention concerning the WTL can depend on and stand for. Concerning the individual bias, the research focus in the dissemination effort of this thesis concerns the main challenges for disseminating the WTL. Thus, the focus is rather on different characteristics of the WTL, related to how it is perceived by the participants. Since this research includes a time aspect and consists of a longitudinal study, recall problem is something that was

difficult to fully avoid. On the other hand, since a majority of the participants either quite recently took the course or still used the WTL in their daily work during the survey, characteristics of the method were still probably not too difficult to recall. The issue of equality is not in this research found to be a problem, since the participants in the social system were largely homogeneous with respect to having the same education, occupation and working in the same school organization and municipality.

According to Rogers (2003, p. 5); "Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system". Diffusion is defined as social change – a process by which alteration occurs in the structure of a social system involving interpersonal communication relationships. "Adoption" of an innovation is when the adopter decides to adopt the innovation, "rejection" is when the potential adopter decides not to adopt the innovation, and "re-invention" is defined as "…the degree to which an innovation is changed or modified by a user in the process of adoption and implementation" (Rogers, 2003, pp. 17).

The four main elements in the diffusion of new ideas are: (1) an innovation, (2) communicated through certain channels, (3) over time, and (4) among members of a social system (Rogers, 2003). "The characteristics of an innovation as perceived by the members of a social system determine its rate of adoption" (Rogers, 2003 p.36). Adoption of an innovation generally depends on three sets of factors, those relating to the innovation itself, those relating to the adopters, and those related to the ways in which an innovation is disseminated.

An innovation – in this thesis the WTL – is an idea or a practice perceived as new among the adopters and "…the characteristics of an innovation as perceived by the members of a social system determine its rate of adoption" (Rogers, 2003, p.36).

According to the theory of diffusion of innovations the five characteristics of an innovation are: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. Innovations offering a higher degree of these attributes will be adopted faster than other innovations; however, out of the four attributes, relative advantage is the overall strongest predictor of adoption of an innovation.

Communication channels – in this case the teachers training course called Teachers Formative Assessment Learning (TFAL) – an 'on-the-job' course transmit information from some individuals to others. Channels can be active in promoting the message (like a course) or passive (like a book) merely

providing means for people to share information about the innovation (Rogers, 2003). Mass-media channels are most effective when it comes to transmitting knowledge of innovations from one or few individuals to a large audience. Interpersonal channels, on the other hand, comprise some sort of face-to-face exchange between two or more individuals and are, according to Rogers (2003), more effective when it comes to forming as well as changing traditional attitudes towards a new idea. Interpersonal channels are therefore more likely to influence the adoption or rejection of a new idea and interactive communication channels have become crucially more important for the diffusion during the recent decades.

An important principle of human of communication, according to Rogers (2003), is that the transfer of ideas generally occurs in situations between individuals that are similar to each other. Homophily thus occurs in situations where individuals belong to the same groups, sharing similar views and social status. Heterophily is by Rogers (2003 p.19) defined as the opposite to homophily, and thus defined as "…the degree to which two or more individuals who interact are different in certain attributes". According to Rogers (2003, p.19) "One of the most distinctive problems in the diffusion of innovations is that the participants are usually quite heterophilous". The reason is that in a situation where a technically much more competent individual is to introduce a technical innovation to another individual, the ineffectiveness of not sharing the same vocabulary affects the diffusion process negatively. On the other hand, as stressed by Rogers (2003), when individuals are more or less identical as regards their technological competence diffusion will not occur since there is no new information to exchange. Therefore, when the innovation WTL in this research was to be disseminated through the TFAL, the leaders of the course were teachers from the municipality and the participants were divided into a mix of homophily and heterophily groups. Homophily (in respect to being teachers and school leaders) but heterophily (in respect to coming from different schools in the municipality), more or less used to using digital technologies in teaching and learning practice, but also different with respect to which grades and subjects the participants were teaching.

Time is a factor in the diffusion process in several ways. Innovations may be diffused at a very different pace among different individuals and different social systems. As social acceptance of change is important for it to take place, there is a need for a critical mass of individuals embracing the new views required for the innovation to take root. This makes it difficult to enforce change; it has to come from within. Time is an important factor for:

(i) the innovation-decision process, i.e., for an individual to move from first knowledge of an innovation to decision about adoption or rejection, (ii) the relative earliness/lateness by which an innovation is adopted among different individuals in a social system, and (iii) the rate of adoption in a system, the number of individuals in a social system adopting the innovation within a given time period (Rogers, 2003). Time in this respect was not measured compared to adoption, rejection or re-invention but rather was important due to how long-lasting the impacts of the TFAL were.

Diffusion occurs within social systems consisting of individuals engaged in solving a problem or attaining a mutual goal. This common goal, the sharing of objectives and cooperation, binds the whole social system together. The social structure includes the patterned arrangements that give stability to human behavior in a social system and norms are established to guide behavior patterns for participants in a social system. In this thesis the schools and the TFAL – which is the channel for disseminating the innovation – consists of teachers and school leaders engaged in learning and using the WTL in practice. The social and the communication structure in a social system, as well as the role of the leaders and change agents, can according to Rogers (2003), either complicate or facilitate the diffusion process. Individual factors also influence how an innovation is received and disseminated by each individual in case adoption is voluntary. In this case, the dissemination however is organized within the TFAL, which is why individual blame bias is here considered a minor problem.

Re-invention is defined as to what degree adopters change and modify the innovation in the implementation process. Rogers (2003) suggests that, in early diffusion studies, adoption meant the exact use of the innovation, but this has changed as innovations are not always fixed entities but rather proposals for change. More commonly in the diffusion process the innovation ideas evolve and transform to some extent. This is particularly true for innovations which do not require exact technical tools or procedures, such as teaching which always allows some, or a great degree, of freedom for the teacher. Even though innovation may be reinvented there is a need to understand the point at which it has changed so much that it no longer resembles the original innovation. This is in particular a problem when second order change is concerned, as it always includes an element of activity which is easily adopted (such as typing into a computer) but loses its meaning if the views underlying the change are not adopted. People may adopt the mechanical parts of an innovation without adopting its purposes, theories and

evaluation measures; in which case the innovation is lost. Some of the criticism concerning the DOI implies that there is a lack of cohesion which brings with it difficulties in applying with consistency to new challenges and problems. Rogers (2003) suggests that, in early diffusion studies, adoption meant the exact use of the innovation, but this has changed as innovations are not always fixed entities but proposals for change.

Hence, in the diffusion process, innovation ideas commonly evolve and transform. This is particularly true for innovations which do not require precise technical tools or procedures but allow some degree of freedom, such as teaching, and corresponds with the diffusion process of the WTL, where the DOI conceptualization of elements and characteristics has been important for understanding how an innovation can be disseminated by a local school authority school and diffused within and across a school organization.

4. Research design

The theoretical foundations of this research project, including Design Science Research (DSR), which is used as the framework and methodology of this research, are presented in chapter 3. The thesis combines qualitative and quantitative research methods. The focus of this chapter is the research design and methods, data collection and analysis as well as case description.

The epistemological and methodological approaches of this thesis are in accordance with DSR. According to Vaishnavi and Kuechler (2008);

> Epistemologically, the design science researcher knows that a piece of information is factual and knows further what that information means through the process of construction and circumscription[...][i]t's meaning is precisely the functionality it enables in the composite system (artifact and user). (Vaishnavi and Kuechler, 2008 p.18)

According to the assumption that the behavior of a designed artifact is the result of interactions between different components and that its usefulness is what it enables in the system between the artifact and the user is the foundation of this research. Therefore, DSR is chosen as both a theoretical standing point and a methodological approach when seeking an answer to the overall research question:

How can a school organization at municipal level lead digital transformation through the digitalization of teaching- and learning processes in an organized, professional, and, as far as possible, scientifically based way?

A multimethod approach i.e., a combination of methods from qualitative and quantitative approaches, is used. The underlying philosophical assumptions in this thesis are grounded in social constructivism (see 3.2) where knowledge of learning in social contexts in everyday experience through reflection and meaning-making is important. It is my belief that, in order to learn how to improve the use of digital technologies in different teaching and learning contexts and environments, the basic belief that knowing comes through making and that this includes design within a context is important.

As put by March & Smith (1995) "Whereas natural science tries to understand reality, design science attempts to create things that serve human purposes. It is technology-oriented. Its products are assessed against criteria of value or utility - does it work?" (March & Smith, 1995 p 257).

Therefore, in order to learn more and broaden the perspectives in this context I use DSR methodology and the assumption of "knowing through making", aiming to contribute to the area of focus in this thesis.

According to Vaishnavi and Kuechler (2008); "A practical or functional addition to an area body of knowledge, codified and transmitted to the community where it can provide the base for further exploration, may be all that is required of a successful project" (Vaishnavi & Kuechler, 2008 p. 18).

In this research I have followed the requirements of a design strategy based on the methodology of DSR (chapter 3) making extensive and iterative use of the different flows, steps and outputs comprised in the general methodology of DSR (Figure 5) (Vaishnavi & Kuechler, 2008). In that design, the DSR process consists of the steps: Awareness of a problem, Suggestion, Development, Evaluation, and Conclusion. Due to the iterative process of DSR, each step can be revisited from any of the other steps, which to some extent is also the case in this research process. Each of these steps will be described further in chapter 5.

4.1 Data collection and Analysis

Multiple methods are used for the empirical studies in this thesis and were motivated by the objective and nature of each study.

Table 4 Overview of empirical data techniques and informants

Study	Data collection techniques	Respondents	Respondents categories
Study 1	Standard tests (ST)	87	Students
Study 2	National Standard Tests (NST)	502	Students
Study 3	Survey	92	Teachers
Study 4	Interviews	12	School leaders

Study 1 is a pilot study in the form of a quasi-experiment where a tentative design of the teaching method WTL, at that time named "Integrated Write To Read" (iWTR), was implemented and tested by measuring the improvement in literacy during one year in two classes with 7-year-old students within a school in the City of Sollentuna. Data on learning were collected by means of post-tests using instruments commonly used in Swedish schools. The research questions for the study were:

RQ1: *Does WTL improve children's skills in reading and writing?*
RQ 2: *What teaching factors are essential in order to make the integration of ICT and the students' literacy development as favorable as possible for the students' reading and writing capabilities*?

A first version of the method was tested by measuring performance in reading and writing using two test groups (two classes) and two control groups (total n=87) by systematically measuring performance in reading and writing and by using standard tests (ST) in combination with observations and student evaluation. This was conducted to assess the social and individual effects of using the method.

Study 2 uses quantitative methods for testing the effects of iWTR – at this time renamed "Write To Learn" (WTL) because of the findings from study 1 – on a larger scale (n=502) with a broader focus (both mathematics and literacy), and with a longer test period including three years, grades 1-3. This time the test group was compared to two control groups, one using a traditional method (no ICT) and one using technology individually (without integrated social interaction and formative feedback). Learning results were measured using the year 3 national standard tests (NST) in mathematics and literacy. The overall hypothesis of study 2 is that:

ICT use in combination with a pedagogical method including formative feedback and assessment as a digital social interaction among peers improves results in literacy development and in mathematics.

The overall hypothesis is operationalized by eight more specific ones (see 6.2). The study in total included (n=502) students who had been exposed to different teaching methods, and the use of digital technologies, over a period of three years during year 1-3. Data were collected from the results of the compulsory nationwide standard test (NST) carried out by all grade 3 students in Sweden. The NST tests a number of abilities related to reading, writing and mathematics with a total of 15 tests (8 in literacy and 7 in mathematics). The study tested WTL regarding both the use of ICT tools and the use of a specific social pedagogical method. The traditional method was used as control group for the ICT use, and the group using technology individually was used as control for the social interaction arrangements – such as the formative feedback supported by ICT – that were a crucial part of the intervention. Data analysis was conducted by descriptive statistics using the software program STATA. Potential bias caused by socio-economic factors was tested using the model for calculation of such bias that was used

by the municipality in which the study was conducted; the test used the Pearson correlation index.

Study 3 investigates how WTL can be disseminated across the school organization and sustained over time. The study is a survey among 92 teachers who at different times over a 5-year period participated in a training course, organized by the local authority to disseminate the method within and across the school organization within the municipality. Data were collected by means of a questionnaire (distributed using the software tool Survey Monkey) based on the DOI theory (Rogers, 2003), sent to all teachers who had participated in the teacher-training course Teachers Formative Assessment Learning (TFAL) within a 5-year period. The analysis was conducted through descriptive statistics and qualitative content analysis.

Study 4 uses qualitative methods to investigate the results and challenges of leading digitalization of education in the municipality. This study draws on interviews with school principals guided by Rogers (2003) theory of dissemination of innovations (DOI). Data were collected by means of semi-structured interviews with 12 out of total 13 school leaders from the City of Sollentuna – who had been involved in an organized diffusion process involving a course given to teachers. One school leader did not have the possibility to participate in the interviews. The interviews were conducted in the summer of 2015 at the municipal educational department. They were 30-45 minutes long, audio recorded and thereafter transcribed. The qualitative data analysis involved different stages of analysis in accordance with Bazeley (2013), including: (1) transcription of the interviews, (2) a reading and annotation process, (3) an exploratory process of breaking open the data and placing these data into overarching themes, and (4) coding in hierarchic nodes and child nodes using the software program NVivo. The coding was based on the main elements of diffusion of innovation in accordance to Rogers (2003): innovation, channel, social system, time, and the characteristics of the innovation, which are; relative advantage, compatibility, complexity, trialability and observability.

4.2 Case description

In this section I present the overall and regional context of the case with respect to the challenge of moving from digitization towards digitalization of education in a municipality in Sweden. Included is my role as a researcher and the ethical considerations. The research process of the case is, in chapter

5, presented step by step and in accordance with the general methodology of design science research (Vaishnavi & Kuechler, 2008) (Figure 5).

4.2.1 Sollentuna – a municipality in Sweden

The research within this thesis derives from the process of digitalizing education in Sollentuna, a medium-sized municipality in Sweden bordering Stockholm. Sollentuna is home to some 73,000 citizens and belongs to the capital region of Sweden. Sollentuna, as with all the 290 municipalities in Sweden, is responsible for providing a significant proportion of all public services, which includes schools.

A municipality in Sweden is highly autonomous and has independent powers of taxation. Already by 1862, the right for municipalities and regions to levy their own taxes among their citizens was established and local self-government is stipulated in the Swedish Constitution (SALAR, 2019). The municipality is steered through the council, the highest political body in the municipality, elected in general elections every four years. In the council, financial decisions are taken concerning how the money is to be distributed, what taxes the citizens must pay and what fees are to be charged. The Municipal Board is the executive body of a Swedish municipality and is thereby responsible for both leading and coordinating municipal activities. Local politicians in the municipality take the overall decisions whilst officials at the different local departments implement the decisions being taken.

There are five administrative offices in Sollentuna, of which the Education Office is one. The Education Office is responsible for pre-school, primary-school, secondary school and upper secondary school.

4.2.2 My role and the formation of a research case

The starting point for the digitalization in the municipality was a study trip to Maine in 2009, where the theme was the use of digital technologies in school. During this time, I was still working as a teacher in one of the schools of the municipality, not yet aware of the political aim that would be the result of the trip (on which I did not join). On the trip was a group of local political representatives together with school leaders from the city. The study visits during the trip resulted in the local politicians formulating a local policy requiring all schools to, by 2013 at the latest, distribute one digital device, a laptop or tablet, per teacher as well as one laptop per pupil between the ages of 7 and 16. This political decision was to be implemented by the school leaders in all schools of the municipality. With this political decision at hand the Educational Office of the city decided to implement the

cloud-based application Google Apps for Education (the former name for what is now called G Suite) consisting of a variety of digital tools and sharing spaces for social interaction and collaboration between students and teachers. The Educational Office also decided to support the schools in financing some, but not all, of the digital technologies needed. In order to execute the political aim in the municipality, the Educational Office invested in one ICT champion per school. The ICT champions were all equipped with a computer and met once a week at the Educational Office testing different software programs. The ICT champions, of which I became one, were responsible for disseminating what the group learnt and decided for each local school within the municipality. After one year the group, due to a shift in leadership at the Educational Office, was terminated. Instead, the Educational Office now focused on implementing the new curriculum of 2011 (Lgr11), increased student results, but also on the political aim of 1:1, to be fulfilled by 2013 at the latest. Since the group of ICT champions in the municipality no longer existed as a group, there was, at the beginning from the local educational board, no plans on how to lead the change and support teachers integrating the digital technology into practice. In my role as a teacher in the municipality, former ICT champion, (and at that time without knowing) future doctoral student, I started to elaborate how digital technologies could improve my teaching and enhance learning among students in literacy. In a local project within the municipality and together with a teacher colleague at the time, we applied for the financial means to, beforehand, and in two classes of 7-year-old students, purchase computers to be implemented into practice. During the project I elaborated on how digital technologies could improve early literacy among pupils in early years. The project worked out well, indicated improved learning in literacy, and was the starting point for me to continue the work and, to the Educational Office, advocate some sort of support for teachers to integrate digital technologies into practice.

At the same time, anxiety among teachers in the municipality increased concerning the use of the new technology brought in and decreasing results in the 2009 PISA. Thus, the idea to use the experiences made from the former project of testing the use of computers for early literacy and design a research-based and ICT-supported pedagogical method for supporting teachers in how to plan, execute and assess the very teaching practice by the use of digital technologies, was accepted by the Educational Office in 2011. At the same time the municipalities' decision of 1:1 had become noticed and

discussed by media. This national attention also aroused the interest of research communities, e.g., the University of Örebro, at that time involved in a research project entitled Unos Uno, focusing on 1:1 in the school sector. This was thus the starting point for me as a PhD student within Informatics at the University of Örebro.

The first iteration of the designed method was initially given the name integrated Write To Read (iWTR) since it was primarily designed for increasing the results in literacy among young students equipped with digital technologies. Further on, the method, with important support from my former teaching colleague in mathematics, was redesigned to also include mathematics, and renamed Write To Learn (WTL), but still with the focus on reading and writing as the very foundation of learning. The results of the iterative design according to DSR are further described in chapter 5.

4.3 Ethical considerations

Since my research takes place within the Swedish school system, I follow the ethical research guidelines recommendations of the Swedish Research Council (Vetenskapsrådet, (SRC)). According to the SRC, ethics in research concern two issues: i) "The nature of the research – the interests of participants and research subjects in research projects", and ii) "The researcher´s conduct – personal ethics in the pursuit of research".

The question of ethics in research is to a large extent a balance between "the quest for knowledge" against the risk of harm (Swedish Research Council, 2019). Ethical considerations with respect to the interests of participants in this thesis have been important since it not only involves adult individuals but also young students. It has therefore, throughout the research process, been important to take into consideration the values of interest for research with respect to ethical considerations. This overall research project, including the design and collection of data, has been approved by the municipality as well as by the participants. The data collection of the student results was performed in agreement with the municipality, available through national and local databases and made anonymous with assistance from the municipality. Regarding teachers and school leaders, prior to surveys and interviews all informants were informed of the research and the purpose for which the data were to be used. Participating in this research as a school leader or teacher was voluntary. A majority of the individuals contacted agreed to participate. For ethical reasons, and to reduce possible bias since I was known by the teachers in the in the munici-

pality an external researcher, not known by the teachers or part of the research, was the one asking the teachers to participate in the survey (study 3) and also the one who sent the survey to the participants. This way I did not know the respondents reaction, who decided to participate and who did not. Hopefully also those who participated did so because they wanted to evaluate the WTL rather than fulfilling my wish for them to do so.

The interviews with the school leaders were semi-structured but mainly based on elements and characteristics of Rogers (2003) DOI. The interviews were conducted by me as a researcher, since I did not have the opportunity to get external help. Still, since the school leaders were on a higher hierarchical level than me, and all of them part of the school board having decided on the dissemination effort I considered the risk for bias relatively low, even if aware of the probability and of any such signs.

4.4 Limitations and future research

One limitation is that the empirical basis from the national test of student results derives from one municipality only. It would of course have been better to test the method on a larger scale. This was, however, not possible at the time as the method was then only used in Sollentuna. On the positive side, it was tested in all primary schools in the city so the empirical base is as large as it could possibly be at the time.

Moreover, the artifacts, including the WTL method and the TFAL course, have been adopted by other municipalities. Further research following up student results from the WTL and the use of TFAL for sustainable school improvement outside the municipality of origin hence is suggested but was not possible within the time frame of this thesis.

In addition, an evaluation of the nationally managed TFAL program, called TFAL blended, that has comprised teachers from all over the country is suggested for future research.

5. Results

5.1 Implementation of Write To Learn

This section describes the implementation of the WTL method in Sollentuna organized by the steps, as defined in the general methodology of DSR (Figure 5), by Vaishnavi and Kuechler (2008). This means it is also, basically, but not strictly, in chronological order, as there are at times iterations between steps.

5.1.1 Phase 1: Awareness of the problem

Implementing technology into schools by the motto one to one (1:1), i.e., one computer/digital device per student in both compulsory and secondary school at the latest in 2013 in Sollentuna was a political decision taken in 2009 (see 4.2.2). During the same period student results in literacy were decreasing, also showing in the 2009 and 2012 PISA measurements (OECD, 2010; 2012) why anxiety grew among teachers concerning how to use technology effectively for learning. This problem aroused an urgent need in the city for learning how to effectively use pedagogical methods for more effective learning outcomes among the students. With the aim of introducing digital technologies in the municipality, the local educational department in the municipality decided to assemble a group of 15 teachers, one from each school in the city, who were given the mission to inspire and support colleagues in using the new technology by being entitled "ICT champions". During the course of one academic year (2010-2011), the group of ICT champions met once a month at the municipal educational office, together exploring the use of different technologies and the possibilities for implementing them into the pedagogy. The group though was discontinued in 2011, after which time each school was left to individually implement the decisions of 1:1 taken by the local politicians and educational department in the municipality. This was no small challenge, as at the time there was no empirical research on 1:1 in schools, and it was a new situation for school practice. Technology was brought into schools, drawing on a strong technological imperative and hope for improvement, not based on empirical research. Examples of improved operations due to digitalization came from evidence from other businesses, not from the school environment. Even that evidence was not unequivocal, as many risks and failures were also known.

With the backdrop of the 1:1 decision in the municipality, I was given the opportunity to start this research project. The problem was how to make

the best use of the digital technologies that had been brought in. Hence, the objective was to learn and study how the design, testing, evaluation and dissemination of a research-based innovation could be used as support for municipal leadership in the process of moving from digitization towards digitalization.

The idea of a research project, including the design and dissemination of a research-based pedagogical ICT-supported method for implementing the new technology into the pedagogy, was presented and accepted by the Educational Office in the municipality.

5.1.2 Phase 2: Suggestion

The suggestion consisted of the design and iterative development of an artifact based on the Information Systems Artifact concept (Lee et al., 2015) comprising the technology information and social artifact, applying DSR as the general method due to its suitability to change situations where the role of technology is not clear and progress has to be cautious, stepwise and based on recurring evaluation of each step.

The idea was for the IS artifact to align with the learning paradigm of social constructivism (Vygotsky, 1962; 1978). To this end a new learning environment was designed where the use of a number of digital technologies was inserted into a pedagogical method which teachers could follow. This would give them a stable foundation to build upon in their efforts to improve teaching and enhance learning using technologies. The method would provide a framework in which each technology had a clear and well specified place and where teachers' focus was not on "using technologies so as not to fall behind other businesses" – which was a frequently heard tagline at the time – but on improving learning.

The suggestion was thus to support teachers in how to implement digital technologies for improved teaching and enhanced learning through an ICT-supported pedagogical method including a step-by step cycle, supporting the integration of digital learning environments and activities in combination with physical and digital interaction. This was to be manifested in an IS artifact, in which the social artifact was designed as an ICT-supported teaching method, initially inspired by the work of Trageton (2014) and first called integrated Write To Read, (iWTR). Later on, when also including mathematics, the method was successively revised and renamed to Write To Learn (WTL).

5.1.3 Phase 3: Development

The initial and tentative method, iWTR, later on redesigned and renamed as WTL, was designed, elaborated and tested during the course of one year in two classes with 7-year-old students within a school in the municipality. The young students in the two classes learned how to read, write, formatively assess and give formative feedback to each other by the teachers' structured use of the method.

Now follows a description of the designed method, iteratively redesigned to include other subjects, e.g., mathematics, as well as the use of teachers with older students. Even though the method was further developed, the core of iWTR and WTL remains the same, focusing on improved teaching and learning through structured use of digital technologies for social interaction and formative learning activities between teacher-student and student-student.

5.1.4 The WTL method

WTL is composed of a cycle including six elements used as a guideline for supporting the integration of digital technologies into learning processes. Key factors underpinning the design of the WTL method, aside from the use of digital technologies and key factors for learning, e.g., formative assessment and feedback, build upon the assumption of social constructivism; that reality is built on personal experiences and knowledge is constructed by the learner and developed within a social context. The WTL method supports teachers in how to design teaching and learning activities that include social interaction activities and collaboration, e.g., digitally written formative assessment and feedback in digital learning environments.

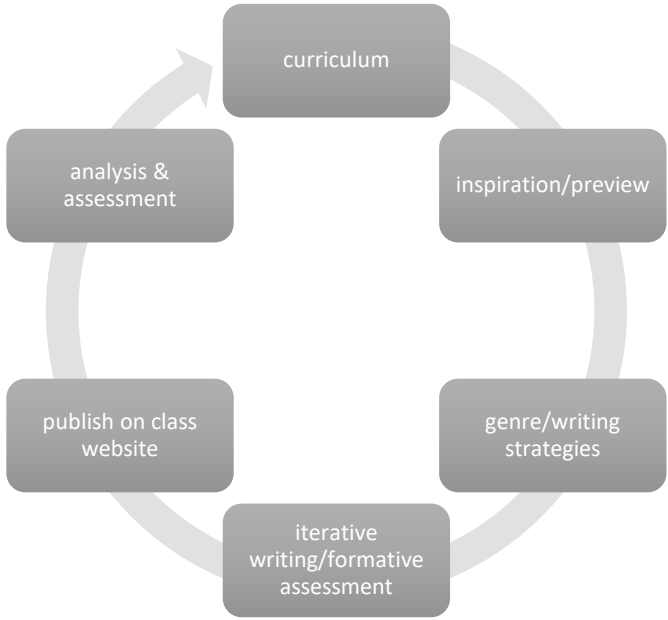

Figure 6 *The Write To Learn (WTL) method*

Teachers and students apply the method of WTL through: (i) following all the six elements of the cycle, (ii) using digital technologies in all parts of the cycle, (iii) using software-based documents for formative feedback between peers, and (iv) a template for a digital class site as a base for the designed activities, publishing and final feedback (Figure 6). Accordingly, the WTL cycle contains a logical flow for the teaching and learning process, following steps 1-6.

In Table 5, an overall description of the elements concerning main purpose, focus and what this means for the teachers and for the students respectively, is provided.

Table 5 Elements of the WTL cycle

Element	Focus	Teacher	Student
1	**Curriculum:** Framing core content, abilities and knowledge requirements	Plan of instructions and design of assignments and learning activities for all elements with regard to selected objectives from the curriculum	Information of objectives to aim for and abilities to develop (both for themselves but also used in the formative assessment and feedback among peers)
2	**Inspiration and preview:** Inspire creativity and pre-understanding among students	Inspiration and preview in conjunction with setting the topic and creating a pre-understanding of the entire process. Here, different multimedia and previously distributed materials, e.g., videos, podcasts etc., are distributed to the students through the digital learning environments, e.g., class sites or shared documents to help all students be better prepared for the tasks	Preparing for the task through inspiration and previews distributed by the teacher in the digital environment designed for the class. Dependent on prior knowledge and/or special needs, students can repeatedly use the preview to better prepare for the task
3	**Genre/Writing strategies:** Instructions and strategies for the appropriate genre in focus	Modeling different types of writing strategies appropriate for the subject and genre in focus, both physically in the classroom and digitally communicated through the digital learning environments designed for the purpose	Scaffolding and learning writing strategies in focus of the assignment by modeling from teachers and together with peers
4	**Iterative writing/Formative assessment:**	Continuous written and formative feedback on digitally shared written drafts (based	Iteratively improving their texts through receiving

		on the objectives and abilities selected for the assignment and communicated to the students within the first step of the cycle)	and giving formative feedback to peers with the backdrop of (if younger students a predetermined checklist) the previously communicated objectives
5	**Publish in online learning environments/on class website:**	Final feedback to students before publishing the final draft on the class site of the whole class (or to other classes in the school)	Finally, posting the final draft on the class site/and or other digital learning environment designed for the purpose and open to a larger group of receivers. Final feedback on the class site was not formative and used for improving the text but rather as a general guideline
6	**Final analysis and assessment:**	Final (and summative) assessment of students' work (due to personal integrity not in the cloud-based environments). Assessment of how the planned activities and learning process (all elements in the cycle), both pedagogically and technologically, have served to improve teaching and enhance learning	Participating in some sort of (oral or written) final assessment of the different elements and learning activities comprised within the learning process

The duration of completing the WTL cycle in all its parts differs depending on which objectives are selected, age of the students, type of subject, etc., is not strictly formulated. It is thus for the teachers to decide and varies from a few lessons up to weeks of more thematic character.

Applying WTL is to allow students from the age of 7 and upwards to use computers and/or other technological devices and, together with peers through cloud-based software, digitally write, share and give each other written and digital formative feedback towards the curriculum goals. Normally, this is difficult for younger students, not always having acquired sufficient fine motor skills or literacy to both write readable formative feedback and be able to read the handwritten feedback given from peers. Therefore, WTL allows the technology to function both compensatory (through speech synthesis and spell-checking) and socially (through digital environments for social interactive and written interaction) in combination with the physical environment of a classroom.

From a socio-cultural perspective and according to the "Four literacy resources model" (Luke & Freebody, 1997) of practices important for the development of literacy, WTL applies the practices: breaking the code of texts, participating in the making of texts, functional use of texts, and critical analysis of texts.

Underpinned by this perspective the WTL method includes teaching and learning activities designed for all four abovementioned practices. WTL also extends the fourth practice, critically analyzing texts, by the use of formative feedback and assessment. It also uses the technology and informational artifact for all stages, which distinguishes it from other ICT-supported methods, even those using similar names.

The six elements of the WTL cycle together comprise the teaching and learning process, from the first step in the cycle (awareness of which the objectives of the curriculum that are in focus for the current work, selected and explained by the teacher), through the process of formative assessment and feedback, publishing and the final step (teacher analysis of the teaching process through the cycle).

Two of the key factors in WTL are formative feedback and formative assessment, where feedback is, by Hattie and Timperley (2007), identified as an important factor for learning. According to Cohen (1985) feedback "is one of the more instructionally powerful and least understood features in instructional design" (p 33). Even more important for the design of the WTL method is that feedback, if combined with well-adapted instructions

in classrooms, is, by Hattie and Timperley (2007), found to be even more effective in enhancing learning. Despite the interactivity and formative feedback between peers as central parts of elements 5 and 6 (Table 5), the apparent and important role of the teacher through all parts of the cycle is crucial.

Mueller and Dweck (1998) argue that the way the feedback is delivered to the student determines the quality of a learning activity, stressing that teachers' praise for effort supports the learning whilst praise for intelligence can instead be counterproductive. Since WTL includes both teachers' and students' feedback the method includes careful instructions and manuals (for younger students' checklists) of how to give feedback, which are also designed according to the type of assignment, age of the students, subject, objectives, etc.

Another key factor important for WTL is for students to provide formative feedback to their peers. According to Shute (2008), feedback can significantly enhance learning processes and, as stressed by Latham and Locke (1991), "bridge the gap" between the current and desirable level.

The other side of formative feedback is formative assessment – also an important part of element 4 in the WTL (Table 5). According to Black and Wiliam (2009);

> Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted and used by teachers, learners or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited. (Black & Wiliam, 2009, p 9)

During the implementation of WTL in literacy, the mathematics teacher in one of the classes where iWTR was implemented elaborated on the possibility of using WTL in mathematics. This was important information for the development of the WTL method to also comprise mathematics. The digital learning environments, e.g., in the form of a digital class site used for formative feedback and publishing in literacy, were also used in mathematical assignments. The crucial point proved to be the communication, the way mathematical problems were explained and discussed. Earlier, problem-solving tasks were written by hand and posted on walls, and subsequently not further discussed among students to any great extent. Using WTL in mathematics made it easier for all students, regardless of fine motor skills or other problems in formulating mathematical expressions into writ-

ten words to put together mathematical problem-solving tasks by themselves – for peers to solve. Not only did this lead to more written communication among students, but it was also available for the teachers to participate in, which provided more accurate feedback of the students' reasoning in mathematics. This was, at this point, only anecdotal evidence, but interesting enough for further research and the development of the WTL method to comprise subjects other than literacy.

This gave rise to an interest in looking more closely into how the pedagogical model could be used within mathematics, which is why an extension of the WTL model to comprise mathematics was now designed, tested and implemented followed up by a research study.

5.1.5 Phase 4: Evaluation

The use of WTL for implementing technology into classroom practice was evaluated through the results of the students using WTL and consists of two parts – a pilot study and a follow-up study. The pilot study (study 1, reported in paper 1) was a quasi-experiment involving two existing 1st grade classes using the method and two other 1st grade classes (not using technology or the method) as a control group. The test group included 41 students and the control group 46. All students were 7 years old. The pilot study presented empirical evidence of the effectiveness of the WTL method and showed that reading was improved, but writing even more so. The method also shown to be effective for high- as well as low performers – regarding the results for both reading and writing.

Based on the positive results from the first evaluation showing the method's effectiveness in improving literacy among young students and with indications of it also being effective in mathematics, the method was judged to qualify for being disseminated within and across schools in the municipality. In order to disseminate the method, a parallel design activity, also this time following the DSR work model, aimed at designing a training course for teachers. Entitled "Teachers Formative Assessment Learning" (TFAL), (see 5.2) the course was established. In this thesis, following the terminology of the Diffusion of Innovations (DOI) theory, it functions as the "channel" for disseminating the WTL method (see 5.3). The course ran over one year and consisted of nine meetings in real life (IRL) in combination with professional learning activities such as weekly synchronous and/or asynchronous interactions, analyses and formative assessments among the participants.

The training course was managed from the educational department and comprised teachers from all schools within the municipality as well as their school leaders. It was not possible for all teachers in the municipality to participate in the TFAL course at the same time, so the course ran over several years. The second research study, evaluating the effectiveness of the method among students who had passed the first three school years using WTL in terms of their achievements in both literacy an mathematics, was conducted at a time when about one third of the teachers in the city had taken the course and the remaining two thirds had not. That timing meant that we could arrange two control groups. The study thus comprised a test group of teachers using digital technologies following WTL, one control group of teachers who had not attended the TFAL course but yet were using technology in their teaching, and another test group not having attended TFAL course and who were also not using digital technologies in class.

This second research study, reported in paper 2, extended the previous pilot study both in size and scope. It was set up with two control groups, a traditional (not using digital technologies at all) group and one where digital technologies were used, but individually, without a specific method for learning through social interaction and formative feedback among peers. It was also a larger sample of students, comprising 502 students in grade 3. For measuring the outcomes, the standard national tests of literacy and mathematics in grade 3 were used. The ambition of using two control groups was to separate the technology and method factors by using the third "method" where digital technologies were used but more individually and without applying the WTL method. By this I mean "method" in quotation marks because each teacher had obviously devised some method for their work, but these methods were typically personal and not explicitly defined or clearly based in research.

Overall, the results of the study showed that students using WTL performed better than students in both other groups. In the WTL group 78% of the students passed all 15 national tests in literacy and mathematics, better than both the traditional groups (59%) and the ITU group (50%). The mean was higher and the standard deviation lower in the WTL group compared to both control groups. Moreover, concerning gender, WTL was shown to result in higher equality and scored by far the best in closing the gender gap in performance. The most conspicuous result was that, in mathematics, boys and girls performed equally well, which showed that a structured method integrating social interaction seemed to be beneficial for both boys and girls in both literacy and mathematics. The biggest gain in the

results was boys' performance in literacy, in which they traditionally perform worse than girls. Overall, boys performed almost 30 percentage points better in literacy using WTL compared to both other methods. In literacy girls did 3% better, still increasing their results but from an already high level.

This follow-up study gave further evidence for the WTL method enhancing learning and increasing student results. At least as important was the result of the ITU method, which was the one using technology without being integrated into pedagogy, but rather used individually as an add-on tool in traditional teaching.

5.1.6 Phase 5: Conclusion

The contribution to research and practice, and notably to the municipality, was empirical evidence that the WTL method was effective in both literacy and mathematics, and that the use of digital technologies without thorough integration into pedagogical settings and learning activities is not effective but may in fact prove detrimental.

Hence, the results of the both research studies showed the importance of not simply digitizing – but instead *digitalizing* – teaching and learning in order to improve teaching and enhance learning.

The conclusion made by the municipal school board was to continue arranging the teacher-training course with the aim of disseminating the WTL method to teachers throughout the municipality. This also required some further elaboration of the TFAL course model and resulted in a redesigned version of TFAL, now comprising all subjects within the curriculum, but still with a linguistic basis and focus on literacy and mathematics, foremost with students in years 1-3 (the age of 7-9). Later on, the TFAL came to include teachers from other subjects, teaching in the years 4-6 (the age of 10-12) and to some extent in the years 7-9 (the age of 13-15).

5.2 TFAL - Teachers professional learning

Because a relatively comprehensive change of teachers' practice was needed, Teachers Formative Assessment Learning (TFAL) was designed as a 'professional learning' course, inspired by Timperley (2013) stretching over one academic year. According to the four elements of Rogers (2003), the TFAL course represents the communication channel transmitting information and fostering social interaction between teachers within the course.

The TFAL course was designed as on-the-job training during which participants practiced the WTL method in their classrooms, gathering on a

number of occasions to discuss progress and challenges, consequently including formatively assessing each other's progress. This was also the very core of TFAL – namely that teachers, after using WTL in practice, continuously (once a week) analyzed their own teaching. The analyses were then shared with other participants on a uniquely designed course web site among the teachers within TFAL. The task was to formatively assess the results - and use of - WTL and conduct analyses, consequently aiming for progression in using the technology as well as the WTL model for teaching. TFAL is based on key principles found to be important for promoting professional learning by Timperley et al. (2007);

> [P]roviding sufficient time for extended opportunities to learn and using the time effectively; engaging external expertise; focusing on engaging teachers in the learning process rather than being concerned about whether they volunteered or not; challenging problematic discourses; providing opportunities to interact in a community of professionals; ensuring content was consistent with wider policy trends; and, in school-based initiatives, having leaders actively leading the professional learning opportunities. (Timperley et al., 2007)

According to the first key principle it was important to provide sufficient time, why the TFAL course lasted one academic year, included monthly meetings and in between also digital interaction and formative feedback.

The second key principle concerns the engagement of external expertise. The course leaders were external so far as being engaged from the local educational department but came from different schools within the municipality.

The third key principle concerned engaging teachers in the process. Most (but not all) school leaders let the teachers choose to voluntarily apply to the TFAL or not. Despite of which, no teacher was recommended to join the course without a colleague from the same school, since this facilitated the learning process and increased the engagement.

According to the fourth principle, more or less all activities promoted different challenging and problematic discourses since the theoretical discussions and practical use of the WTL cycle often challenged ordinary practice as well as beliefs and attitudes among the participants.

The fifth key principle concerns the possibility for teachers to interact in a community with other professionals and was accomplished since participants every year were mixed so that 2-4 teachers from each school attended the course.

The sixth key principle was to make sure that the content was consistent with other policy wide trends. This principle was ensured through the joint decision from the politics and local educational department in the municipality of; 1:1 (one computer per student), overall use of cloud based and that, the WTL (the content of the course) was consistent with the national curriculum, relevant pedagogical research and local objectives of increased student results in literacy and mathematics.

The seventh key principle of Timperley et al. (2007) concerns that school leaders were to be engaged in and lead the professional learning communities. In this case the school leaders decided on, took part in the TFAL and gave feedback to the teachers participating from their own school.

In-between meetings in the TFAL the teachers were instructed to continuously share experiences, analyze the results using a predefined manual and, based on that analysis, give asynchronously written formative feedback to each other. This was an on-the-job course, including an extended set of colleagues from other schools within the municipality, thus forming an extended social system. The TFAL course in addition to applying the key principles by Timperely et al. (2007) and with the backdrop of professional learning (Timperely, 2013) includes a substantial element of collegial learning. The TFAL was organized inspired by the form of a professional learning community (PLC) as suggested by Stoll et al., (2006). According to Stoll et al. (2006), a PLC includes; shared values and vision; collective responsibility; reflective professional inquiry; collaboration; group – and individual learning.

Teachers were to apply to the TFAL by themselves, explaining why they were interested in attending the course, even though in some cases the school leader was the one promoting the teacher to participate in the course. Hence, the majority of the participating teachers in the TFAL shared similar visions and values of improving teaching and enhance learning, in this case by the use of WTL. The collective responsibility when joining the TFAL was crucial, since the formative assessment and feedback between participating teachers were dependent on all teachers both giving and receiving the feedback decided on within the groups of the TFAL course. Continuously, activities and analyses within the TFAL required both oral, but foremost written reflections and professional inquiries, but also collaboration among the participants why both group and individual reflection and learning was promoted.

The TFAL course was with the backdrop from the key principals of Timperley et al. (2007) and (Timperely, 2013) initially in 2011/2012 designed to focus on early literacy development. After one year, due to earlier indications of the WTL positive effects in mathematics among young students (study 1), the TFAL to the educational department was proposed to also include mathematic teachers. This, which was decided by the local educational department in 2012, resulted in the TFAL comprising both literacy and mathematic teachers from 2012/2013. The TFAL course was, over time, further extended to comprise more goals and subjects from within the curriculum, thus participants teaching in other subjects and grades. This meant that the formative assessment, as well as the manuals instructing teachers in how to go about it were further elaborated over time.

The extended dissemination process of WTL in 2012/2013 to all schools and teachers within the municipality through the TFAL, required a mix of a more generalized and interdisciplinary approach of the use of WTL together with more specific activities and analyses within smaller groups. In practice this meant that overall seminars and meetings in the TFAL mixed teachers from different subjects whilst analyses in specific subjects and formative assessment of teachers use of WTL and practice though, as far as possible, was made in groups of participants teaching within the same subject. In the TFAL teachers were to test, use and assess the effects of WTL in real classroom settings. Hence, teachers needed to change much of their ordinary practice, integrating digital technologies accordingly to the WTL cycle in different teaching- and learning processes. This in turn required fundamental changes of ordinary practice which can be compared to a form of second order change.

5.2.1 First- and Second-Order Change

Beyond increasing the students' results, teachers' use of WTL was also expected to further enhance the teachers' process of second-order change, thereby transforming traditional classroom practice.

First-order change is, by Marzano (2005), defined as incremental, consistent with ordinary practice and current values, whilst second-order change, is driven by innovation and the renewal of consistent practice and requires fundamental changes from current practice. This aligns with Ertmer et al. (1999) and Vanderline (2015), arguing that first-order change often only requires relatively small changes in the pedagogy or in organizational strategies, whilst second-order change places greater demands on classroom culture, teachers' adaptability to new conditions, as well as organizational

factors such as leading and supporting the change. First-order change then can be defined as a way of adjusting ordinary practice, doing about the same things as before, but in a somewhat different way, often with the aim of reaching more efficiency. One example could be exchanging a pencil with a typewriter, or a typewriter with a computer.

Second-order change, on the other hand, confronts fundamental beliefs about how a process should be undertaken, which, in this thesis, means using digital technologies in order to improve teaching and learning by re-defining activities and practices in school. First-order barriers to technology integration are foremost extrinsic, such as a lack of digital devices or inadequate technical support. Second-order barriers are instead intrinsic, and include beliefs about digitalization, teaching practice and resistance to change. First-order barriers can often be decreased by some sort of external resources, whilst second-order barriers require changes of practice and preconceptions (Ertmer et al., 1999).

As argued by Parks & Pisapia (1994) teachers do not only need training in the practical use of digital devices but also need to acquire an understanding of how digital technologies can be effectively integrated into the pedagogy to improve both teaching and learning. Participating in the TFAL course requires practical use of WTL in teaching- and learning practice which in turn, for most teachers, means fundamental changes in ordinary teaching practice, hence second-order change. Therefore, in order to address the challenges of second-order change and support teachers participating in the TFAL struggling for improved teaching, key principles from Timperely (2007) together with characteristics of a PLC suggested by Stoll et al., (2006) was important parts of the TFAL (see 5.2)

5.3 Dissemination of the WTL through TFAL

This section describes the dissemination of the WTL method organized by the steps of DSR as defined by Vaishnavi and Kuechler (2008).

The guide for the dissemination, and for the ensuing evaluation of it, was Rogers (2003) theory of Dissemination of Innovations.

5.3.1 Phase 1: Awareness of the problem

The first efforts of implementing WTL in the municipality, followed by the first two research studies, showed substantially improved student results. As the control group who used technology but not the WTL method showed poor results – worse than the group using the traditional pen-and-paper method – the conclusion was that, in order to use technology effectively to

enhance learning, there was a need for training and some sort of transformation of the thinking about teaching and learning. In other words, it was not about adding technology but about new perspectives, that is, second-order change. This meant the importance of the training course TFAL became obvious. Accordingly, a new challenge appeared, namely how to extend the dissemination of WTL to all schools in the city in order to help close the gaps between the effective and ineffective use of ICT. Because pedagogy is normally considered a matter for teachers, the idea of disseminating a specific method top-down is not straightforward. According to Swedish law, each school is to some extent run autonomously and certainly it is up to schools to themselves decide which pedagogical methods to use. An overall decision of standardizing a pedagogical model, such as WTL, and to disseminate it through a whole city would therefore require a specific vision, joint decisions and tangible changes of the structures in the school system of the municipality. It requires agreement among school principals. The good results from the tests were conducive to reaching such an agreement. The Educational Office, together with the researcher and development strategists, agreed on the importance of proposing that the WTL method become an overall standard model for the municipality and the TFAL training course, over time, should be made available for all teachers, and that school principals should take an active part in the course, not just by assigning teachers to take the course, but by themselves engaging in the content and actively following up the results in the classrooms.

5.3.2 Phase 2: Suggestion

After a joint decision from the school leaders in the municipality it was time for a suggestion of how to make this possible. The idea for how to more effectively disseminate the WTL method was to further develop the former teacher-training course TFAL drawing on previous experiences and to make arrangements for ensuring all teachers could take the course. This plan would stretch over several years as not all could possibly take the course at the same time. Among other things, this meant that more people had to be involved in course leadership.

The theory Dissemination of Innovations (DOI) by Rogers (2003) highlights the importance of social acceptance of the innovation. In order to achieve this, channels for communicating the innovation are most important. The TFAL course would be the main official communication channel, and, because the training involved the challenging task of achieving second-order

change, there was a need for involving course participants actively – second-order change must come from within, it cannot only be imposed from without. The TFAL course was therefore designed to function as a professional learning community (PLC), see (5.2) including a number of forums for people to meet, both physically and online. In practice this meant that the teachers besides actively interacting in (physical) course meetings, worked a great deal in-between meetings with reading about the underlying research, practicing in their own teaching, and describing, analyzing and discussing results. The recurring work model for each assignment in the course was for each teacher to:

1. Practice the teaching model of WTL in their classroom
2. Make a written analysis of the outcomes of their teaching
3. Publish the analysis on the digital space shared within TFAL
4. Read and formatively assess analyses made from peers within TFAL

In accordance with the suggestion for reconstructing the TFAL course, a quantitative follow-up research study of the adoption rate and sustainability of WTL was suggested (study 3). It was considered important to learn how to, through the long-term management of a training course - such as the TFAL - used for enhancing digitalization, lead transformational change over the school organization. This would also include following up to what extent second-order change among the teachers participating in the TFAL course actually occurred.

5.3.3 Phase 3: Development

The TFAL course designed for large-scale dissemination covered two semesters and was planned to be given once every school year over five years. The first design included nine IRL seminars (later reduced to six) as well as digital synchronous and asynchronous digital meetings between the participants. As it was well-known that attending the course would include transformational change of ordinary teaching for the teachers participating at the TFAL course, the school leaders were expected to apply for at least two of their teachers to attend the course at the same time. The reason was that the second-order change related to the use of WTL required support not only from the school leader, but also participation from at least one teaching colleague – there had to be at least a minimal group from each school so

there would be at least some professional interaction. On the other hand, it was also very important to include several schools so the learning community would be larger, in order to include more views and more new inputs. The teachers participating in the TFAL course were divided into smaller groups used for analyses and formative assessment between each other. Except for the course leaders – which were development strategists from the Educational Office – a group of teachers in the city that had already practiced WTL became mentors for the TFAL participants. The mentors' overall task was to support the formative assessment both through giving formative assessment to participants and by having the function to inspire and give actual examples from the practical use of WTL. At the IRL meetings the course leaders held both theoretical and practical lectures and all together with the digital interaction among course leaders and teachers the course contained;

- Theoretical connection to pedagogical key factors for learning
- Theoretical and practical explanation of each phase of WTL
- Examples of student tasks from WTL
- Training and supporting the participants in analyzing their own teaching practice
- Training and supporting the participants in writing formative assessments on each other's practice
- A digital space in the shape of a website, shared within TFAL, where instructions from the course as well as analyses and formative assessments between the participants was published

The main objectives of the TFAL course then were that the teachers attending the course needed to:

- Through the practical use of WTL learn how to integrate technology into their teaching practice and make continuous analyses of the outcomes of their own teaching practice
- Read, analyze and formative assess other teachers analyses as "critical friends"

After five years of running and further developing the TFAL course by iteratively adjusting some of the content, such as different tasks, timespan

for analyses, and establishing self-assessment tools, the dissemination and adoption rates were studied and evaluated (study 3).

5.3.4 Phase 4: Evaluation

The evaluation of the dissemination effort, presented (study 3), showed a total adoption rate – meaning they kept on working along the WTL method guidelines also after the end of the TFAL course – of 78% among the teachers attending the TFAL course. This was interpreted as a relatively high rate of adoption and it also did not show any signs of decreasing over the five years that had passed from the first TFAL course to the date of study 3. This indicated that the transformation from ordinary teaching practice disseminated through TFAL was palpable, but also, according to what Borman (2003) calls "critical time", quite sustainable. The teachers reported a view that the WTL method in itself was moderately demanding in regard to skills and knowledge of the key factors for learning, e.g., formative assessment and feedback, whilst challenging as concerns the second-order changes, e.g., by the integration of digital technologies in pedagogical activities. Almost two thirds, 65%, of the teachers having passed the TFAL course thought they had to transform their teaching practices, making fundamental changes compared to previous practice. The fundamental changes experienced by the teachers of the TFAL course foremost involved the technological aspect of designing teaching and learning activities where the technology was to serve as leverage for the pedagogical factors.

Study 3 also noticed the importance of support and interaction from the school leaders to the teachers attending the TFAL course. One reason that this support was clearly felt is attributed to the unanimous decision among the educational department and school leaders in the municipality. The teachers whose school leaders were actively engaging in the course by reading their analyses, attending the IRL meetings of the TFAL course, giving them supportive comments on the course site where all analyses were published, showed more progress and were more positive during the course. This was confirmed in the next study (study 4), showing from a leadership point of view that active engagement and support from the school leaders to the teachers attending the TFAL had a positive effect on the improvement of teaching and on the learning among students. This, overall, confirmed the importance of leadership for driving and supporting change.

The research (study 3 and study 4) further concluded that the course had been both effective and sustainable in regard to second-order change. It was

also clear that the course in itself was quite demanding, challenged traditional thinking and required significant support from the school leader and colleagues but most of all a willingness to challenge predetermined perceptions towards change of ordinary practice (study 3 and 4). Results from study 4 also suggest that leadership factors conducive for the effectiveness of TFAL was that the effort was organized and sustained by the local educational department in a joint decision with the school-leaders; consistent with overall policy in the municipality; made an overall standard course and engaging teachers as course leaders and mentors during the course.

The evaluation led to the decision of continuing the TFAL course for the purpose of sustaining the dissemination of transformational change and digitalization in all schools over the city. The school leaders wished to let more teachers at the same time attend the course, this though not possible to arrange since each course only could manage around 30-40 participants at a time. There was by now also a growing interest from other municipalities.

5.3.5 Phase 5: Conclusion

The positive results from the TFAL evaluation in combination with the demand from school leaders to let more teachers attend the course now placed a demand on the educational board to further extend the dissemination effort. At the same time the positive results from the municipality aroused interest from a national point of view. The Swedish Association of Local Authorities and Regions (SALAR) found the research results of sufficient interest to assist the dissemination efforts. Under their auspices, and with the support from me as a researcher and course leader, the TFAL course was scaled up to become a national course open to all Swedish municipalities, focusing on locally administrated TFAL courses supported by the local municipal leadership from educational departments and school leaders. The national course was held at SALAR in Stockholm, the capital of Sweden, and launched in year 2016/17 in the form of a replica of the course in the municipality but now focusing on educating course leaders in other municipalities in Sweden. In 2017, due to an increased interest from more municipalities located further away from Stockholm the national course in 2017/18 was redesigned into a blended course. The course named WTL blended learning (STL blended) consisted of only two IRL meetings and all other activities, including webinars with course leaders similar to the TFAL course including theory and practice of WTL as well as digitally written formative assessment between teachers all over Sweden in a software-based application, Canvas. The course leaders in the national blended course were

course leaders and WTL-mentors from the TFAL in the municipality of origin, together with teachers from other municipalities all attending the SALAR in the national course held 2016/17. The newly designed blended course included teachers from all over Sweden, but also some participants from the neighboring country Norway. The blended course was held for three years; 2017/18, 2018/19, 2019/20 and was thereafter redesigned into a new form by one of the former course leaders of the TFAL in the municipality of origin, now the overall responsible national course leader at the SALAR.

The national course, now focused on supporting more municipalities in designing their own TFAL course, is still ongoing at the time of writing (October 2020). To date, 320 teachers have taken the one-year long TFAL course in Sollentuna, and 580 teachers from 52 municipalities during 3 years have taken the blended course arranged by SALAR. In addition, 17 other municipalities in Sweden, trained by SALAR, also arrange yearly local training courses in WTL. The total number of teachers that have fulfilled the TFAL course up until today is approximately 1500-1800 and in the municipality of origin, Sollentuna, the course was in 2020 arranged for the ninth consecutive year. All together, including Sollentuna, teachers from 70 municipalities in Sweden so far have participated in a local (or national) training course in WTL.

6. Summary of Papers

The objective of this research was to learn how to make leading digitalization a matter of learning and pursuing an effective and efficient digital transformation, instead of "implementing solutions". This thesis investigates the struggle for digitalization by asking:

> *How can a school organization at municipal level lead digital transformation through the digitalization of teaching- and learning processes in an organized, professional, and, as far as possible, scientifically based way?*

This chapter summarizes the findings from the four studies conducted in this thesis. For each paper the aim and research questions are presented followed by a brief description of the research methods used, the results, and the conclusions drawn. In Table 6 an overview of the studies, corresponding research questions and key findings is provided.

Table 6 Summary of studies, research questions and key findings

Studies	Research Questions	Key Findings
1. Improving literacy skills through learning reading by writing: The iWTR method is presented and tested	Does the iWTR method improve children's skills in reading and writing? What teaching factors are essential in order to make the integration of ICT and the students' literacy development as favorable as possible for the students' reading and writing capabilities?	Reading was improved, writing showed an even greater improvement. Effectiveness for both high- and low performers, indications of increased results in mathematics. The importance of written and social interaction for making the best use of technology use and learning.
2. Closing the gaps – improving literacy and mathematics by ICT-enhanced collaboration	The overall hypothesis of this study was that: ICT use, in combination with a pedagogical method including formative feedback as a digital form of social interaction among peers improves results in literacy and mathematics	WTL yields higher average scores both in literacy and mathematics, a smaller gender gap, and significantly better results for the under-achievers. The control group where technology was used only as an add-on tool performed worst, which indicated that technology use had to be well integrated into the pedagogy to be useful.

3. Disseminating Technology-driven Innovation in School – Managing Educational Change of the Second Order	How can a pedagogical method that requires integrated ICT use and second-order change be disseminated?	An adoption rate of, in total, 78% with no radical fluctuation over the five years. WTL required teachers to not only add technology to some of their traditional methods but fundamentally rethink their teaching practice and considerably change ordinary practice.
4. Disseminating digital, science-based innovation in education – a leadership challenge	What are the main leadership challenges for successful dissemination of a research-based pedagogical method aiming to support ICT use, create transformational change and improve teaching and learning?	Major findings conducive for positive development were that: The innovation was tested in research. That the effort was endorsed and sustained by the central management together with: Active support from principals. A professional management language. Developing and nurturing an external professional forum.

6.1 Study 1

Improving literacy skills through learning reading by writing: The iWTR method presented and tested

Study 1 was a pilot study conducted to learn more about how effective methods can be designed, used and evaluated in the settings of education. Therefore, the aim of this first paper was to innovate, design and evaluate such a method. According to the Information Systems (IS) artifact theory, advanced by Lee et al. (2015) and already well-known key factors for learning, i.e., effective instructions (Hattie & Timperly, 2007) and formative feedback (Black & Wiliam, 2009), the iWTR method was designed as a structured ICT-enhanced pedagogical method for increasing literacy among 7-year-old students.

Study 1 was a small-scale study, providing empirical research of young students learning to read and write by using the model of iWTR integrated with digital technologies and digital learning environments used for teaching and learning. The study primarily seeks to test the iWTR method

through comparing the learning outcomes with learning outcomes from the non-use of digital technologies and traditional teaching of literacy in early years. The iWTR method is underpinned by a socio-cultural learning perspective where learning is expected to be built upon, and increase, social interaction between teacher-learners and learners-learners.

Two overall research questions are inherent in this study;

RQ 1: *Does iWTR method improve children's skills in reading and writing?*
RQ 2: *What teaching factors are essential in order to make the integration of ICT and the students' literacy development as favorable as possible for the students' reading and writing capabilities?*

The tentative method was tested by measuring performance in reading and writing using two test groups and two control groups (total n=87) by systematically measuring performance in reading and writing and by using standard tests in combination with observations and student evaluation. Cumulatively, this was to assess social and individual effects of using the tentative method.

As there was no possibility of recruiting students on a random basis, this first pilot study was a quasi-experiment using the existing available classes.

The findings showed that the three hypotheses made were supported by the results. The hypotheses were as follows:

iWTR leads to better reading and writing skills (H1) and that ICT tools (H2) and a well-designed social environment including peer feedback (H3) would be instrumental to achieving those results.

Whilst reading skills were improved considerably, the greatest improvement concerned writing skills among the 7-year-old students. In addition to writing longer texts, students using the iWTR method also wrote more advanced texts with significantly better structure and more elaborate language.

Overall, the study showed that: reading was improved, writing improved even more significantly, greater effectiveness for both high- and low performers, indications of increased results in mathematics and illuminating the importance of written social interaction for making the best use of technology use and learning.

Study 1 contributes to both research and practice by providing an innovative, theory-based ICT-supported method for literacy. The results shown in study 1 further led to a redesign of the iWTR method, now also comprising other subjects and extending the formative feedback among peers.

6.2 Study 2

Closing the gaps – improving literacy and mathematics by ICT enhanced collaboration

Study 2 was conducted for a broader testing of the effects when using the iteration of iWTR, now renamed Write To Learn (WTL), by comparing the test group and two control groups, one using a traditional method (no digital technologies) and one using technology individually (without integrated social interaction and formative feedback), to compare results from students in grade 3 national tests in mathematics and literacy. The overall hypothesis of study 2 was that:

ICT use in combination with a pedagogical method including formative feedback and assessment as a digital social interaction among peers improves results in literacy development and in mathematics.

The overall hypothesis was operationalized by eight more specific ones (see paper 2).

Study 2 included 502 students, exposed to different teaching methods over a period of three years during grades 1-3. The data were collected through the use of a nationwide test (NST) carried out by all grade 3 students in Sweden. The NST test abilities related to reading, writing and mathematics, with a total of 15 tests (8 in literacy and 7 in mathematics).

The study tested WTL both regarding the use of ICT tools and the use of a specific social pedagogical method. The traditional method was used as control group for the ICT use, and the ITU method was used as control for the social interaction arrangements – such as the formative feedback supported by ICT – that were a crucial part of the intervention.

The findings showed that WTL yields higher average scores both in literacy and mathematics, a smaller gender gap, and significantly better results for the under-achievers. The control group where technology was used only as an add-on tool performed worst, which indicated that digital technologies have to be deeply integrated into pedagogy in order to lead to improved student results.

Study 2 contributes to both research and practice by providing an innovative, theory-based ICT-supported method for literacy and mathematics. The results shown in study 2 further led to an extended dissemination effort of the WTL through the TFAL, aiming for managing educational change of the second order.

6.3 Study 3

Disseminating Technology-driven Innovation in School – Managing Educational Change of the Second Order

Study 3 was a response to the positive results of the two former research studies within this thesis and aimed at understanding opportunities and challenges involved in disseminating the WTL method. Study 3 provides empirical research from a five-year dissemination effort to implement WTL, proven to yield improved student results but requiring a measure of second-order change. As stated by Rogers: "Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003 p 5) and "The characteristics of innovations, as perceived by individuals, help to explain their different rates of adoption" (p. 15).

In order to address the challenge of disseminating the WTL method it was necessary to both design and evaluate a communication channel explicitly for the dissemination process of WTL. Hence, TFAL was designed as a teachers' course and – according to Rogers (2003) as the communication channel – for disseminating the innovation and to be evaluated according to the: (i) adoption rate, and (ii) characteristics of the WTL method.

A communication channel transmits information from some individuals to others and can be active in promoting the message, in this case the TFAL course. According to Rogers (2003), mass-media channels are more effective regarding the transmission of information of innovations from a few individuals to a large audience whilst channels characterized by face-to-face interaction are more effective in regard to changing ordinary beliefs or attitudes towards a new idea. Five years, according to Borman (2003), is a critical time for an innovation to survive in school, unless the champion is still present to lead and inspire.

Study 3 provides empirical research covering the effects of the TFAL course after a five-year dissemination effort.

The key research question of the study is:

How can a pedagogical method that requires integrated ICT use and second-order-change be disseminated?

Study 3 investigates the adoption rate of a survey to 154 teachers who attended the TFAL course during the years of 2011-2015.

The findings showed a total adoption rate of 78% during the five years the TFAL course was studied. The results showed no radical fluctuation

regarding the teachers' adoption over the years. The adoption rate can be considered relatively high as the method required teachers to not only add technology to their traditional methods, but also fundamentally rethink their teaching practice and considerably change their habits. Major implications from study 3 concern: (i) having enough evidence for the quality of the innovation, (ii) the creation of an extended social system – involving many schools which helps foster and spread shared ideas, (iii) handling diversity, hence allowing time for change but relatively fast creating a sufficiently large professional community.

Study 3 contributes to both research and practice by providing insights and implications from a five-year long dissemination effort of the WTL.

6.4 Study 4

Disseminating digital, science-based innovation in education – a leadership challenge

Study 4 aims to more deeply study and learn from the experiences of school leaders attending and supporting teachers participating in TFAL, organized with the aim of disseminating WTL. The study uses qualitative methods and studies the challenges of leading digitalization of education in the municipality, in focus in this thesis, and which decided to implement an IT-supported method for teaching literacy in primary school across the city. Implementation was achieved through the dissemination of the WTL method through teacher training and leadership instructions to school principals. Study 4 draws on interviews with school principals guided by Rogers (2003) theory of diffusion of innovation. Data was collected by means of semi-structured interviews with 12 school leaders who had been involved in the TFAL course given to teachers in the municipality for five years. The total number of school leaders (and schools) in the municipality was 14. One was a special school for students with severe disabilities where the WTL was not applicable, hence the TFAL not to be considered. One school leader from the 13 ordinary schools was not available for interview. This means the 12 respondents represent a good coverage of the schools where the implementation of the WTL through the TFAL took place. The interviews were conducted in the summer of 2015 at the educational department of the City of Sollentuna. The interviews and coding were based on the main elements of diffusion of innovation as found by Rogers (2003): innovation, channel,

social system, time, and the characteristics of the innovation, which are relative advantage, compatibility, complexity, trialability and observability. The key research question of the study was:

What are the main leadership challenges for successful dissemination of a research-based pedagogical method aiming to support ICT use, transformational change and improve teaching and learning?

Study 4 showed that critical factors according to elements and characteristics of Rogers (2003) DOI were; the communication channel, e.g., the TFAL; internal and external social systems (within and between schools); characteristics of the WTL e.g., compatibility and observability. Major leadership factors conducive for positive development were: (i) an effort organized and sustained by the senior educational management of the municipality (ii) engagement and active support from principals at all stages of implementation (iii).

Study 4 contributes to both research and practice by providing implications for leadership from a dissemination effort of the WTL in the form of the TFAL.

7. Discussion

Against the backdrop of the poor and uneven progress of school digitalization, this thesis aims at supporting the process for improving the use of digital technologies.

Noting the problem of leading digital transformation in a sector which is largely decentralized as regards administration, economy, and pedagogy, and where the role of technology is yet at an exploratory stage, the thesis started from the overall research question:

> *How can a school organization at municipal level lead digital transformation through the digitalization of teaching and learning processes in an organized, professional, and, as far as possible, scientifically based way?*

This overall question was operationalized by three research questions. In an overview, the answers to these questions, to be discussed in this chapter, are as follows:

RQ1: How can improved teaching and learning methods be designed and implemented?

While there is obviously not just one single way in which this can be achieved, this thesis answers this question by designing and implementing it in one particular way and showing that this way works and addresses some of the shortcomings of much of the current practice. The answer includes two main parts:

1. Using a framework for development that can cater for the complex nature of teaching and learning in school settings, the Information System Artifact model. This has been shown to help overcome the problem of unfocused development and imbalance between technology, instruction and teaching and learning processes which has put schools very much in the hands of technology manufacturers and political wishful thinking about technology as a silver bullet for improving education.
2. Using a development method that involves users in a concrete way. The Design Science Research method has been shown to make it possible for technology users – primarily teachers, but also school leaders – to clearly see how technology and teaching practice can develop

together and produce visible results. The main advantage, from this perspective, of DSR is the stepwise development of an artifact involving users and real use situations.

RQ2: How can we measure the result of the use of such a method outside the classroom of origin?

1. Focus on student results. It is important that measurement focuses on student results in a long-term perspective. Measuring the performance of a school in terms of student results is difficult and linking the results clearly to school operations is even more difficult. Nonetheless, it is important to devise ways of doing this, because there is a need to learn what can be considered effective teaching and what is not. In this project, student results were measured using a standard national test and using two control groups in order to be able to measure the effects of technology and method independent of each other. Such situations can be hard to arrange in a school setting. In this case we were fortunate enough to be able to evaluate at a point in time where such a setup was possible. This is not the only way to do it, but it is important to ensure as good an evaluation as possible.
2. Move on in a stepwise fashion. Effective digitalization often requires considerable change – as was certainly the case here – and investing in major changes in operations requires some credible evidence that the effort will yield positive results. While increasing, the evidence to be learned from research and best practice is still fragmentary. Moreover, in schools "all business is local". The teacher is the most important factor for students' learning, and hence pedagogical development must, to a considerable extent, take place locally. This means that importing "solutions" is not possible (but looking for new ideas elsewhere is important!), evidence for the effectiveness of new methods needs to be gathered starting with small-scale testing based on research and good practices observed elsewhere. Upscaling must also be accompanied by close monitoring. In this case the development sequence included: (1) a small pilot study, (2) a course for some teachers, (3) a test of student results in grade 3 for a large student sample, and (4) expansion of the course to encompass all teachers in the city. After the thesis work the development has continued with other parties joining in to make the course a national effort.

RQ3 How can such a method, if successful, be disseminated across a school organization and what is needed to make other teachers and schools adopt the method?

1. Stakeholder engagement: Dissemination of a pedagogical method across schools in a city or a region is complicated as teachers have professional freedom. School organizers who wish to impose some fundamental changes need to start from professional innovation and respect professional integrity. This thesis shows the necessity to involve the entire school organization, from teachers and principals to the local school authority, including the local political School Board.
2. Professional and inclusive management: Dissemination takes a long time and requires sustained effort. It must be managed by the school authorities and include an agreement of active and sustained engagement and joint leadership from both the school authority and the school leaders within the organization.
3. The artifact: The innovation must be manifested in a way that makes it possible to be easily adopted by others. In this case, both the learning artifact (WTL) and the teacher education artifact (TFAL) were adopted as both were designed to work together. The WTL method was adopted by both individual teachers inside and outside of the municipality of origin, and by school organizations in other cities. The TFAL course was adopted by other cities and by the national organization of municipalities and regions. In this way it developed to both various local courses and a national one.

This thesis has presented a successful case, but this does not mean that the success can necessarily be easily repeated elsewhere. The findings can be generalized to some extent, but because teaching and learning are social activities, they are dependent upon the social system in which they take place. Any teaching method is dependent upon the teacher who is using it. Any teacher is dependent upon the student he or she is teaching, and on other factors in the local social setting. Therefore, WTL is a method that can produce good results if correctly used. However, it does not automatically lead to success. TFAL was designed to help achieve good use of WTL, but like WTL it is dependent on how it is conducted and in what social setting it takes place.

This thesis shows that a method designed for supporting the balance and interdependence between technology, instruction, pedagogy and learning environments can support teaching and enhance learning, thus leading to significantly increased student results. It is important, however, to stress

that the use of methods includes both strengths and weaknesses as dependent on how they are applied by the users, in this case both the teachers and the students situated in different socio-cultural and contextual environments. Moreover, the design and implementation of a method to be used in school settings is not clear cut and comprises challenges with respect to intruding on the professional territory of the teacher. Beyond this, methods – and particularly strict ones – tend to become obsolete faster and since the area of digital technologies is evolving rapidly methods risk being outdated, hence jeopardizing the implementation process. As a result of such challenges in designing and implementing the teaching and learning method within this thesis, the design of the WTL method has comprised a difficult and delicate balance between clarity in guidance and free space for teachers to exert their professionalism.

Some evidence of the generalizability of the method is that, after the completion of this work, both the WTL method and the TFAL course have been adopted by different cities. While this shows that teachers and school leaders find the method useful, there is so far only anecdotal evidence of the success in terms of student results.

What is definitely a generalizable finding is the demonstration that the "*silver bullet technology myth*" is not valid. The thesis shows that technology use without a good method is not only useless, but even counterproductive, and can lead to deteriorating results. While this finding is not unique to this thesis, it is an important takeaway for the school sector as often technology is in fact presented as a silver bullet for schools. Letting technology dominate other factors important for teaching and learning can be compared to letting digital technologies steer pedagogy in school. It is therefore of great importance that we can distinguish the unconsidered use of digital technologies in school from well-integrated ones and learn from what works and what does not.

Hence, we need to learn both how to design for improved teaching and learning by integrating technology with instruction and socio-cultural interaction and how to implement this ecosystem of artifacts into real-life teaching and learning contexts. The ISA model has shown to be a good tool in this process.

The use of DSR as a framework for the iterative developmental implementation process, involving users along the way, has been shown to benefit the stepwise advancement of the artifacts in this thesis, relative to real-life contexts. On the other hand, in the same way as real situations and condi-

tions are an advantage for the development of the artifacts, they entail disadvantages in terms of generalizability. Inevitably, the use of DSR in this research includes situational and contextual conditions associated with the municipality, e.g., the school organization, school leaders and users in an internal (within schools) as well as the external (between schools) social system and socio-cultural context. There is a risk that, during the efforts to improve the local situation, some solutions are very local and may not work in other contexts. In other words, in order to improve generalizability, the boundary conditions for the method must also be tested in other contexts. For such tests, again a DSR approach can be recommended, not least because it helps the user to adopt a structured and reflective approach to technology use. There are many details pertaining to the use of the method, for example exactly which technical tools to use, that can be changed without jeopardizing the basic thrust of the method and the overall design of the technological setup. Technology develops and new tools appear that make use easier or more effective in various ways. Such opportunities must of course be taken advantage of whenever possible.

7.1 Contributions to practice

Teaching practice and school leadership are often, in practice as well as research, considered separately. This thesis studies them together and demonstrates how a model that includes both of them can be effectively applied to the problem of succeeding in digital transformation

This is a contribution to both teaching and school leadership practice as, used skillfully, the experiences from this case will give school professionals and school organizers tools for improving their own digitalization process. It will also give them a better position in handling technology vendors and politicians as they will be more skilled in presenting requirements on technology in procurement processes and discussing how resource allocation and school management affect school performance in terms of student learning results.

A main concrete contribution is the design of two IS artifacts WTL (Write To Learn) and TFAL (Teachers Formative Assessment Learning). Together they provide tools for both teaching in a blended learning environment and professional development for such teaching.

Table 7 summarizes contributions to practice.

Table 7 Practical contributions

Practical Contribution	Description	Beneficiaries
WTL	Improves knowledge of designing learning contexts Improves learning contexts	Teachers, School leaders Students
	Improves integration of digital technologies into pedagogy	Teachers, Students, School leaders
TFAL	Improves knowledge of designing for dissemination of innovations over a school organization	Policy makers, School authorities School leaders, Teachers
	Improves teacher training Creates an external social system within the organization	Teachers, School leaders, School authorities
Digitalization leadership using ISA model and DSR method	Improves knowledge and skills for leading digitalization	Policy makers, School authorities, School leaders

7.2 Contributions to research

One contribution to research is the *successful case*. The method designed, the setup of technology applied to support the method, and the implementation in the Sollentuna schools, together produced very good results in terms of student learning, as measured by the national tests in grade 3. Showing a considerable quantitative positive contribution to learning from the use of digital technologies is not very common. Because both the method, the technology use and the evaluation method are clearly specified, they are also possible to reproduce and test in other contexts.

The thesis also provides some evidence regarding *how to achieve such positive change*, namely the method by which it was achieved. While the WTL method itself may not be applied to any and all educational problem situation, the method for its design can. The thesis has contributed to research

by demonstrating the usefulness of applying the ISA model and the DSR approach in an educational setting.

Demonstrating the usefulness of ISA

Most research agrees that the educational setting is complex, yet most research focuses on narrow educational situations, on students and teachers. Research on school leadership, on the other hand, focuses less on pedagogy and more on administration and general leadership. This thesis shows that the success in both developing and disseminating the innovation was due to determined and well-measured leadership, including not just the school authorities but also the political leadership. It shows that major innovation in education, such that requires fundamental, or "second order", change, requires a comprehensive view of the school environment. Digitalization is such a fundamental change, and therefore research that aims at studying it must take a comprehensive approach.

The thesis has shown that the ISA model is a very useful framework for this purpose. It is a simple model, easy to communicate, it directs attention to the important factors – technology, information and social context – and in particular the importance of creating a constructive balance among these factors in order to make progress.

Demonstrating the usefulness of DSR

Because innovation in school is difficult and the usefulness of technology not well understood – and very costly – it is advisable to proceed with care. The DSR method starts from the understanding that the effect of using technology in a certain context cannot be completely understood theoretically or beforehand, there is a need to have an actual artifact.

This thesis demonstrates such an approach, which included several iterations and adjustments to the design of both technical, informational, and social parts of the ISA.

This is in contrast to much of the purchase of technology, where often technical tools are procured without a well-conceived idea of how they will be used. Hence, requirement specifications are frequently poor in representing the use situation.

Using the DSR method will help the user-side of the procurement process be more prepared and better fitted to specify and argue their needs.

8. Conclusions

The overall research question of this thesis is: *How can a school organization at municipal level lead digital transformation through the digitalization of teaching- and learning processes in an organized, professional, and, as far as possible, scientifically based way?* Therefore, the focus of my research has concerned how digital technologies can be implemented into teaching practice for enhanced learning across a school organization and the challenges faced by those affected by that change.

The empirical basis of this research consists of a case study in a Swedish municipality and includes participation of students, teachers and school leaders. The research is based on four studies in a mix of quantitative and qualitative approaches comprising different methods, e.g., national tests, surveys and interviews.

In summary, the conclusions are:

1. Only supplementary use of digital technologies in school does not per se lead to improved student results. It may even be counterproductive insofar as it reinforces ineffective processes and prohibits change.
2. Digital technologies, primarily used for individual student work, and with less instruction and social interaction (physical or digital) do not per se lead to improved student results.
3. Improving teaching and learning by the use of digital technologies requires the integration of technology into pedagogy and different learning contexts.
4. Successful integration of technology into pedagogy is dependent on conducive alignment of technology, information handling, and the social context of the teaching and learning environment.
5. Successfully integrated digital technologies in learning contexts supported by well-designed teaching activities and social interaction can lead to significantly increased student results.
6. The most challenging part of integrating digital technologies in teaching practice is not related to technical issues but rather to beliefs and attitudes among those affected by the change.
7. Leading transformational change in school – in this thesis discussed as moving from digitization towards digitalization – requires joint and continuous leadership from all levels of the school organization

8. Successful digitalization requires second order change on the part of both teachers and school leaders, in which the barriers are intrinsic, including beliefs about digitalization and persistence to change. Such beliefs are dependent on both internal (within schools) and external (among schools) social systems within the whole organization.

These conclusions have implications for practice. Together they make clear that the way technology is handled in school – including the entire process from procurement to deployment and evaluation of results – must change from a technological imperative, i.e., buy technology first and then let people work out how to use it, to a model characterized by integrated development of technology, information handling and the social context for teaching and learning. This thesis has provided one case and some tools to demonstrate how this can be achieved.

It is in the nature of the challenge of transformational change that the advice, tools, methods and results presented here should not be taken as a blueprint. Transformational change is a creative activity situated in a certain time, place, and social environment. The ISA model for thinking about technology, the DSR method for designing tools for change, the TFAL method for teachers' professional development, and the WTL method for children in primary school to learn literacy and mathematics are useful tools for creative leaders and teachers, but they do not necessarily produce exactly the same results everywhere – like any method for change in, and of, social contexts they are all dependent on the leaders involved. The teacher in the classroom, the facilitator in the TFAL course, managers at different levels in the school system; they all need to understand the nature of change, the potentials and the pitfalls, and how to use the tools to move ahead in a way that gradually leads to better, and more empirically proven, learning environments.

The thesis has provided useful methods and tools and tested them. Now it is up to school leaders and teachers to provide ambition, skills and good judgement in using them.

Oh, and one more thing – perseverance.

8.1 Concluding remarks

This thesis has taken steps towards understanding how teaching and learning can benefit from digitalization and how a school organization can manage the transformation of that process.

During the final work of this thesis the COVID-19 pandemic spread over the world and, due to the lockdown of upper secondary schools and universities in Sweden, the use of digital technologies for teaching and learning now was even higher on the agenda. Sweden had already had ambitious goals for the digitalization of society and school. Challenges however, of equality considering the access to – and wise implementation of – digital technologies have also been well known in the country. When the pandemic spread the school system quickly had to readjust and schools, teachers and students had to do what they could to manage the change. Schools, classes and municipalities where the use of digital technologies in education, before the pandemic, was already a natural part stood better prepared for home schooling.

This said, there is a digital gap between municipalities that know more of how to lead the change of implementing digital technologies for improved teaching and learning and those who do not possess this knowledge. This thesis has provided useful methods and tools and tested them. It is now up to the local authorities and school organizations to provide ambition, skills and good judgement in using them for local development in their own organizations.

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