Towards Visual Literacy in School

Interactions between Students and Interactive Visualizations in Social Science Classrooms

Ulika Bodén
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Abstract

This compilation thesis explores how the double aspect of visual literacy is enacted in secondary schools’ social science classrooms when interactive data visualizations are employed. The aim is to map what characterizes ‘reading’ interactive data visualizations and ‘writing’ knowledge visualizations, as well as implications for a didactic design supporting students’ visual literacy. The interactive data visualization introduced by this thesis is the visual analytics application Statistics eXplorer, which offers support in analyzing vast amounts of data. Such information-rich interfaces provide possibilities for students to find correlations and draw conclusions, but they also generate complexities regarding interactive and multimodal texts and require modes other than the written when insights are to be demonstrated. The thesis is positioned under the umbrella of actor–network theory, thereby a socio-material perspective guides the study of interactions between actors (students, teachers, lesson plans, visualizations, written texts, etc.) Applying design-based research, an intervention is designed and conducted in seven social science classrooms comprised of four teachers and 152 students. The empirical material consists of zoomed-in webcam recordings capturing the students’ faces, voices, and gestures as well as the activities on the screens. It also includes wide-angle captures, field notes, and one focus group. Material discursive analysis guides the analytical work. The findings reveal a reading characterized as intense, performative, collaborative, and dynamic. The reading process is distinguished by searches for a starting point, a production of reading direction, and a continuously changing reading surface. The findings also show how students’ insights from this kind of reading can be translated into knowledge visualizations in a writing process that is characterized by exploring, gathering, and inserting visuals as carriers of information. Furthermore, by identifying critical issues in the classrooms, a didactic design framework of vital components is constructed, which demonstrates how teachers can design teaching that supports the development of students’ visual literacy.

Keywords: design-based research, interactive visualizations, knowledge visualizations, multimodality, social science education, socio-materiality, visual analytics, visual literacy
Acknowledgement

This is the part where I have the opportunity to show gratitude to all the people who, in one way or another, have supported during my time as a PhD-student. I would like to begin with a quote by Nancy Willard, an American writer, illustrator, and professor:

I haven’t a clue how my story will end, but that’s all right. When you set out on a journey and night covers the road, that’s when you discover the stars.

When reading these lines, you will soon find out that I, metaphorically, relate this thesis as if we are on a journey. Some would say that this way of figurative writing does not belong in the traditional scientific realm of how to present your doctoral thesis, but for me it is a way to emphasize the adventures I have experienced during these last years. It has been a curious and committed search for the unknown, combined with an insecurity of leaving familiar grounds, both on a professional and a personal level. The scientific journey has affected me in so many ways throughout these challenging and demanding - but also joyful - years. This endeavor has been made possible thanks to the hard and heartfelt work, uplifting comments, and love of many ‘stars’. As I now reach the end of this journey (and the beginning of a new and unknown one), time has come to acknowledge all of you who have enlightened the path and stood beside me.

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Now I turn to those with a special place in my heart. My mother Åsa and my father Staffan (I miss you), you have supported me in various
ways throughout my life, always being curious and encouraging. Also, my
two beloved sisters Malin and Sofia with families, words cannot express
how happy I am to have you so close at heart. We have shared so many
ups and downs in life and no matter what, our warm love and care will
accompany us - forever and ever.

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Fredrik, my love and co-captain! With your sparkling eyes, enthusiasm,
cleverness, and sense of humor you came into my life during this journey.
You make me stronger and more courageous. I long for new and adven-
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Olle and Erik, I am so grateful for being a part of your lives. You make
me wiser, prouder, and happier than ever before. My decision to enter on
this journey has also affected you in many ways, but hopefully I have
shown you that everything is possible, especially if you work hard. The
three of you are everything to me! I love you to the moon and back!

Norrköping February 2023

Ulrika Bodén
List of papers

This compilation thesis comprises the following papers:


Glossary of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANT</td>
<td>Actor–network theory</td>
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<tr>
<td>DBR</td>
<td>Design-based research (method)</td>
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<td>KV</td>
<td>Knowledge visualizations</td>
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<tr>
<td>OD</td>
<td>Open data</td>
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<td>RT</td>
<td>Research team</td>
</tr>
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<td>TRT</td>
<td>Teacher researcher team</td>
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<td>VA</td>
<td>Visual analytics</td>
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<td>VISE</td>
<td>Visual storytelling in education (the overall project)</td>
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<td>VISLET</td>
<td>The customized teaching material produced at the VA application Statistics eXplorer platform</td>
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<td>VL</td>
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Chapter 1

Embarking on a research expedition in visualized classrooms

This thesis can, metaphorically, be viewed as a research expedition that departs from the well-known ‘port’ of what characterizes reading and writing and how it is usually performed in schools. We sail from that port’s solid wharfs and piers; i.e., practices and procedures necessary to read and write written text, as societal and technological circumstances change the conditions for reading and writing. This thesis/expedition will leave the embankments of certainty and solid ground, as setting out for discoveries of how reading and writing “could be otherwise” 😊 (Woolgar & Lezaun, 2013); i.e., ‘reading’ interactive data visualizations and ‘writing’ knowledge visualizations.

The expedition will maneuver along the shores of challenges in contemporary society and education, challenges that this thesis will show also emerge in a social science classroom when interactive data visualizations are introduced for communication, and visual literacy (VL) becomes important. Where the final port of disembarkation stands is still out of sight, but during this journey, interesting aspects of how the practice of reading and writing can be performed will be discovered and the thesis will contribute deepened knowledge of the relations between students, visuals, and the written. Just think of how the emoticon above affects you! For sure, that visual asserts itself and adds color to all the written black letters. You might find it invigorating or simply annoying. In any case, I am convinced that your gaze spotted the smiley quickly.

There are several reasons for embarking on this research expedition; to explore how ‘reading and writing’ can be done in different ways, or more specifically, to discover what characterizes 13–15-year-old students’ ‘reading and writing’ related to interactive data visualizations in social science classrooms, and to discern critical issues and implications for the didactic design in these classrooms.

The research expedition departs from the post-truth era, mainstreamed into contemporary society, with an unprecedented information overflow which poses fundamental intertwined challenges also related to technological developments and shifting communicative practices.
Together this may influence us to leave the anchoring of usual reading and writing pedagogy in school and force us to adopt altered communicative practices (Figure 1).

**Figure 1. Societal and technological aspects challenge assumptions of reading and writing and impact the communicative practices in school and how to handle content in social science education.**

**A post-truth era**

Throughout history, technological progress has changed and challenged the dynamics of societal interactions and processes (Bijker, 2006; Pinch & Bijker, 1984; Callon, 1987; Hughes, 1987; Perez, 2004). Today, especially given the high pace of information diffusion, the absence of evidence-based explanations, risks spreading unfounded interpretations, perceptions, and opinions at the expense of objective facts (de Pablos & Lytras, 2019; Lewandowsky et al., 2017; Visvizi & Lytras, 2019). In 2016 the concept of ‘post-truth’ became the “word of the year” in the Oxford English Dictionary and is defined as “relating to or denoting circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief” (McIntyre, 2018, p.5). According to Modreanu (2017), the post-truth era emerged due to trends affecting the way we make sense of the world, blurring the demarcation between truth and lies, fiction and nonfiction, etc. For example, Farkas and Shou (2019), Sismondo (2017) and Van Dyk (2022) highlights how values such as democracy are threatened by falsehoods, skewed stories, and conspiracy theories. This continues to be debated as the relationship between society and technology is complex and challenges how people create their worldviews (Visvizi & Lytras, 2019).
Information overflow, open data, and falsehoods

At the same time as the border between truth and lies are blurred and facts are questioned, this is related to how society is flooded by information due to the power of computer technology. Technological developments have fostered and stimulated the production of an “information overflow”, and enormous amounts of information are collected, saved, and used for numerous purposes (Czarniawska & Löfgren, 2019). The amounts—created and accumulated by both human and non-human actions—are impossible to overview (Marr, 2015; Mediratta, 2015; O’Neil, 2016). This puts pressure on authorities and media but also on the public, who are trying to navigate this information overload where both information, and disinformation are available in many forms, in many places, and on many devices or platforms (Nissen et al., 2021; Wikforss, 2017). For example, technically advanced large servers, open data (OD) platforms, and data mining tools are accessible and enable working with, sorting out, and searching for patterns and connections in large data sets (Guru Prasad et al, 2017; Le 2013). While some refer to OD as transparent information that, for example, promotes faster and better decision-making, enhancing efficiency (Cordasco et al., 2017; Davenportis, 2014; Eynon, 2013; Saddiaq et al., 2019) others raise critiques questioning the measurement, ordering, and biases of the data, how it is used, and whether it carries trustworthy facts (Daniel, 2019; Boyd & Crawford, 2012; Mahmud et al., 2017; Selwyn, 2014).

What is apparent is how the terms “data”, “information” and “facts” are often mixed and implicitly attributed almost the same meaning. Rosenberg (2013, p. 33) discusses this and explains how the connotation of the term “data” has shifted during history from the 18th century, where it was “…referring either to principles accepted as a basis of argument or to facts gleaned from scripture that were unavailable to questioning…” to at the beginning of the 19th century, where it was “…referring to facts in evidence determined by experiment, experience, or collection”. The latter meaning suggested that data was thought of as the result of an investigation rather than its premise, which is still today how we commonly think of “data”. Noticeably, it is tempting to define what exact kinds of facts “data” connotates, but according to Rosenberg (2013, p. 37) this misses the most important aspect of the term: assumptions of veracity. It is important to be aware that data has no inherent truth (Chaim, 2007;
It is when data gets processed, organized, and presented in a given context that it turns into information (Chen et al., 2008; Zins, 2007), which also is in line with Ackoff (1989) says; that when processed, data may become useful, and provide answers, true or false, on questions, like, for example, “who, what, where, and when”. However, through gathering, sorting, and extraction procedures, the data risks losing its context, yet it can still be presented as factual information (Sundin, 2017). Also, one challenge is tracing the origin of information, because once data is processed and transformed into information, the source often becomes unknown or invisible (Selwyn, 2015). Hence, determining which information can be labelled as “trustworthy” is not uncomplicated, and must be done in a critical manner. For example, digital texts based on anonymous sources, may be skillfully manipulated, which makes it difficult to verify their credibility (Molin, 2020). Various problems spring from these circumstances, for example the risk of not being able to see beyond what has been commonly labeled as “alternative facts” and “fake news” (Andre & Lavicza, 2019; Journell, 2017; McIntyre, 2019; Tandoc et al., 2018; Wikforss, 2017).

In all, this affects the prerequisites for our possibilities to obtain a view of the world based on facts and trustworthy information. For example, Rosling et al. (2005, 2018) argues that our understanding of global problems like climate change and its impacts, poverty, economic growth, inequalities, etc. are affected by the use, or misuse, of open data and plentiful information.

Consequently, as we are faced with an increased accessibility of large datasets, there is a growing demand that we raise our awareness and actively engage in exploiting OD (Cordasco et al., 2017; Saddiqa et al., 2019; Sundin, 2017). Wikforss (2017, 2021) argues that schools should play a central role in revealing the fake and obscured and instead build knowledge from trustworthy sources. Nissen and Stenlidén (2020) write that it is especially urgent to develop students’ awareness of how to choose relevant data, trustworthy information, and to assist them in developing abilities to handle such information.

*Fact-based worldviews through information visualizations*

Nowadays information technology such as visual analytics (VA) is developed to offer supporting methods to retrieve and analyze relevant
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Information. VA is an interdisciplinary scientific field based on information visualization, and cognitive and perceptual sciences (Thomas & Cook, 2005). It concerns the possibilities of facilitating analytical reasoning through designing and arranging visual interfaces, thereby arranging data using interactive visualizations in order to enable interactive analysis processes (Andrienko et al., 2011). In doing so, interactive data visualization applications may help people understand the significance of large volumes of data by placing them in visual contexts (Andrienko et al., 2011). Tomaszewski and MacEachren (2012), argued that by using VA, the visual capacity should be taken advantage of more often and in more structured ways. Working with data is made possible through software that is compatible with big datasets, and thereby rendered user-friendly (Saddiq et al., 2019). The visuals in a VA application can help users to process data, and understand and learn from the information (Ho et al., 2011; Jern, 2010; Saddiq et al., 2019). Patterns, trends, and correlations exposed visually can be more easily detected with VA applications like Gapminder (Rosling & Zang, 2011), Statistics Explorer platform (Ho et al., 2011; Jern, 2010), Tableau (Jena, 2019), TinkerPlots (Konold & Miller, 2005), and QlikView (Shukla & Dhir, 2016). Statistics Explorer is used in this study. In such VA applications, data in the form of official statistics have been transformed into interactive visualizations like colored maps, scatterplots, and bar charts, etc. Official statistics are gathered and sorted by statistical agencies in regulation to the UN; they do not come from uncertain sources or sourced from any database or webpage on the Internet.

In this thesis data are the uploaded official statistics from various official databases, and when processed by the VA application the official statistics turn into visualized information. Subsequently, interactive data visualizations are viewed as representing relevant facts. Hence, these VA applications support users in acquiring a fact-based view of the

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1 According to the UN (2014), official statistics are based on 10 fundamental principles. They should be compiled and made available on an impartial basis by official statistical agencies; they are an indispensable element in the information system of a democratic society; and statistical agencies should make decisions according to strictly professional considerations, including scientific principles and professional ethics, on the methods and procedures for the collection, processing, storage, and presentation of statistical data.

Altogether, this points towards possibilities developing students’ awareness of not only how to choose relevant data and trustworthy information, but also to use a VA and develop abilities to handle and communicate information to others (Nissen & Stenliden 2020; Haider & Sundin, 2022). This means that it is important for teachers to introduce information technology like a VA (van Laar et al., 2017). So far, VA applications with interactive data visualizations, seem to be rather unexploited in educational practice (Alper et al., 2017; Lundblad, 2013; Saddiq et al., 2019; Wilkerson & Laina, 2017). Relatively few studies have focused on social science education (cf. Stenliden, 2014; 2015; 2018; Stenliden, et al. 2019; Nissen & Stenliden, 2020).

**Shifting communicative ways**

The information overflow, together with digital technology as illustrated earlier, puts forward a shift in how to process and communicate information, which at the same time changes and features assumptions about texts and literacy in society (Jewitt, 2002, 2005; Kress, 2003; 2010; Leu et al., 2012; Serafini, 2011; Unsworth & Cléirigh, 2009). For example, a text in the form of an interactive interface like VA, offers information both in the form of written words, in images/visuals, and through interactivity, thereby reading and writing is performed “otherwise”. Digital screens per se and interactive visualizations in particular change the practices of reading and writing.

*Reading interactive data visualizations—to navigate and interpret*

When reading a linear printed text, we are accustomed to reading from left to right, at least in the Western world, and from one side to another. Compared to reading a digital text on a screen, the reading process is different (Kress & Van Leuween, 2006; Molin & Lantz-Andersson, 2016; Rasmusson, 2015). The range of modes available on the screen offer far more choices in the reading process. The reader must choose where to read, what to read, or in other words how best to design the reading (Bearne, 2009; Kress, 2010; Serafini, 2011, 2012, 2014; Walsh, 2006). In specific, a digital text often includes written text, hyperlinked text,
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images, graphs, charts, interactive visualizations, color, movement, etc. Several studies point at the importance of paying attention to the visual elements that compose the digital text, such as forms and spaces, dots, lines, color, typography, and how visuals and text are arranged (Burmark, 2002; Kress & Van Leeuwen, 2006; Samara, 2007; Walsh, 2017; Watzman, 2003). The many different modes require an interpretation in accordance with the multimodality of the text (Bowen & Roth, 2005; Bearne, 2003; Serafini, 2012, Walsh, 2017). In correspondence, Coiro (2003, 2014) and Serafini (2011, 2017) describe how digital reading is affected by multimodality and explain that specific reading strategies are needed. When interacting with various modes, readers must be more active and employ other strategies as there is no pre-established beginning, middle, or end in the reading (Hamat et al., 2010; Snyder, 1997). Simpson et al. (2013) refer to this type of reading as “multidirectional”. However, few studies specify what kind of strategies can support such reading.

Many research studies that focus on digital texts mostly concern texts in the format of e-books or webpages with static linear text combined with images; i.e., not interactive texts (Kucirkova, 2019a; Reich, Yau, & Warschauer, 2016). Yet, according to Jin (2013), there are limitations when it comes to research on interactive and multimodal texts; studies use various epistemological perspectives, little empirical work has been reported and most design guidelines are based on static digital text (Kucirkova, 2019b). So, although access to multimodal and interactive texts increases, few studies have explored how these texts influence the development of students’ multimodal reading (cf. Brown, 2016; Kucirkova, 2022; Rowsell & Walsh, 2011; Rvachew, 2017; Tomopoulou et al., 2019; Støle et al., 2020). Studies by Felten (2008), Elkins (2008), Bresciani and Eppler (2015) and not least Serafini (2014, 2017, 2020, 2022), and Serafini et al. (2016) have shown that it is especially important to promote students’ ability to assemble meaning—not only from a printed text, but also by interpreting or reading images—and their ability to represent and produce visual messages to use in communication with others. Also, Cope and Kalantzis (2000), Bearne (2009), Purdy (2014), and Baldwin (2015; 2016) emphasize that when working with multimodal digital texts in schools, it is important to not only thoroughly develop students’ ability to understand what is seen, interpret what is
experienced, analyze what they have been exposed to, and evaluate and
draw conclusions, but also to develop their methods for representing
‘multimodal’ knowledge formation.

Writing visualizations—to produce and communicate insights

As described, the reading practice shifts when interactive and multi-
modal texts are to be navigated through and interpreted. Also the process
of writing shifts when this process is digitalized (Clarke & Svanaes, 2012;
Ghandoura, 2012). Digital writing is often a rather complex undertaking,
as the writer plans, writes, and reorganizes the writing/the written in de-
tail, all at the same time (Williams & Beam, 2019). Hence, the digital
writing process can include a great deal of editing while writing. This is
different from writing with pen and paper, which is a process where the
disposition and planning of the writing often is emphasized (Nordmark,
2014). Instead, a digital writing process means that the writer moves
back and forth in the text, and does not, as had been the case with pen-
and-paper writing, follow a linear writing process (Kress, 2003; Staple-
contexts is often impossible to see as separate from reading, as they fre-
cently occur together. Furthermore, this kind of dynamic digital writing
appears to provide new opportunities for creating texts (Dahlström,
2019; Hitchcock et al., 2016). Also, many studies have shown that digital
resources support students in writing longer texts and show that they are
particularly supportive for struggling writers who become engaged in
writing activities to a greater extent (Batsila & Tsihouridis, 2016; Dahl-

However, even if these results are promising, solely text-based writ-
ing, in analog or digital modes, often narrows students’ possibilities to
represent their knowledge (Jaafar & Pedersen, 2021; Mangen & Balsvik,
2016; Williams & Beam, 2019). Both Godhe (2014) and Åkerfeldt (2014a)
emphasize that although students read multimodal texts and use several
different multimodal representations in their assignments during class-
room work, these are rarely shown or included when handing in their
work to teachers for assessment. Likewise, Stenliden (2014), demon-
strated that even though students can read and draw conclusions from a
VA that carry lots of information at the visual interface, it is, understand-
ably difficult for them to summarize the complex insights that they have
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gained by transforming them into writing solely through a text-based mode. Stenliden (2014) concluded the possibilities for students to transfer and demonstrate their achieved knowledge are limited as long as students have to switch from one mode to another; i.e., translate visuals into written text. She suggested that students should be encouraged to develop their digital writing by also including a visual mode.

One way of overcoming these problems can be to promote students to write and communicate their insights by introducing knowledge visualizations (KV); a form of ‘writing’ based foremost on visuals. KV is a research field that deals with information processes such as creating and applying visuals with the purpose of constructing and communicating meaning (Crawford, 2012). More specifically, it addresses how to gather, interpret, organize, and design information in/through a communicative practice (Crawford, 2012; Bertschi et al., 2011). As signs of knowledge, concepts are mapped in a graphic manner by structuring text and visuals in an intelligible order, and are possible to share with others and communicate through the process of storytelling (Bertschi et al., 2011). In other words, KV is a non-linear process of presenting knowledge by gathering, interpreting, developing understanding, organizing, designing, and communicating information (Crawford, 2012). The different steps may be linked to each other in an iterative process, as the knowledge changes, and therefore it is difficult to make a closure of a KV. In any case, it is about creating and applying visuals and text with the purpose of constructing and communicating meaning (Crawford, 2012). This communication, according to Bertschi et al. (2011), is not necessarily about communicating to others; it might also be to communicate to yourself what you have learned. In educational practice, both these kinds of KV use occur; sometimes students produce a KV just to understand and remember information, and at other times they communicate their knowledge by making some sort of presentation to others. Various studies argue that KV is an important stage in the knowledge process (Eppler, 2013; Sabol et al., 2012). In this thesis, the KVs in focus are digital KVs, but it does not always have to be a digital process, as KVs can also be an analogue communicating/visualizing a message with pen and paper.

So, while interactions between humans and visualizations at the interface of a VA aims to support the navigation and interpretation (the reading), KV targets expression and communication of the gained
knowledge (the writing). Both these fields share several common features: they assist students in producing new knowledge, provide support for understanding, and aid in decision-making (Sabol et al., 2012).

Visual literacy as a requirement for reading and writing

Shifting communicative practices are neatly described by the multi-disciplinary field of visual literacy (VL), (Avgerinou & Pettersson, 2011; Bamford, 2003; Brumberger, 2019; Kedra, 2018). VL focuses especially on the visual aspects of both reading and writing and the literacy concept is defined as capabilities that, on one hand, assemble meaning from images and interpret them, and on the other hand are able to produce images for others; thereby communicating a message (Avgerinou & Pettersson, 2011; Bamford, 2003; Metros, 2008). Accordingly, VL includes both a focus on being able to ‘read’ (navigate through and interpret) visual information, and to ‘write’, (produce and communicate) visual representations of gained insights. Kress (2005) has highlighted for a long time the importance of revealing more of this kind of literacy skills as we increasingly turn from books to screens and, in doing so, from texts to visuals.

Several literary reviews of the field of VL describe and categorize different abilities included in such reading and writing processes, but the studies seldom express implications for the educational practice (Bresciani & Eppler, 2015; Brumberger, 2019; Kedra, 2018).
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Social science education, technology, and altered literacy

Given the intertwined societal challenges related to a post-truth era, to information overflow, technological developments, and shifting communicative practices, pressure is put on the school to handle information by adapting VA, to adjust the communicative practices of reading and writing, and to develop adequate didactic designs. The arguments are reinforced by the following citation:

Pupils should be able to find their way around and act in a complex reality with a vast information flow, increased digitalization and a rapid pace of change. It is therefore important to have the ability to study and methods to acquire and use new knowledge. It is also necessary for pupils to develop their ability to critically review information, facts and relationships, and to be aware of the consequences of different alternatives.

(The Swedish National Agency for Education, 2022, p.7).

This citation is permeated with the importance of students to develop abilities to handle information overflow and relevant digital technology as well as to find ways to make insights and draw conclusions from relevant information, and thereby understand the fundamental building blocks for democratic values which will prepare students to live and work in a democratic society. Promoting this is indispensable for every teacher, in every subject, throughout every year of schooling. However, social sciences (social study subjects) become a significant arena for this endeavor. The Swedish National Agency for Education (2022) highlights the subject’s importance of:

- developing an overall view, based on facts, of societal questions
- building knowledge from tools by managing, searching for, and assessing information
- being allowed to take part in a complex world
Sandahl (2015) and Jägerskog (2020) underline that social science in school focuses on educating students on societal issues, making them understand complex and dynamic structures and processes in society, and prepares them for citizenship. The subject has a long, and strong, position as a compulsory subject in the Swedish curriculum and includes content matters in political science, sociology, economics, and human geography, strongly emphasizing the importance of conveying facts (Bernmark-Ottosson, 2009; Sandahl, 2015). Accordingly, schools, and perhaps most of all the subject of social science, holds a firm position in promoting students’ awareness of societal issues, and how to use technology to obtain and analyze relevant facts, and promote them to be good democratic citizens. As accounted for, the technology to both retrieve and visualize fact-based information and to produce visualizations is available in terms of VA.

In general, schools often face pedagogical challenges when applying information technologies in classrooms (Ilomäki & Lakkala, 2018; Meates, 2020; Sofkova Hashemi & Cederlund, 2017; Stenliden, 2014). As stated by many researchers (cf. Bodén & Stenliden, 2019; Hillman & Säljö, 2016; Hutchison & Reinking, 2011; Selwyn, 2014, 2021), integrating digital technology in education is a multifaceted and complex process, pointing towards a need to develop appropriate pedagogical methods. For example, in terms of developing teachers’ understanding of how to integrate it into instruction, there is a shift in the practices of how we access and transform information, as well as a lack of control over the information that students are exposed to. Willermark (2018) reports that although teachers express a lack of sufficient preparations for digital teaching, they are at the same time required to integrate technology into their classrooms. According to Willermark (2018), teachers express a demand for educational efforts to heighten their competence in using digital technology as a pedagogic tool, and therefore, she claims, it is crucial to support them in developing their teaching practice.

In particular, a shift toward processing information visually through VA challenges social science classrooms in several ways. It appears that a lack of experience in both pedagogical strategies of how to implement the technology and subsequently how to didactically design such educational settings is a hindrance to being regularly employing VA in classrooms (Saddiqa et al., 2019; Stenliden et al., 2017). For example,
Stenliden (2014, 2015, 2018) shows that: a) the VA application Statistics eXplorer is useful for teachers in their practice, and b) that students can use this type of interactive data visualization. However, as mentioned earlier, she also reveals that students face difficulties when transferring visually gained knowledge to written text. So, it seems to be challenging for teachers to pedagogically support such processes. Saddiqa et al. (2019) write that although students find the data visualizations to be interesting and help to improve skills in, for example, social science subjects as Geography and Civics, the visualizations are seldom used. They argue that for teachers and students to actively use visualizations it is necessary to improve their digital skills as well as to develop new interactive learning and teaching resources. However, they continue to claim that not much attention has been paid to pedagogical ideas about increasing visualization literacy at the school level. Likewise, Börner et al. (2016), Kennedy et al. (2016) and Schönborn et al. (2016) highlight that it is urgent to address the problem, even with limited knowledge of comprehending data visualizations. To support essential visualization literacy skills, Alper et al. (2017) express that more research is needed that focuses on how such visual skills can be developed and improved by composing pedagogical guidelines. To sum up, it is argued that social science teachers need to be able to introduce VA and support their students in seeing past disinformation campaigns created by skeptics of knowledge and truth. They need to equip students with the ability to find accurate and relevant (digital) information, to encourage them to critically analyze and handle such information, and to inspire them to read (visually) and (visually) present their insights of the world (Haider & Sundin, 2022; Heafner, Hartshorne, & Thripp, 2019; Nissen & Stenliden, 2020; Wikforss, 2017).

Altogether, based on the presentation of research in this introduction section, clear arguments for the importance of exploring the double aspect of VL have been raised. That means on one hand the importance of investigating how visual information comprised of maps, graphs, and written text in a VA application may be ‘read’ (translated, navigated through, or interpreted) by students. On the other hand, it means the significance of investigating how students gained insights from reading such visual interactive texts can be composed and presented by ‘writing’ in terms of producing (translating) KVs. Also important is a
consideration of how students can be supported in developing VL. This means a focus on teachers’ didactic design of how students build and acquire VL (Avgerinou, 2007; Bamford, 2003; Serafini, 2017).

Figure 2. The relationships between VL, reading and writing, VA and KV.

Aim and Research questions

This thesis explores how the double aspect of visual literacy is enacted in school when interactive data visualizations are employed. It is carried out in social science lessons with 13–15-year old students. The aim is to map what characterizes ‘reading’ of interactive data visualizations and ‘writing’ knowledge visualizations, as well as implications for the didactic design in such classrooms. Thus, this thesis is guided by the following research questions:

1. What characterizes the development of reading interactive data visualizations as students and visual analytics interact?
2. How are students’ insights from a visual analytics translated to knowledge visualizations?
3. What critical issues emerge as important in the support of students’ visual literacy?

The thesis is part of a larger research project, Visual Storytelling in Education (VISE), started in 2010, which is a multidisciplinary collaboration and implementation project at Linköping University, the National Center for Visual Analytics and researchers at Pedagogic Practices and Media and Information Technology. Thus, the project consists of researchers experienced in information visualization, visual analytics,
Embracing a research expedition in visualized classrooms

digital technology in education, and educational practice. The research group has developed a VA application, the *Statistics eXplorer*, where interactive data visualizations can be produced through storytelling processes (explained further in the next section) and systematically introduced and explored the application in educational practices. I joined the VISE project in 2014, when I worked as a social science teacher in secondary school. Together with my students I tried out the VA application Statistics eXplorer in classroom activities and provided feedback on how it worked and what could be improved. I learned the interactive features and functions and produced visualizations as social science teaching material. In collaboration with two researchers in the VISE project, I organized and carried out workshops for other teachers in the municipality, I shared my experiences, demonstrated the Statistics eXplorer, and guided the teachers on how to produce visualizations appropriate for their own teaching. Simultaneously, I supported the researchers in conducting classroom studies as they explored the implementation of the VA in classroom. Based on the first results of the VISE project (Stenliden, 2014), it became evident that there was a need to continue with investigations of how to didactically design activities that take into consideration emerging challenges when implementing VA technology in classrooms. A more detailed outline of the first results in the VISE project are accounted for in the section “Earlier explored territories”. As the research results were presented, I became interested in a continuance of the project but no longer from a teacher’s perspective. From 2016 I have participated in VISE as a PhD student. Altogether, these earlier experiences from a teacher perspective have given me certain preunderstandings which are incorporated into my thesis work. The specific focus of the thesis, and what separates it from other studies in VISE, is to increase knowledge of what VL is needed in a visualized classroom.

In the subsequent paragraph, the VA application Statistics eXplorer is described. It has been developed and used within the VISE project and thereby plays a vital role in this thesis.

The VA application Statistics eXplorer

The VA application Statistics eXplorer offers a platform for storytelling methods that supports creating interactive data visualizations; henceforth the word *data* will be removed from this conceptualization, and I
will only refer to these as “interactive visualizations”. The application is built around methods for visual storytelling which include, production, presentation, and publishing of visual stories.² This means for a teacher (or any other analyst, like experts in the public sector, banking system, or military industry) it is possible to transform large-scale statistical datasets—indicators related to circumstances in the world—into an understandable interactive visualized story. In other words, it is possible to customize teaching material applicable in education. The production step consists of downloading relevant data in the form of indicators about, for example, economy, demography, and health indicators. These statistics are imported from official statistical databanks such as the World Bank to the platform through integrated database interfaces.³ By proceeding through the production phase, the teacher can gain insights on the statistics that are transformed into visualizations like maps, scatter plots, bar charts, etc.⁴ The visualizations are interactive; i.e., they can be explored, zoomed in on, and analyzed differently depending on which areas one focuses upon. Also, the data displayed can be adjusted and altered by changing indicators (Figure 3).

The presentation step includes creating a story; i.e., according to the educational goals the teacher can orchestrate the indicators, design a visual story around the content of the indicators by highlighting different visuals through hyperlinks as snapshots, and combine these with explanations in written text, and also presents the students’ assignments. In the final step, publishing, the story can be turned public and disseminated to others. By using the inbuilt publisher tool, that transform the story into a vislet, it is easily displayed on a blog or a webpage. From there it is accessible to anyone with access to a digital device (Ho et al., 2011). To be clear, while working on the Statistics eXplorer platform, the work is referred to as a story but when published it is called a vislet.

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² For information on Visual storytelling and Vislets: https://ncva.itn.liu.se/vise?l=sv
³ The integrated database World eXplorer: http://mitweb.itn.liu.se/geovis/eXplorer/world/
⁴ For technical more aspects of Statistixcs eXplorer see Jern (2010), Ho et. al. (2011), Lundblad, (2013) and National Center for Visual Analytics, https://ncva.itn.liu.se/?l=en&sc=true
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Figure 3. Different visuals in the Statistics eXplorer application, a story with map, diagrams; and on the right the section where the teacher can write and elaborate upon what the students’ assignments.

In sum, learning the storytelling methods of creating a visual story allows teachers to create the teaching material, vislets, to be used by themselves or others (Figure 4).

Figure 4. Model presenting the storytelling steps from an education goal to a product that provides an interactive text in the form of a vislet.

Used in school, the vislets enables teachers and students to explore and examine large quantities data of official statistical information in a visual and interactive manner (Stenliden, 2014). The teacher or students may alter indicators in the vislet and thereby change the entire interface. If they, for example, want to explore General Net Income instead of what is already displayed, they can scroll down the indicator list and choose...
accordingly (Figure 5). The different visual views and their visuals are connected to each other, or dynalinked, so when clicking on a country on the map, it is also highlighted in the charts. In addition, if there are hyperlinks inserted in the vislet it is possible to press these snap shots, thereby changing the interface to a pre-adjusted view, which direct students to a specific area of the visualization that highlight something or may direct them to another web page (see at the bottom of Figure 5).

Figure 5. A vislet about the demographic development in Sweden. Statistics imported from the Swedish Central Bureau of Statistics.

To conclude, this is a short description of a technologically advanced VA application. The application is introduced to teachers, which through visual storytelling create and implement vislets in the classrooms studied in this thesis. As explained, the application provides possibilities to produce vislets; a text to be ‘read’ by the students. In this thesis, a vislet with all visualizations and written text is referred to as ‘text’; an interactive and multimodal text that the students ‘read’. For students to present their gained insights from that visual reading surface (the visualizations) they may ‘write’ by producing KVs.
Structure of the thesis

This is a compilation thesis, comprised of a comprehensive summary in seven chapters—the ‘kappa’—and four papers separated by roman numerals. Following this first introductory chapter, where I outline societal and educational challenges, and the focus and rationale of the study, the second chapter outlines previous research of interest and relevance to the specific research areas. Then, in the third chapter, I discuss the theoretical approach of Actor-network theory (ANT) and how it is applied. I emphasize how this approach focuses on both social and material actors and presents main concepts that are employed. After this, in the fourth chapter, I describe the methodology and research design, which is divided in two studies, together with an account of the empirical data produced. Also, analytical attention, ethical considerations, and methodological reflections are presented here. The fifth chapter consists of findings through a summary of the papers, constituting the thesis. There, I focus on the different papers’ aims, results, and contributions, together with an outline of emerging critical issues important in the support of students’ visual literacy. The results from the papers, together with the critical issues all contribute to the overall aim of the thesis. Next, the sixth chapter consists of the discussion part where I revisit the research questions and previous research, and address different themes related to the overall aim and results of the thesis. This chapter also includes implications for educational practice. The final seventh chapter presents the thesis in a short summary in Swedish.
Chapter 2

Earlier explored territories

This second chapter deals with earlier research about visual literacy in the context of social science, interactive visualizations, and the didactic design of such education. Social science as school subject is, in this thesis, viewed in a broad way and treated with an interdisciplinary focus. The research selection addresses the aim and the arguments posited by the thesis according to the context of a post-truth era, information overload, communicative shifts, and circumstances in school. The selected research focuses to some extent on secondary school, but also has a broader scope when describing earlier findings related to ‘reading’ interactive visualizations and ‘writing’ knowledge visualizations (corresponding to RQ 1 and 2). This means that the chosen research regarding visual literacy is narrowed to that kind of reading and writing. It also means that selected research focuses on both analog static and digital interactive visualizations in school, and foremost in social science education. Neither research on traditional literacy nor digital reading or digital writing in general terms (e-books, iPads, tablets, etc.) are addressed. Moreover, the research selection regarding didactic design (corresponding to RQ 3) mainly focuses on teaching and pedagogical strategies related to multimodal and digitally distributed learning resources (including interactive visualization) in education. Of course, it is not possible to be fully comprehensive, but the section as a whole aims to further support the understanding and analysis of the research results in the thesis’ different papers.

Visual literacy

The concept of literacy, originally described as the ability to read and write written text, has expanded to include other media (Godhe, 2014; Olin-Scheller & Wikström, 2010). Therefore, as explained by Jewitt (2005) and Davies (2017), among others, the traditional concept of literacy is reshaped. The literacy of today can be described as multi-literacies comprising of various denotations of literacy; for example digital, information, critical, visual, and visualization literacy (Bawden, 2008; Kedra, 2018; Sundin, 2015). These perspectives on literacy have evolved within
different fields but they often overlap each other (Sundin, 2015). Mullis and Martin (2019), for example, explain how students must now become competent readers of not only linear text but also texts in a variety of forms, constructed in a variety of modes and existing in interactive fluidity, as is the case with interactive visualizations (Bodén & Stenliden, 2019; Clinton-Lisell, et al., 2021). Interpreting and comprehending the meaning of visual data such as interactive diagrams and graphs offered by a VA application like Statistics eXplorer necessitates a literacy built on multimodality, with a visual mode and sign interpretation combined with a text-based mode (Glazer, 2011; Roberts & Philip, 2006). Following the rise of visualizations used in educational practice, correspondingly there is, as mentioned earlier, a shift toward VL (Serafini, 2017). As novel visualization techniques have become more frequently used, the concepts of (data) visualization literacy, and lately even more specified, interactive visualization literacy have emerged as a topic of research (Firat et al., 2022). Described by Börner (2019), these kinds of literacy skills are essential. Lee et al. (2016, p.552) defines them as “the ability and skills to read and interpret visually represented data and to extract information from visualizations”. Suggested by Chevalier et al. (2018), the aspect of literacy that adds the principles and skills for creating visualizations should also be included. However, as expressed by Firat et al. (2022) in their literature review, visualization literacy still is considered a small sub-field. So, to encompass a broader take, this thesis embraces the wider concept of VL.

In fact, VL is far from a new concept, as Debes (1969) coined the concept in 1969. Since then, many scholars have tried to build upon and expand the definition and establish a research agenda for this multi-disciplinary field (cf. Bamford, 2003; Brumberger, 2019; Kedra, 2018). In general, the concept is defined as the double capability to assemble meaning from visual images, interpret them, and be able to produce images to others thereby communicating a message (Avgerinou & Pettersson, 2011; Bamford, 2003; Metros, 2008). According to Serafini (2017) a more recent understanding of VL expresses a process to produce meaning in transaction with multimodal ensembles comprising visual images, different design elements and written text, to meet what might be called for in specific contexts and settings. Bresciani and Eppler (2015) also explain how users of interactive technologies are invited to interpret,
design, and produce visualizations. They say that knowledge of visual representation and interactive composition constitutes important aspects of being visually literate. Consequently, the importance of visual design and visual elements such as forms and spaces, dots, lines, color, typography, and how visuals and text are arranged, are addressed in several studies (Burmark, 2002; Kress & Van Leeuwen, 2006; Samara, 2007; Watzman, 2003). Kress and Van Leeuwen (2006, p. 177) propose that the representational and interactive composition and meaning of visual texts relates to three interconnected aspects. They highlight how:

1) the placement of elements, for example the various ‘zones’ of the image, left/right, top/bottom, and center/margin, create information value/quality; 2) the salience of elements, for instance positioning items in the foreground or background, or using size, contrasts in tonal value or color, differences in sharpness, etc., attract the viewer’s attention; and 3) the presence or absence of framing devices such as lines dividing, connecting, or disconnecting elements in the image and manifesting whether something belongs where it is, belongs together, or does not belong at all, etc. Consistently, Eppler (2013) introduces the concept of visual guidance, which means that images also act as signposts regarding the order in which the visualization should be ‘read’ and discussed in a combinable manner. Many studies stress that reading these kinds of multimodal texts or visualizations involves strategies and literacy abilities other than simply engaging with the written (Coiro, 2003, 2014; Hatam et al., 2010; Serafini, 2011, 2012; Snyder, 1997).

Furthermore, according to Avgerinou and Pettersson (2011), Bresciani and Eppler (2015), Brumberger (2019), and Kedra (2018), several attempts have been made to categorize different VL abilities that are required in such reading. In literature, such abilities are frequently specified by general concepts, such as: competencies, skills, or capabilities, and there is often a mix or alteration in their use (Avgerinou & Pettersson, 2011; Kedra, 2018). However, there are also attempts to specify these abilities more narrowly by using concepts like critical viewing, visual reasoning, visual discrimination, visual thinking, visual communication, visual association, or visual reconstruction (Avgerinou & Pettersson, 2011). Kedra (2018) divides such VL abilities in three thematic categories: 1) visual reading (visual perception, interpretation, analysis, understanding etc.); 2) visual writing (visual communication, visual
creation, and image production and image use); and 3) other visual literacy skills (visual thinking, visual learning, and applied image use). In other studies, these skills might be called “graph interpretation competence” or “graph reading competence” (Glazer, 2011).

In sum, there are a multitude of concepts describing VL. Relating to this study, the double aspect of VL includes the ability to interpret information from the VA application, and to communicate and express insights by using some form of KV. The term “ability” is used, “…specified as to (a) read/decode/interpret visual statements, and (b) to write/encode/create visual statements” (Avgerinou & Pettersson, 2011, p. 10). In this thesis the equivalent is referred to as (a) to read/navigate and interpret and (b) to write/produce and communicate.

Interactive visualizations in social science classrooms

The studies accounted for here concern visualizations or interactive visualizations in school, and are chosen since they, in different ways, cover one or more issues of importance to this thesis. Using VA the way it is applied in the classrooms that are in focus in this thesis is, so far, not common in social science education or in other subjects. First, studies with a focal point on how analog static visualizations play a part in social science education are presented. After this, studies are presented that focus on digital interactive visualizations in such contexts. There are several studies that have a similar orientation but a specific focus on statistical aspects, statistical literacy, or statistics education; therefore they fall out of the scope for this review (cf. Garfield & Ben-Zvi, 2008; Francois et al., 2020; Le, 2013; Prodromou, 2017, 2021; Ridgeway, 2016; Watson, 2017).

There are several studies with a focus on analog printed visualizations, often also defined as “representations” (cf. Behnke, 2016; Berson & Berson, 2009; Jägerskog, 2020; Reingewertz, 2013; Reynolds & Vinterek, 2016; Roberts & Brugar, 2017). Although these studies are not based on interactive data visualization, but often demonstrate results from students’ activities with analog printed visualizations like models, flowcharts, and diagrams in social science classrooms, they contain results that in a general all-encompassing way are relevant for this study. For example, Behnke (2016) study how information (text and visual representation) in social science textbooks (in this case geography) may
influence secondary school students’ visual attention to graphics, photos, and text in current geography textbooks. With help of eye-tracking software, 20 students’ reading activities were followed. Behnke’s (2016) study shows that the degree of how coherently a textbook layout is organized and how clearly the content of depicted visuals is designed might influence the degree of visual attention paid to the textbook elements on the pages. The study conducted by Roberts & Brugar (2017) addresses the aspect of how elementary students understand visual representations that frequently occur in social studies texts: 1) captioned images, 2) maps, 3) tables, and 4) timelines. Using verbal protocol data collection procedures, they collected information on students’ metacognitive processes when they were explicitly asked to engage with these kinds of visualizations. The results were clear—none of the students understood all aspects of all four devices, although levels of understanding varied greatly. While students were not entirely successful at linking signs to signifiers, their logic tended to follow similar patterns. It seems that applying knowledge from outside school as a bridge to understanding the various and more abstract purposes of maps used in social studies curricula likely requires explicit instructions and scaffolding.

Jägerskog (2020) explored in her study a similar path; namely the use of visualizations (a causal loop diagram and a supply/demand graph) in upper secondary schools’ social science teaching. Three kinds of research data were analyzed: 1) students’ written answers to pre- and posttest questions; 2) transcriptions of the research lessons; and 3) transcriptions of small group discussions. One important result is that the compositional structure of a visualization is central if students are to discern aspects of the phenomenon and understand the visualized content. Another result is that using simplified visualizations of a complex reality involves several risks. Jägerskog (2020, p. 82–83) highlight three of these risks: 1) students tend to focus on how to understand and manipulate the form (the representation itself), rather than on how to understand the conception or phenomena which it represents; 2) students misunderstand the inner workings of a phenomenon and draw simplified or mistaken conclusions; and 3) teachers use simplified visual representations without really knowing to what extent, or in what way this facilitates, or even hinders, a complex and qualified understanding of the visualized content. Although visualizations are useful in teaching and
learning in social science, it is demonstrated that to choose and compose visual representations, as well as working together with students to make the content understandable, can be difficult. All in all, studies under this umbrella argue that visualizations play a central role in shaping the emergent reading–learning–teaching practices.

There are also studies that explore the ability of reading, understanding, interpreting, and constructing knowledge by involving digital interactive visualizations (cf. Andre & Lavicza, 2019; Alper et al., 2017; Fuchs et al., 2019; Koedinger et al., 2001; Krekhov et al., 2019; Saddiq et al., 2019; 2021; Stenliden, 2014). To begin the account of relevant research concerning this aspect, a comprehensive survey paper focusing on interactive visualization literacy studies by Firat et al. (2022) is helpful. The research overview shows that most classroom-based research studies use pre- and post-experiment tests, where a visual designs’ effectiveness and VL tests are examined. The conclusions reported that students performed moderately well when asked to interpret graphs, while generating their own visualizations was much harder. However, according to conclusions by Firat et al. (2022), students’ constructions of visualizations are motivated by experimenting with different methods to communicate and promote engagement. Not surprisingly, it is also emphasized that students can understand many visualizations when they have clear features guiding them, but that too much information is challenging. A paradox is that teachers often assume students already know how to interpret visual data (Bowen & Roth, 2005; Schönborn, 2005). For example, teachers may assume that students can immediately grasp the meaning of diagrams and graphs, even though reading a diagram is a learned skill (Glazer, 2011; Schönborn & Anderson, 2006, 2010). Instead, this complex activity often results in misinterpretations of a graph’s characteristics, a graph’s content, and a viewer’s prior knowledge (Bresciani & Eppler, 2015; Bowen & Roth, 2005; Glazer, 2011; Janvier, 1998; Nissen & Stenliden, 2020; Stenliden, 2014). These remarks are in line with the earlier studies of the VISE project which, as mentioned earlier, this thesis is a part of. Stenliden (2014) found that Statistics eXplorer was usable for both teachers and students in social science education in school. However, it was also established that in using this VA students often ended up in ‘problem spaces’, as their ambition was to quickly transform their insights into written text. The verbally expressed
Earlier explored territories

conclusions, drawn from the visual information, were often of a higher quality than the content in students’ written texts. The (often correct) conclusions and interesting reflections made by the students were seldom adopted by teachers in joint classroom discussions. Students were often left to individually summarize the complex conclusions drawn from the visualized information in written. Stenliden (2014) concluded that VA, which consists of a fast and interactive interface, ‘collides’ with the practice in school to demonstrate knowledge in written. A clash between two ways of communication emerges; on one hand, visualizations support students in interpreting, analyzing, and gaining insight into vast amounts of information. But, on the other hand, transforming the insights and communicating them based only on written text, limits the possibilities of transferring and demonstrating insights (Stenliden, 2014).

Two other studies, reinforce these results (Stenliden, 2015, 2018). Despite learning occurring within problematic spaces, students reach reasonable conclusions. But again, when their insights are to be presented in written text as a form of knowledge visualization, problems arise. In both studies the conclusion is that it is not enough to introduce these new requirements associated with the use of technology; new pedagogical practices have to be adopted at the classroom level. This account both concerns how to teach and work with the technology and how gained insights can best be presented and afterwards assessed by teachers (Stenliden, 2015, 2018).

Another study within the VISE project focused on empirical studies of students reading interactive graphs to elucidate their actual visual and analytical reasoning processes (Nissen & Stenliden, 2020). Three patterns were distinguished: decoding, maneuvering, and incorporation of prior knowledge. “Decoding” refers to the ability to understand, interpret, and read diagrams. “Maneuvering” corresponds to the ability to manipulate interactive charts within a VA to achieve a configuration that contains requested data. These two patterns were understood as visual reasoning. Analytical reasoning was recognized when it was necessary for students to relate facts in an achieved chart to the wider context of a given assignment (Nissen & Stenliden, 2020).

Similar results to those presented in the VISE studies are also found in a study by Alper et al. (2017) which focuses on interactive
visualizations and how they can increase elementary students’ visualization literacy related to learning new, and abstract, concepts by integrating pedagogical strategies. More specifically, through a survey and interviews with 16 elementary school teachers, together with design sessions, they developed a tablet-based technology with interactive visualizations in the form of data graphics like pictographs and bar charts. The visualizations were tried out in two classrooms and emerging visualization practices were explored. The results show on one hand fundamental exercises such as interpreting visualizations, answering questions, etc., can easily be performed by students; while on the other hand a gap is identified in literacy education related to visualizations and more complex tasks such as identifying anomalies, clusters, and correlations (Alper et al., 2017).

Chevalier et al. (2018) builds further on the data and results by Alper et al. (2017). Through multiple observation sessions, during which a total of 21 students used interactive visualizations in small groups (pairs or triples), each on their own tablet device, classroom dynamics were observed. Through this conduct, three teaching paradoxes were possible to discern. First, visualizations of different kinds are extensively present in elementary schools and very often used as teaching materials by teachers. Yet, as pinpointed by Chevalier et al. (2018), the curriculum hardly mentions how the development of knowledge and skills about how learning to interpret and create them should be performed. Secondly, it was demonstrated that teachers consider visualizations to be intuitive and therefore not in need of pedagogical training or special attention, still many teachers think their students are not adequately prepared to interpret and create visualizations. Thirdly, it is put forth that students develop skills in both reading and writing visualizations in early grades, yet they are not educated in critically viewing them. According to Chevalier et al. (2018) effort is seldom placed on commenting on misleading or inadequately designed visualizations, which may indicate complexities concerning teaching with visualizations at schools and deceptive uses of visualizations in mass media.

In another study, Saddiqa et al. (2019, 2021) investigated OD visualizations in Danish secondary schools with a focus on students’ possibilities to explore information based on data; to understand, extract, and visually represent their findings. Based on a survey with teachers and
Observations in classrooms of students’ activities with OD visualizations, the findings showed both benefits and challenges for teachers and students. It was found that visualized information assists students in interacting with the data and understanding facts. The activities improved civic awareness and supported students in developing digital skills. At the same time, results also revealed didactical and technical difficulties (Saddiq et al., 2019, 2021). Both teachers limited knowledge about visualization tools in relation to adopting new interactive learning and teaching resources as well as their digital skills to handle them were determined as challenging aspects. For example, as both teachers and students find it difficult to work with large datasets, there is a need for smaller, ‘cleaned’, more specific datasets that they more easily relate to. This is in line with what Cordasco et al. (2017) expressed; it is vital to equip students with abilities to understand and make use of data in processes as part of design and innovation processes.

Letting students use interactive visualizations to transform and communicate their insights has been tested and studied within three VISE studies. The first is one of the papers in this thesis (Paper IV, Bodén et al., 2022). In the second study, the assignment was to answer some content questions and report these through writing a vislet (including included questions, snapshots, and hyperlinks) in Statistic eXplorer (Stenliden et al., 2019). The results show that the student could write understandable and usable interactive stories. The vislets were, however, more technically elaborated than they were elaborated in content. This probably was a consequence of the fact that the technical challenge was new while the content task was more familiar. Knowledge visualization with interactive elements was used in the third study (Stenliden & Nissen, 2022). The assignment was to figure out content-related facts from reading a vislet within Statistic eXplorer and then conducting an oral presentation supported by visuals. Several students chose to include moving graphs in their presentations, while others preferred fixed graphs, but both forms were adjusted by the students themselves. The aim was to analyze students’ practices of communicating visual discoveries, and their insights, by using knowledge visualizations, as a final stage in a knowledge building processes. The results showed clearly how representations of such multimodal knowledge (including visual, corporeal, and verbal repertoires) when analyzed as semiotic assemblages, will
put pressure on schools to assess not only content issues but also how presentations are performed (Stenliden & Nissen, 2022).

In this section it has been demonstrated that visualizations of different kinds can be and are used in schools, in different subjects, and on various levels, from elementary school to higher education. There are studies focusing on analog static visualizations regarding VL abilities in parallel with subject content in the curriculum, but the studies that focus on digital interactive visualizations are not always related to such subject content. In the studies accounted for, methodology has been centered on interviews, surveys, interventions, and pre- and post-tests, etc. These studies demonstrate that students can handle and learn from static visualizations as well as interactive visualizations. However, as several studies address, implementing interactive visualizations can be challenging. Problems concerning the relationship between visualizations, written text, VL, and how to develop required abilities are to some extent addressed in these studies but they do not explore in detail how students and interactive visualizations interact in the interpretation or reading process, nor in the communication or writing process. Yet, studies that follow how such processes are performed through a zoomed-in mode are rare, and there are few distinct definitions of what specific strategies or abilities are called for. Indeed, the language of genre and discipline is central to the ways in which teachers might understand 1) development/progression, 2) complexity, and, 3) aesthetics. All three concerns dominate both teaching and learning, as well as the circulation and assessment of any student-made productions or performances (Sefton-Green, 2021). However, there has been little empirical research on the specific ways in which understanding the conceptual practices of translation/reformulation/representation might transfer across media and develop iteratively when moving from one kind of text to another, or from one form to another; or even how it might mutate into various kinds of hybridized genres (Sefton-Green, 2021).

A need for didactic design

During the last decade, there has been increased emphasis on the impact of the digitalization of schooling both in research and in educational policies and reforms, in which teachers are positioned as key agents in designing the school practice as a digital space (cf. Caena & Redecker, 2019;
Earlier explored territories

Erstad et al., 2021; Lantz-Andersson et al., 2022). It is argued that whether digital alternatives will be developed in school depends first and foremost on the curriculum, existing school traditions, and tools for assessment (Insulander et al., 2021). This emphasis illustrated by Insulander et al. (2021) might lead to certain kinds of relevant knowledge “not being seen” in the school context. Hence, this final section of the chapter will highlight aspects which compel questions about contemporary digital, multimodal, and visual teaching. Also, some brief remarks on teachers’ professional development efforts conclude the section.

As pinpointed by Starkey (2020) in her research review, the teaching profession needs to be prepared for schools and education systems that are more and more digitized. Nonetheless, teachers need to develop their professional knowledge about how to integrate digital multimodal resources in their teaching; for example, by introducing visual literacy into their classrooms, considering that schools have primarily focused on textual literacy (Felten, 2008; Kiili, 2012; Kjällander, 2011; Magnusson, 2014; Metros, 2008; Rasmusson, 2015; Tallvid, 2015). Elf et al. (2018) confirmed in their research overview that books and written texts are still fundamental features when it comes to what kind of literacy skills are taught in school. Yet, demonstrated for example by Brown’s (2016) study of elementary students’ reading of interactive texts, teachers’ professional involvement in such reading processes is of uttermost importance. Teachers are recommended to blend students’ multimodal interactive engagement in the reading with teacher-supported interactions. Such teacher-supported interactions are fundamental; for example teaching students how they are connected to and how they may interact with an interactive text during reading and exploration of such texts. In addition, Brown (2016) highlighted the importance of teacher competence in promoting student-to-student interactions, and in allowing students their own agency and control of their interactive text reading. Brownell (2020) explained that teachers from numerous encounters with digital resources in classrooms know how confusing such moments can be. This is especially because when different or unusual resources are included in teaching, the expectations of such experiences in the classroom can often be as unclear and deflating as they are inspiring and affirming. The specific circumstances emerging when teaching with multimodal or visual approaches are reported by many studies (cf. Aagard & Silseth, 2017;
Cederlund & Sofkova Hashemi, 2018; Godhe, 2014; Stenliden, 2015; 2018). Common themes in these studies are, as mentioned, related to teachers’ competencies, but also to transformed power relations in the classroom, as well as to influence from school traditions. Furthermore, several studies highlight how students who are able to produce multimodal productions in turn challenge teachers’ traditional assessment practices (e.g., Baldwin, 2016; Magnusson & Godhe, 2019; Silseth, & Gilje, 2017; Sofkova Hashemi, 2013; Åkerfeldt, 2014a). For example, Åkerfeldt (2014a) demonstrates that the use of different resources through different media shapes students’ learning opportunities and means of demonstrating their knowledge. Particularly, Elf et al. (2018) found it a challenging task for teachers to give evaluation/feedback on multimodal student work. There are great doubts about relevant assessment criteria that can be used as a basis for characterization of a good multimodal student practice as opposed to a less good practice (see also Stenliden & Nissen, 2022; Björklund Boistrup & Selander, 2022).

Using interactive information visualizations is uncommon in most schools, and because of this there is not much experience to be learned from when developing design for teaching. Yet there are some studies that shed light on this topic. Digital competence, as a part of teachers’ profession is the ability to work in the context of a digitized school. This includes mastering a range of teacher competencies, such as being able to teach in a digitally infused context, managing digital learning environments, and carrying out the broader professional work of being a teacher (Starkey, 2020). That this is not only a matter of mastering technology has been empathized by many; for example Hudson (2011) and Duchak (2014). They argue that for teachers introducing new technologies the traditional didactic questions of what, why, and how should not only be focused on the curriculum content per se but to also relevant technologies.

TPACK is a well-known framework supporting teaching with digital technology. It suggests that employing technology in teaching requires technological, pedagogical, and content knowledge. The TPACK framework not only emphasizes the knowledge domains independently of each other, but also emphasizes the complex interplay of content, pedagogy, and technology within given contexts (Mishra & Koehler, 2006). In a study of teachers using TPACK to develop their teaching practice,
Willermark (2018) pointed toward a need to carefully craft teachers’ professional development and enable time to reflect and experiment. Also, concluded was that the focus on technical, pedagogical, and content knowledge within the TPACK model can contribute to teachers’ development of the didactic design of teaching practice (Willermark, 2018). Corresponding results are found by Nilsson and Lund (2022). They express that the TPACK framework can encourage teachers to explore, analyze, and reason about didactic design processes, thereby promoting students’ learning.

Taking an approach other than the TPACK model, Moreno and Mayer (2007) distinguished five design principles in a review of interactive and multimodal learning environments: guided activity, reflection, feedback, control, and pretraining. In short, students learn better when they interact with a pedagogical agent (teacher, authors’ remark), are encouraged to reflect, receive explanatory feedback, are allowed to control the pace when processing dynamic visual displays, and when they receive focused pretraining that activate prior knowledge (Moreno & Mayer, 2007, p.316). Similarly, Schweitzer and Brown (2007) underline the importance of involving students in active learning when working with interactive visualizations. Their results demonstrate that an active approach supports students in developing higher-order thinking in tasks that include analysis, synthesis, and evaluations. Active learning is characterized by interactivity (engaging the student to do something), and possibilities to operate the tool, work in a collaborative way, promote creativity, and by being relevant.

As mentioned earlier, Schönborn and Anderson (2006, 2010) argue, based on education in biochemistry, that students should be explicitly taught visual literacy and that skills for using visualization tools are essential components for learning. They discuss pedagogical strategies in specific and detailed terms. Asserted is, that although dynamic and multimedia visualizations progressively enter into education practice, too little pedagogical effort and research has been directed at visualization and visual literacy. Nevertheless, although research has shown that a visualization process requires a high level of VL, they highlight as well, how teachers often mistakenly assume that students automatically understand visualizations, such as diagrams, animations and dynamic models for communicating and constructing knowledge. This points towards the
need for knowledge on how teachers may support their students to develop VL in parallel with subject content in the curriculum.

Identifying visual skills, Schönborn and Anderson (2006, 2010) propose a set of guidelines supporting visual literacy and thereby the use of visualizations. In short, the guidelines highlight that students need explicit training in the process of reading visualizations, especially complex and dynamic ones. This can be done by allowing students to handle the visualization; i.e., to have control over speed, ‘pause’, and other features; to be able to actively read and make sense of the visualization themselves. Suggested is that teachers ask questions and provide tasks where their students can practice interpreting, analyzing, critiquing, and discussing visualizations, both by themselves and in collaboration with each other. Also claimed is the importance to support the development of students’ reasoning skills, to explicitly teach “visual language” like symbolism and graphical markings contained in the visualization, and to observe students while they are working. One important finding is that teachers benefit from preparing themselves by interpreting the visualizations on their own before exposing students to them. This makes it easier for them to support students when they encounter difficulties. It enables teachers to explain and clarify examples of the type of insights the visualization might offer. Also recommended as a powerful method for supporting VL, is to support students’ abilities to construct and refine external representations made on their own from a phenomenon depicted by, for example diagrams, flowcharts, or other types of visualizations.

Another dimension concerning frameworks regarding didactic design is the importance of coherence between ordinary learning activities and situations when students shall present their insights. As Åkerfeldt (2014) has shown, the positive effects (in form of better opportunities for knowledge representation) increase if students can use digital resources in both those phases. This research is based on the Learning Design Sequence (LDS) model (which will be further described in the method section.) This approach was further explored by Svärden-Aberg and Åkerfeldt (2017) who affirmed the need to develop a pedagogy of multiliteracies, pointing toward both teachers’ teaching and students’ design processes in relation to digital tools and multimodal possibilities in the making of multimodal texts.
Besides the aforementioned dimensions, ethical issues can be added, although they are not addressed in depth in this study. Very recent attention toward AI in education has raised awareness concerning digitalization and ethics. Information visualizations might lie, manipulate, and mislead. Therefore, it is important for teachers and students to avoid inadvertent deceptions and to raise their awareness of deceitful visualizations (Mahmud et al., 2017). Exploring visualizations displaying large amounts of data and specifically how students can communicate such information, Mahmoud et al. (2017) revealed that it is vital for them to understand what data is, the source of the data used, and suitable methods of how to create visualizations with information that is not dishonest or misleading. They conclude by providing a framework of exercises that teachers can apply when supporting students to reflect on their visualization designs, containing opportunities for critical assessment of visualizations (Mahmud et al., 2017).

To conclude this chapter, recurring results in existing research are that the ability to use the technology must be trained in education, students need guidance, but also that other aspects must be considered. Existing research underlines the need of continued work concerning didactic design framework for VL. However, the question of how to promote students’ ability to engage in multimodal reading and writing is complex. One major challenge is how to develop staffing processes related to teachers’ multimodal competence (Elf et al., 2018). Some studies highlight that such efforts should not only support teachers in developing their operational skills, but also focus on the implications of technology use for students’ learning and determine how it informs and impacts teachers’ pedagogical processes and practices (cf. Björk Gudmundsdottir & Hatlevik, 2018; Brevik et al., 2019; Tondeur et al., 2021).

One way, emphasized by Voogt et al. (2015, p. 262) for reaching such professional development is by including teachers in educational design research projects. That kind of process may imply development for teachers, and such engagement could mean that chances increase both for individual and collective responsibility, which may lead to intentional and transformative action and learning from the educational design process. Lantz Andersson et al. (2022) found in their study of an educational design project how participating teachers were able to both envision transformative and later enact transformative agency. This means that
the teachers were able to collaboratively envision an intention to take action, which in turn could enable a changed way of teaching. A conclusion from this study is that the method requires teachers to be included in the entire process not only as co-participants but also as co-contributors and co-designers. These kinds of insights have influenced the conducting of this study, which will be thoroughly described in the methods section of this comprehensive part of the thesis. First, however, the next chapter will introduce the theoretical starting points that underpin the thesis.
Chapter 3

Entwining with the theoretical perspective

This third chapter lays out the thesis’ theoretical standpoints. To study what characterizes ‘reading’ of interactive visualizations and ‘writing’ knowledge visualizations the work is positioned under the umbrella of actor–network theory (ANT) (Callon, 1986; Fenwick & Edwards, 2010, 2012; Latour, 1987, 1993, 2005; Law, 1987, 2004, 2007; Law & Hassard, 1999). Of note, terminology within ANT is complex. Terms are rather unfixed, which means that definitions have been moving or shifting over the years (Fenwick & Edwards, 2012). I find it productive to align with Law (2007), who suggests that instead of applying the broad concept of ANT, to use another concept to narrow down the conception so as to better guide the understanding of the theoretical stance. Therefore, I use a socio-material perspective, or socio-materiality, to denote the standpoints and emphasize the entanglement between the social and the material which is essential in this thesis.

This perspective can address the shifts in reading and writing related to technology and provide a springboard for future epistemological developments within the field (Kucirkova, 2019b). The argument put forward is that socio-materiality can account for the complex character of student’s reading and writing in technology (interactive visualizations) and help to overcome the inherent dualism that most often either privileges the social or the technical while failing to provide proper attention to socio-material assemblages (Dezuanni, 2015; Johri, 2011; Mackey, 2016). However, the perspective is not to be seen as one limited theoretical domain that may be neatly applied and explain why something happens or what to think. Rather, it is a sensibility; a way to intervene, discover, and describe how something happens while taking into account both the social and material (Fenwick, 2012; Law, 2007). In my view, the theoretical starting point allows me to capture the unclosed, diverse, messy, and uncertain aspects of the world (Law, 2004, 2007).

The theoretical approach guides the formulation of the research questions that encompass how both social and material aspects shape the study of reading and writing activities in the classrooms. It therefore makes it possible to study how students, teachers, and visualization technology interact in classrooms with a focus on how the humans, the
technology, and other entities shape and affect the emerging activities. It provides analytical tools that enable an analysis which puts focus on the involvement of both the social and material interactions in those processes. Hence, it is the connections between teachers and students (social) and the technology (material) and how these actors are woven together by their actions that is central for this thesis (Latour, 2005).

In the following sections in this chapter, I strive to clarify and discuss the socio-material perspective and its concepts and argue for its relevance in this work.

Enrolling into the socio-materiality of reading and writing

This thesis is interdisciplinary in its character and relates to several research fields. Except for visual analytics and knowledge visualization, visual literacy, multimodality, reading and writing (in a digital context) are also present in various ways in the exploration of how the double aspect of visual literacy is enacted in school when interactive visualizations are employed.

A socio-material perspective emphasizes that action is shaped by relational materiality and performativity and asserts the principle that any entity (either human or non-human) takes its form and acquires attributes as a result of its relations with other entities (Latour, 1993, 2005; Law, 1987). Thus, in accordance, my point of departure is that to answer the above research questions, it is crucial to detect and describe the relations between the social actors (students and teachers), and the material actors (lesson plans, computers, cursors, visualizations etc.), by focusing on both social and material actions. What can be studied is how social and material actions together constitute a particular enactment. In other words, the way in which students and interactive visualizations are acting together are in focus, or differently put enactments of their interrelatedness (Latour, 1987). For example, a range of interactions emerges between, for instance, students’ gazes; visuals like colored countries in a map or graphs like bars in a bar chart; cursors moving around and clicking on web links or bubbles in a scatter plot; moving timelines demonstrating visualized statistical information; students’ voices commenting about what is displayed on the screen; and teachers designing lesson
plans. When describing large technological systems, such as electric light and power systems, Hughes (1987) refers to them as system building, messy and complex, consisting of interacting physical and nonphysical components. In line with Hughes (1987), I consider the interactions as a sort of system-building, albeit small-scale in comparison to the systems he explores.

With this approach one can investigate and analyze characteristics of ‘reading’ interactive visualizations and ‘writing’ knowledge visualizations, as well as implications for the didactic design in such classrooms in relation to social concerns (teachers and students); but also in relation to how material entities (the technology as well as other objects and matters) form activities. I am aware that plenty of studies explore and analyze similar phenomena using other theoretical approaches—such as a sociocultural perspective—often accompanied by a social semiotic and/or a multimodal perspective (Bezmer & Kress, 2016; Jewitt, 2002, 2005; Kress, 2010; Kress & Van Leeuwen, 2006; Lave & Wenger, 1998; New London Group, 2000; Rogoff, 1995; Selander, 2008; Serafini, 2017; Säljö, 2005; Vygotskij, 1978). However, even if these studies have made very valuable contributions my position is, as mentioned earlier, that applying a socio-material perspective is fruitful, as the theory makes it possible to study the shifts in reading and writing related to technology. Thus, the perspective helps to overlook common assumptions of the social, brings forth the material, and questions what is often taken for granted in the relationship between the social and material (Fenwick & Edwards, 2010; Law, 2007). As argued by Gale, Turner, and McKenzie (2013), and Gunnarsson (2018) the socio-material perspective offers productive ways to conduct research in collaboration with school practice, as material aspects of such practices otherwise often go overlooked. In the following section I present the main concepts that is employed in this study in relation to the socio-material perspective. My attention and engagement in the exploration of the enactments in the studied classrooms have, at every step of the way, been guided by the theoretical standpoints.
Networks: the entangled relations of reading and writing

In this section I elaborate on the central concepts to this thesis which will be used to study activities that emerge in the classroom where interactive visualizations are employed. I explicitly make use of the concepts actors, interaction, and network in all papers included in the thesis (cf. Papers I, II, III and IV). In addition, I thoroughly explore and unpack how reading is constructed in interactions between students and VA with support of the concepts relational materiality and performativity (cf. Papers II and III). Additionally, the concept of translation is employed to explore how students’ insights from a VA through writing or producing visuals are translated into knowledge visualizations (cf. Paper IV).

Table 1. The main concepts used in the various papers.

<table>
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<tr>
<th>Papers</th>
<th>Concepts used</th>
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<tr>
<td>Paper I</td>
<td>Actor Interaction Network</td>
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<td>Paper II</td>
<td>Actor Interaction Network Relational materiality Performativity</td>
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<tr>
<td>Paper III</td>
<td>Actor Interaction Network Relational materiality Performativity</td>
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<td>Paper IV</td>
<td>Actor Interaction Network</td>
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Webs of relations—actors, interactions, and networks

A fundamental cornerstone of the socio-material perspective is to follow how different heterogeneous webs of relations are built and held together by social and material actors’ (human and non-human) actions; or rather their interactions. By applying this perspective to all heterogeneous actors, which may be social and/or material, all actors are treated the same way, in “generalized symmetry” (Callon, 1986; Fenwick & Edwards, 2010; Latour, 1987). Thus, henceforth this text does not repeat that the
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The concept of “actor” applies to both social and material entities; heterogeneous actors are called simply “actors”. This is beside when this matter is highlighted again in the forthcoming section “Analyzing - thinking with data”, and due to necessary explanations of how the theory is plugged in with the data analytically. So, an actor is anything or anyone that can make a difference in a situation, exert force, and can be an identifiable entity but it can also be seen as an assemblage consisting of many actors (Fenwick & Edwards, 2012; Latour, 1990). For example, a computer consists of many connections, both in time and space—design ideas, manufacturing procedures, screen, the mouse, dashboard, text, images, and memory functions, among others—all of which may be depicted as assemblages. But it is also possible to view the computer as one actor, capable of affecting students’ interests, pedagogy, educational finances, politics, and so on. Hence, the computer as an apparently single actor is also a network of others that act (Bencherki, 2017). In this thesis, it is implied that the VA application, students, teachers, and others cannot be seen as separate, fixed, and stable actors. On the contrary, they will be looked upon as actors with the possibility to influence and change each other; not fixed in place but changeable external objects (Sismondo, 2010). Hence, it is important to be aware of the terminology; i.e., to be careful when explaining these actors and their actions by using the same terms and abstaining from establishing hierarchies (Bencherki, 2017; Callon, 1986). In relation to the idea of generalized symmetry I depict and follow actors like students, interactive visualizations, lesson plans, teachers, etc., in an equal manner (Callon, 1986; Callon, Law, & Rip, 1986) throughout my exploration.

The actions of actors can bring actors together. It is their interactions that form links, which metaphorically can be described as a “network”. A network, in this context, is a web of relations created by the actions of the actors, and accordingly, their relations construct networks (Law & Hassard, 1999). As I see it, this is also how a classroom may be depicted; as a network composed of interactions of actors such as maps, students, computers, teachers, and other entities (books, graphs, cursors, lesson plans, presentation programs, etc.), all engaged in, and affecting, each other in webs of relations, the networks.

When following examining how networks are constructed the interest is not in finding out why actions take place but in discovering how
relations emerge and how these relations become stable or unstable (Law, 2007). This is also emphasized by Fenwick & Edwards (2010), who assert that, by following networks, the idea is to understand how networks are constructed as interactions occur, not why they do what they do. It is about studying the effects, not where the actors and their activities come from, but rather where these activities end up (Mol, 2010).

Following such webs of relations make it possible to describe how interactions are enacted when reading and writing takes place, or rather emerges, in the networks. The two first research questions in my work involve explorations of actors interacting, building networks where reading might emerge through interactions between students and the visual interface of a VA; and how writing might emerge related to production of a knowledge visualization. This means that in the empirical data, the aim is to explore how relations between actors and their interactions shape networks (or not). I also try to identify the emerging effects produced in the networks to address emerging characteristics of the interactions between students and VA employed in social science classrooms. Regarding the third research question, I also have an explicit focus on actions, actors, and networks encompassing ‘reading’ and ‘writing’ interactive visualizations in relation to the design of such entangled educational practices. This is to identify the emerging effects produced in the networks with the intention to address critical issues that might appear in the didactic design of the classroom.

*Relational materiality and performativity*

Applying a socio-material perspective will, as established above, enable me to study how different actors interact and through this how networks are constructed, and how they can expand across space, distance, and time (Fenwick & Edwards, 2012). To facilitate an even more thorough and detailed exploration of that process: how actors connect, interact, are attracted, coerced, or even seduced in a network, the concept of *relational materiality* and *performativity* are added as theoretical concepts.

A central idea within a socio-material perspective is that ‘everything’ are effects of the myriad webs of relations within which all actors and actions are located (Fenwick & Edwards, 2012; Law, 2007). In this manner, the perspective emphasizes that all actions are shaped by relational materiality. In fact, as different actors come together, act and connect,
they also change and are changed. The results of those changes are described as “relational effects”. To put it another way, as actions are shaped through relational materiality, actors take form and adopt attributes as a result of their relations with each other (Law, 2007). This could also be described as performativity; namely the interdependent relationship between certain words, objects, and actions. For example, performativity helps us study and reflect on how visuals—for example a blue-colored country in a map or a red bubble in a scatter plot—work performatively. In a classroom where a VA is employed, this means that performative forces affect the students’ gazes and students’ mouse clicks in different ways. These actions are unquestionably affected by the visualizations’ performativity. The visuals displayed on the screen affect, and in one way or another, shape the actions that take place. This is illustrated by the event presented below from one of the studied classrooms, where two students (Adam and David) work together with Statistics eXplorer to solve an assignment (for more examples see Papers II and III).

The cursor scrolls up and down, passing both the visuals (the map, the scatter plot, and the bar chart) and the storytelling box; first without any visible interaction except for the scrolling of the interface. Then, as it moves around and as passes the border of the ‘blue’ country, a small black and white text box becomes visible, displaying the GDP of that country (Figure 6). David and Adam lean towards the screen and their gazes connects with the textbox.

![Figure 6. Interactions shaped by performativity, visuals, and students.](image)
Then the cursor moves towards the scatter plot. It quickly goes to the red bubble in the top of the row. Simultaneously, Adam’s gaze moves and stops, focusing on the bubble. At the same time, the cursor stops at the bubble and a black and white text box with the name of the country folds out and becomes visible (Figure 7).

Figure 7: The actors’ enactments are established in relational materiality.

After this, the cursor moves and tooltips the next two bubbles. Adam reads the names of the countries and their GDP out loud, and David writes them down on the other computer.

What is illustrated here is how the actors both perform in, and witness performances by, the interactions, negotiated by the emerging relationships. When the actors come together and interact, they establish enactments in what can be expressed as relational materiality (Law & Hassard, 1999). Differently formulated, at the same time that they shape and affect each other, they form links and build networks. As this happens, the actors are simultaneously intermeshed and interdependent, which can be understood as performativity, or as performative effects (Hayles, 1999). I use these concepts to shed light on how actors assemble, associate, and produce forces and other effects in a way that either maintains or dissolves the networks (Carroll, 2014; Fenwick & Edwards, 2012; Law & Hassard, 1999). These concepts help me investigate how effects from interactions between visualizations and students may result in possible
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reading that include a visual interface of a VA. This means that studying how information is displayed together with the students co-constructs the reading as relational materiality and performativity.

Translations

Having considered relational materiality and performativity, another concept plays a central role in exploring networks of reading and writing. That is the concept of translation, which further helps guide my attention when trying to follow actors in-depth. Simply put, the concept of translation defines in detail what happens in a process when actors connect, interact, form links, and affect each other (Callon, 1986; Fenwick & Edwards, 2012; Latour, 1987; Law, 2007). In this study, translation can be described as the process where visualizations, students, teachers, and other actors affect each other, coordinate actions, and are transformed as they join in a multimodal and interactive reading activity, engage in producing knowledge visualizations or engage in the didactic design of such activities. This means that I can identify how some of the myriad and minute negotiations (Latour, 2005; Harman, 2007), between the actors (e.g., students, visuals, written text) proceed and effect the network establishment.

Another way to describe this more thoroughly, according to Callon (1986) there are four ‘moments’ in the translation process: problematization, intersettement, enrollment, and mobilization. By an understanding of these moments, various interactions can be materialized and described to an excessive degree. However, it should be noted that these moments always may overlap each other, so it is not necessary that they occur precisely in the presented order to establish a translation. Although, to reach an understanding, each one is deliberated upon in the following section.

The problematization moment is when actors try to define the nature of a problem, propose a solution, and discern the identity and role of other actors. This is to establish links and alliances with those actors who/which align with the own interests, correspondingly with actors sharing the same aim. In this study for example, this could be the moments in a reading classroom employing a VA, when the different actors exploratory begin to connect with each other. As an example, when the cursor moves around tentatively on the interface, when students’ gazes
try to focus on different areas or when the students start to comment on visuals; i.e., trying to figure out their meaning, how the visual interface works, or what other actors do. Therefore, the roles of the different actors involved in this network start the process of translation.

Actors which are involved in the problematization moment may either refuse interaction or continue to interact. The latter means that an actor become integrated in the next moment, or “interessement” occur (Callon, 1986). Here, attempts are made to impose the identity and roles of the involved actors. Callon (1986) describes this as a crucial moment. Simply put, intressement is when actors seek to stabilize what they are and how they can be locked into place, and how they can interact in a more assertive and purposeful way towards a task or a solution. For example, this (interessement) may happen when students, a computer interface, a cursor, various zooming functions, visuals, and written text act and affect each other in a more straightforward way. At this point in the translation process, multifaceted negotiations between the actors take place. Also, competing associations may cut links between the actors, putting relationships to the test. However, if the outcome is that actors manage to interest and attract others, the interessement supports actors in moving on to the next moment of translation—enrollment (Callon, 1986).

According to Callon (1986), previously uncertain questions about how actors’ roles are defined and interrelated have been negotiated and actors enroll and move into more definite statements. Enrollment is thus actors’ acceptance of remaining in the network. Therefore, enrollment means support of strong relations or alliances between the actors. This can happen when the actors’ engagement with other actors is apparent and without doubt. For example, enrollment occurs when the cursor quickly moves without hesitation between different webpages and documents, and visuals and text are copied and coordinated in apparent and evident ways. Of course, these relations may be contested by other forces that may hinder or stop the relationships between the actors; there are no guarantees. Nevertheless, if the actors are willing to yield and adapt, enrollment is seen as successful and powerful systems of alliance are constructed, even if they remain rather precarious.

The last moment in the process of translation is mobilization. This is when the proposed solution reaches wider acceptance from many actors.
Entwining with the theoretical perspective

(who/which has/have enrolled), and an even larger or stronger network is mobilized. This may happen through the interests of other actors (Caroll, 2014) or some actors may act as spokespersons for others and are able to represent and speak in the name of others. For instance, mobilization occurs when a visual at the interface of a VA is tool-tipped by a cursor and becomes highlighted, a student aligns her gaze to the highlighted visual, a hand and a mouse move at the table, the cursor at the interface moves to another detail, another student focuses their gaze at the detail and articulates something. To repeat, every connection through interaction between actors causes a transformation of these actions. At the beginning of translation processes, actors might be dispersed, but, as the actors’ interessement proceeds, roles are established; and as the actors enroll, they become reassembled and as the spokesperson speaks in their names, they become mobilized (Callon, 1986; Law, 1987).

Indeed, by drawing on the socio-material perspective, my point of departure is that the relations (between the actors, in interaction) that I can identify in the data not only work together, but also work upon, or translate, each other, thus forming a network of coordinated things and actions. It is in this process of translation that reading and writing together with a VA emerges.

In addition, translations do not always succeed. In the different moments of the translation process, various trials of strength may appear in several forms. For example, the zooming functions of a VA might affect the reading surface and accidently conceal information, and in result other actors may become uncapable of connecting with specific visuals that display fundamental information. Here it is the zooming function that becomes a trial of strength in the translation process. In fact, the network may be difficult to sustain, and in this case the reading network becomes weakened, and in a worst scenario, the network risks dissolution. However, there are also actors capable of strengthening these relations. By imposing solutions or forces on one or more moments of a translation process such actors become lines of force supporting the process (Latour, 1987; Law, 1987). In the studied classrooms, for example, a line of force might be the teacher who states clarifying questions or makes a visual demonstration, or it could be the cursor clicking on a colored link which brings forth visuals and changes the interface. These two
concepts—trials of strength and lines of force—are employed when following how reading and writing networks are constructed. The concepts assist to explore what actors might function as enablers or create barriers through interactions in various translations.

Summary of the theoretical starting points

One of the main advantages of the socio-material perspective argued for in this chapter is its emphasis on treating heterogenous actors the same way. Unquestionably, this perspective helps to overlook common assumptions of the social, as it brings forth the material and questions what is often taken for granted (Fenwick & Edwards, 2010; Law, 2007). In other words, the perspective calls attention to the heterogenous and complex character of student’s reading and writing with technology. Explicitly, the main concepts are actors, interaction, and networks. Additionally, the concepts relational materiality and performativity are adopted, as is the concept of translation. The inherent meaning of these concepts, as accounted for above, constitutes a theoretical lens that allows me to:

1. follow actors’ interactions and emerging network effects
2. trace actors’ relations, their relational materiality, and performativity
3. track whether and how translations produce durable networks (or not).

Therefore, according to this account of the socio-material perspective, subsequently, material discursive analyses (Callon, 1986) are used in relation to the specific research questions. More on this matter will be elaborated further on in this thesis. With this outline of the chosen theoretical perspective, the next chapter moves forward and discusses methodological concerns.
Chapter 4

Engaging in methodology and research design

This chapter presents and discusses methodology and research design. First, an overall structure of the research process is presented. Then an account of the methods of data production is given. After this, the conduct of the present studies is described, as are the analyses performed. Ethical considerations and procedures are also described. Finally, reflections on methodological issues are provided, and the matter of trustworthiness is pondered upon.

Overall structure of the research process

First, there are important parts of the efforts to set up the research process, corresponding to the aim of this thesis, which must be highlighted. Since the use of VAs are not yet common in schools, it was essential to establish collaboration with teachers that were interested in employing and trying out VAs in their teaching. Such collaboration was initiated with inspiration from Design-based research (DBR), (Easterday et al., 2018; Wang & Hannafin, 2005). A close collaboration between teachers, with expert knowledge of the practice, and the researchers, with experience and expertise of the chosen VA application and different KVs, was recognized as a reasonable platform for jointly designing an intervention. Therefore, a research team (RT) consisting of myself and two other researchers was formed and prepared the first stages of the research process. After a while, a team with teachers and the three researchers (TRT) was formed with the aim of developing an intervention in social science classrooms. The intervention was conducted and followed through two different studies within the thesis (Figure 8).

![Figure 8. One intervention conducted, evaluated, and developed through two studies.](image-url)
The two studies were (as touched upon earlier) inspired by the basic features of DBR, which includes a research procedure that: is situated in and has a practical impact on a real educational context; is based on a collaborative partnership between researchers and practitioners; focuses on the design and testing of a significant intervention; uses mixed methods; is performed with multiple iterations; and generates design principles and theory (Anderson & Shattuck, 2012; Barab & Squire, 2004).

Accordingly, the two studies consisted of a research process that in short included initiating the collaboration with teachers, informational meetings, hands-on work with the VA application in relation to educational goals, discussions and deliberations on didactic design, and modelling of an intervention in the form of concrete lesson plans. In both studies a common goal for the two different TRTs was to conduct the intervention in the classrooms.

Furthermore, following DBRs iterative procedure, it was possible through the conduct of the intervention in the first study to focus on RQ1 (the reading), and by an evaluation of the intervention initially address RQ3 (early stages of the didactic design), and in the second study through an adjusted version of the intervention address RQ2 (the writing), and elaborate further upon RQ3 (the didactic design) (Figure 9).

Figure 9. The two studies different focus on the research questions.

The first study lasted between October 2016 and June 2017. It encompasses researchers and teachers’ collaborative work. Fifteen teachers joined the preparational work of designing the intervention through concrete lesson plans together with the three researchers. Four of the 15 teachers participated in the work to realize the intervention in their classrooms. The intervention took place in three Swedish schools, in five different social science classrooms, with a total of 96 students. The
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empirical data covers the teachers’ lesson plans and how these were realized in practice during 12 lessons (Figure 10).

The second study lasted between October 2018 and February 2019. The study encompasses collaborative work and data production related to an elaborated and updated version of the intervention. The team consisted of two of the four teachers from the first study that also conducted the first version of the intervention, and myself as a researcher. Accordingly, the work in this second TRT was based on experiences and evaluation of the intervention in the first study. The intervention took place in one school, in two social science classrooms, with a total of 56 participating students. The empirical data covers how an elaborated lesson plan (compared to the ones in the first study) was realized in practice over 12 lessons (Figure 10).

Figure 10. Participants, number of schools, and lessons in the two studies.

How the DBR (Easterday et al., 2018) influenced the studies will be elaborated upon more thoroughly further on in this thesis. The Learning Design Sequence model (LDS), originated by Selander (2008) that was also influential in the work for the TRTs will also be addressed. First, in the following section, an overview of the data production is given.
Data production

In total, the data from the two studies include zoomed-in mode recordings of 143.5 hours, wide-angle view recordings of 20 hours, field notes from 24 lessons and from TRT meetings, six lesson plans, and one focus group with the teachers. I took field notes during the lessons. I participated in all analyzed lessons; mainly to manage the recordings and take field notes. The two other researchers from the VISE project participated in few lessons each.

Data production in the studies differs somewhat. In the first study, the interactions between the VA application and the students were followed and captured by zoomed-in webcam recordings, made possible by Camtasia, a software that use the computers’ webcam, audio recordings with the computers’ microphones, and recordings of movements and actions on the computer screens. These recordings enabled capturing the interactions between the VA (the interface of the screen), the students, and, to some extent, the teachers. Students’ faces, voices, and gestures, as well as the activities on the screens were recorded in a zoomed-in mode. Advantages of video observations are the capturing of gestures, actions, talk, etc., which allows for a broad spectrum of observations and allows for multiple viewings of the films (Heath et al., 2010). Altogether, the recordings in Study 1 consist of 82 hours. The webcam recordings were analyzed, and the results are presented in Papers II and III. The field notes were used as complementary information to the overall process. Data from the first study also includes field notes taken during the 12 lessons, four TRT meetings, and five lesson plans (Figure 11). The lesson plans were analyzed, and the results are presented in Paper I.

In the second study, classroom interactions were also captured by zoomed-in webcam recordings (61.5 hours). One insight from analyzing the webcam recordings in the first study was that it might prove interesting to follow how the teacher and students as they communicate and move about the classroom. This could only be captured fragmentarily by the webcam. Therefore, in study two, a wide-angle camera was placed in the back of the classroom, to enable recording classroom activities from the beginning until the end of the lessons; for a total of 20 hours. It provided possibilities to both obtain an overview of a large part of the classroom as well as allowing a focus on the actions that occurred in the front of the classroom. This was the spot where the teachers usually were
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positioned when they introduced assignments, gave instructions, and led discussions. This was also the place where actions on the teachers’ screen were projected on the white board, which was visible to all students. The intervention in the second study lasted for six lessons per class, for a total of 12 lessons. Data from the second study also included one lesson plan, field notes taken during the lessons, and seven TRT meetings, as well as one recorded focus group (Figure 11). The webcam recordings were analyzed, and the results are presented in Paper IV. Wide-angle recordings and field notes were used as complementary information to the overall process. The lesson plan was used as a tool to plan and then guide teachers during the lessons. The focus group was essential for identifying critical issues.

Conducting the studies

In this section, the process of conducting the two studies is presented in-depth by elaborating on activities in the different DBR phases (Figure 12). As Easterday et al. (2018) describe, such research processes involve recursive movements between the different phases, which was also the case in these studies. The interleaved phases will, in the following section, be used to structure an account of how the two studies were
conducted. The first study is dealt with in Papers I, II, and III, and the second study is addressed in Paper IV.

Figure 12. The interleaved phases of the design process (Easterday et al., 2018).

**Implementing the first study**

The RT in this first study included myself, Linnéa Stenliden, and Jörgen Nissen, and we began by planning the research direction. Then, the TRT was formed as 15 teachers joined and became involved in the design of an intervention; i.e., elaborating on lesson plans. Four teachers (out of 15) participated in realizing the intervention, which meant trying out the lesson plans in their classes.

**Focus: Mapping out the research direction (Phase 1)**

The first phase, focus, consisted of identifying the problem, scope, and bounds (or rather what is out of bounds), and the roles of the studies’ stakeholders (Easterday et al., 2018). The focus chosen by the RT was based on earlier findings in the VISE project where, as mentioned earlier, several ‘problem spaces’ had been identified; namely that the visual learning environment, consisting of a fast and interactive interface, ‘collided’ in various ways with practice to demonstrate knowledge in written text (Stenliden, 2014).

**Understand: Figuring out the problems (Phase 2)**

In the understanding phase, an investigation should be made of the context, stakeholders’ needs, existing solutions, and synthesizing what might be useful; for example models of learning and research that promote an understanding of the problem (Easterday et al., 2018). In this phase, to better understand the problem, the RT evaluated earlier findings of VA and KV in classrooms.
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Besides earlier research on interactive visualizations in education, the RT decided to use the model Learning Design Sequence (LDS), originated by Selander (2008) as a platform for future discussions and for understanding the problem together with the teachers. The idea was that it could be a useful tool for elaborating different elements in teaching. The RT team arranged various activities; for example contacting headmasters of secondary schools, holding information meetings for teachers, preparing a series of future tutorial sessions, and supporting teachers in learning the technical features of the VA.

To set up a collaborative partnership between educational practice and research, teachers in one municipality were invited to an information meeting about the VISE project. Social science is the main school subject of the VISE project, but teachers representing natural science were also invited. An argument was that the official statistic in the VA offers data concerning, for example, energy, mining, health issues, and climate change. Later, participant invitations, together with information on studies within the VISE project, were distributed to the teachers that had attended the informational meetings. A total of 14 teachers in the municipality were interested in participating. Additionally, one teacher from another municipality found web-based information about the study and wanted to participate and were accepted. At this point, the RT was enlarged with the teachers and, consequently, the TRT was formed. This enabled the establishment of a close collaboration between teachers and researchers that made it possible to set up and design the future intervention. The RT identified that it was considered vital for the teachers to become sufficiently competent in handling and understanding the basic characteristics of the VA.

Define: Outlining desirable changes or goals (Phase 3)
To define is to frame the problem, decide on goals, and define the desirable changes in, for example knowledge or skills (Easterday et al., 2018). On four occasions (half or full days), the TRT jointly elaborated on these matters. The meetings began with tutorial sessions, when technical features of the VA application were demonstrated and then tried out by the teachers.

In joint discussions within the TRT, the researchers provided theory and earlier research findings concerning emerging learning conditions when implementing a VA application in schools (Stenliden, 2014),
together with theories of VA, VL, and KV (Avgerinou & Pettersson, 2011; Bertschi et al., 2011; Thomas & Cook, 2005; Tomaszewski & MacEachren, 2012). Through this collaborative work, discussing earlier insights of students and teachers working with vislets in schools (Stenli-den, 2014), efforts were made to address and pedagogically deal with the aforementioned ‘problem spaces’. The LDS model, as mentioned, (Figure 13) was introduced, with the intention that it could provide a common platform and framework for mutual thinking and discussion.

![Figure 13. The formal learning design sequence (LDS) that illustrates a learning process (Selander, 2008).](image)

The model is structured around the concept of design in the sense that it is a transformational process where students and teachers are interacting with each other as well as with other actors (available resources). Reading the model from left to right, attention is drawn to potential resources, the purpose of the learning process, and the teaching setting. The primary transformation unit demonstrates the formation and transformation of knowledge. The secondary transformation unit illustrates how transformed knowledge is then presented and assessed. There is no time limit in the model; the learning process might consist of everything from a few lessons to several weeks, but it can play an
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important role as a reminder to teachers on how to form and transform information to knowledge via a thorough process.

The teachers shared their classroom experiences, well-tryed methods, and didactic skills in relation to developing an intervention related to how the didactic design of the classrooms could be adjusted and linked to curriculum goals. The concepts in the model contributed to a mutual language which facilitated the TRT to carry through in-depth discussions. For example, as the TRT discussed the transformation units and concepts in the model, these became shared elements used in the production of the lesson plans (see the lesson plan template in appendices). The illustration of a learning process, demonstrated in the LDS model, thereby assisted in providing the TRT with a common language and image of how learning activities can be arranged. Through this, the model supported the TRT in the process of defining goals and desirable changes (vis-à-vis problem spaces) and how this might be realized in relation to future interventions.

Conceive: Modelling lesson plans (Phase 4)
In the conceive phase, a design plan was outlined; i.e., modelling the design of the intervention together with the imagined effects. Easterday et al. (2018, p.142,) refer to this phase as “the heart of the design process”, where a conceptual plan is conceived, and the solution is imagined. This was a central phase for this thesis. The TRT jointly elaborated upon lesson plans’ didactic design in relation to the introduction of the VA and KV in classrooms, and a lesson plan template that pedagogically guided the teachers was developed. The idea behind the template was to facilitate teachers’ development of didactic design. The lesson plan template consisted of headlines and instructional subsections connected to the LDS model. After tutorial sessions and in-depth discussions related to earlier findings and curriculum goals and the production of vislets, the teachers outlined the didactic design of the classroom activities together with the educational goals in a lesson plan. As expected, when several lesson plans were produced, their content differed. However, they shared much in common as the TRT had discussed the ‘problem spaces’ and didactic design in-depth, and there was a common outset from the LDS model and the lesson plan template.
Build: Adjusting and shaping lesson plans (Phase 5)
The lesson plans were then elaborated upon further in the building phase. The TRT jointly reviewed content and activities in the plans and the teachers made final adjustments to their own plans.

All teachers planned, in the first transformation unit, to start with teacher-led instructions, both spoken and visual, introducing the VA, the vislet. Then students were to work in pairs (all teachers had made that choice), solving different assignments formulated in a way that were supposed to encourage the students to engage in the interactive visualizations. The lesson plans included instructions for the students to use various forms of KV—for example digital mind maps, digital maps or oral presentation recorded by mobile phones—together with a text mode, to illustrate/formulate their answers and reflections. The teachers planned joint reflections about the visualized content during the lessons, both among the students themselves, but also in discussions with the whole class. In the secondary transformation unit, the students should transfer their insights (from their work with the VA) and then demonstrate their knowledge through different KVs.

Test: Trying out the lesson plans (Phase 6)
In the test phase, the lesson plans were supposed to finally be realized as an intervention in the classrooms. All teachers had the opportunity to participate in this ‘research-focused’ part of testing and realization of the lesson plans, but some chose to withdraw from this part of the TRT work. Out of the original members of the TRT, four secondary social science teachers continued the process and implemented the lesson plans in five classrooms (ne teacher used the same lesson plan in two different classes).

The intervention was performed at five social science classes at three different schools and lasted for two to three lessons in each class. The four teachers in the TRT implemented their lesson plans in grades 7, 8 and 9. In all classes, the teachers introduced the vislets and then students worked on the assignments in pairs. The vislet for grade 7 included indicators showing demographic composition in Sweden, and the assignment was to examine how the population is stratified by age and geographic location. The vislets for grade 8 and 9 encompassed statistics showing demographic development and relationships between, for example, expenditure on education, health, general
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net income (GNI), trade, and life expectancy in the world. The students’ assignments were, for example, to compare where various goods and services are produced and consumed, funds spent on education, and life expectancy in different parts of the world. With support from the vislet, the students explored connections and drew conclusions using various indicators.

The testing phase also calls for evaluation according to the DBS-model, often with a formative focus, as to whether the solution works in context and if the goals are achieved (Easterday et al, 2018). In this thesis this was done through conversations after each lesson with the involved teacher and the researchers on site (normally only me). The TRT engaged in formative talks of how introducing VA, KV, and the planned didactic design was perceived, and reflected about the learning activities and what actions that were visible during the classroom observations. Thoughts on what might need to be changed, added, or done differently next time, in relation to reaching the goals, were expressed. For example, it was discussed that the teachers in the classrooms observed and assisted the students only when the students requested, and that it could be difficult to handle the technology. These informal talks after each lesson were documented in short notes.

Awhile after the intervention, the four teachers who participated were invited to a more formal reflective meeting.

Present: Describing the results (Phase 7)
Following the intervention, analyses of the empirical material by the researchers commenced. The focus was to follow the interactions between students, teachers, the VA application, and KV together with how the education was designed. The field notes helped add details, particularly regarding information that was not visible on the webcam recordings, such as sketches of the classroom or actions occurring on interfaces that were not video recorded.

Central findings when analyzing the empirical data from the intervention were that the planned implementation of the lesson plans did not, in practice, turn out as intended. The content of the lesson plans did not fully direct the actions in the classrooms as expected, and the plentiful learning activities that were planned were not realized during the lessons. The teachers took few initiatives to arrange joint discussions
and analytical reflections, despite having planned for just that. The plans for different forms of KV were not realized entirely as intended.

In a meeting after the conducted lessons, members in the TRT discussed the difficulties in completely following the didactic design in the lesson plans, the critical interactions that emerged in relation to VA, and the unfamiliarity and insecurity about using KV without emphasizing the need for written text. It was discussed that perhaps it is not just a matter of technical and didactical inexperience but also that it is particularly difficult to alter views of how students can demonstrate their knowledge by means other than written text.

According to DBR, in this final phase, the results should be presented to key stakeholders (Easterday et al., 2018). Except for presenting the results in scientific journals and conferences, the results were shared with some of the participating teachers. Critical interactions between students and the VA were presented, such as the different possibilities to connect in a reading process, the strong performativity of visuals, and what might hinder and assist those interactions. Also, emerging literacy abilities in relation to interactive visualizations were presented and discussed.

**A second study**
Consequently, inputs from both the teachers and the researchers were merged, and together the need for another study and an enhanced didactic design were articulated. Two of the teachers expressed interest in continuing with the TRT work and engaged in planning another intervention. In sum, as the data were analyzed, findings from the intervention in the first study laid the foundation for an adjusted re-designed version of the intervention.

**Implementing the second study**
The methodological structure of DBR has so far provided a bridge between theoretical research and educational practice. These findings, the awareness of the interactions, and the didactic design issues that emerged in the first study (Papers I, II, and III), could now iteratively be addressed in the second study. Once again, DBR phases directed this study's processes.
Focus and understanding the problems (Phase 1 and 2)

Based on the results of the first study, it was evident that, although the TRT had addressed earlier known problem spaces by various collaborative actions/steps such as tutorial sessions, in-depth discussions, designing this type of education in carefully considered lesson plans, the evaluation and analyses of empirical data from the first study showed that some problems remained, and new ones were identified:

1. It was found to be troublesome for the teachers to fully follow the intended didactic design in the lesson plans, and the plentiful learning activities that had been planned, such as discussions and common reflections, rarely took place. Hence, the students were very much left on their own and hardly any slowing down of the learning activities occurred.

2. The strong performativity of visuals and vision might hinder or assist how reading is constructed. Efforts to ensure that the visual information got enough attention were lacking. The zoomed-in interactions demonstrated the importance of visual literacy abilities, but little attention was paid to this.

3. There was unfamiliarity and insecurity about using KV without emphasizing the need for students to express their answers and reflections in written text. Through this, the ambition to transform the visual information into written text was encouraged, which meant that too little effort was directed towards visualizing the insights.

These aspects were the focus of the second study. At this point, according to the actions and results in the first study, an even tighter and collective collaboration was needed. This meant that the TRT was (re)formed, and consisted of two teachers from one school, and me. Therefore, an even more active involvement by the members was thought to be possible, compared to the first, larger TRT. The anticipation was that a TRT with teachers from one school would facilitate the intricate and thorough process of designing, and follow an improved lesson plan, aiming to address the problems emerging in the interactions with an enhanced didactic design. As colleagues at the same school, it was easier for the two teachers to have close and supportive contact when planning and preparing the new lesson plan. It was also decided by the TRT that
the researcher’s role this time should be more active and involved in both the vislet production and the process of didactically designing the lesson plan. Developing closer cooperation in that way was thought to raise the quality of the vislet, the lesson planning, and the actual teaching.

By discussing and contemplating the problems that emerged in the first study, the new TRT once again put effort into understanding the current situation. Clearly, there was a need for a new and refined lesson plan, with specific learning activities in both the primary and secondary transformation units. The LDS model (Figure 13) was emphasized even more this time, discussed several times in relation to what happened in the first study, and the model was placed within a new lesson plan template to saliently guide the preparations for redesigning the intervention (see Appendix 2). This was done to assist the teachers in slowing down the pace in order not to rush over various points during the lessons and carry out the intended didactic design in its entirety. The teachers also emphasized the importance of developing well-defined instructions to help students to understand what to do. They also expressed a need to learn more about how students can express what they have learned and how to assess such presentations (i.e., use different KVs). Furthermore, pedagogical implications of emerging visual literacy abilities were carefully considered.

Define: Outlining desirable changes or goals (Phase 3)
The findings from the first study played an important role in guiding the TRT in framing the problem and outlining the research process. Setting out from the three main problems enumerated above, in short: following the didactic design, constructing the ‘reading’, and supporting the visual presentation of students’ insights; i.e., the ‘writing’. For all of these, plentiful desirable changes were defined.

The TRT met at seven occasions, and usually these meetings lasted around two hours and took place at the teachers’ school. In between these meetings, the members of the TRT regularly had contact through e-mail, and sent ideas about the vislet to be produced, suitable assignments related to curriculum goals and comments in lesson plan drafts, etc.

The content of the new vislet as well as how to formulate student assignments, was jointly elaborated upon. An improved vislet was produced. Then, to assist the teachers, I showed them, in detail, how to
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handle technical features as well as content in the vislet, and demonstrated statistical information and interconnections that they could reflect and discuss with their students. By viewing examples of how students’ gazes and visuals connect (findings from the first study) we discussed how to support students’ visual abilities in relation to VA and KV.

I also provided examples of what a KV could look like when insights are presented mainly through visualizations, and where written text merely exists in bullet lists or short notes. These KVs also included how inserted visuals, by the students, such as arrows and color, can reinforce the insights from a vislet (Figure 14).

**Figure 14. An example of a KV.**

Conceive and build elaborated lesson plans (Phases 4 and 5)
In the conceiving and building phase, the TRT modelled and designed the lesson plan in tight collaboration. The lesson plan template used in the first study was revised to make it easier to correspond the didactic design to the intentions in the LDS model (Figure 13). How best to do this was discussed thoroughly during the first meeting and then recursively as the plan was constructed. Together, the teachers also produced a topic instruction which contained specific details about goals, assignments, assessment, etc. This time the lesson plan specified in more detail all activities in the primary and the secondary transformation unit. The teachers planned to begin the lessons by informing students about the
pur
pose of the lesson and carefully explaining the students’ assignments. They planned to encourage the students from the start to gather their insights when interpreting and analyzing the information in the vislet; i.e., to collect screenshots, reasonings, images, short note, etc., that they later could use in their KVs. Also, the teachers intended to carefully inform of the different techniques of how to work with the VA: indicators, the meaning of colors, functions of zooming, highlighting, how to read the axis of a diagram, and so on. The students were supposed to work in pairs with interactive visualizations. The plan was to organize joint discussions several times during the lessons. These should focus on information students had found in the vislet, and on other important conditions and interconnections the teachers wanted to highlight.

**Testing: Trying out the adjusted lesson plans (Phase 6)**

As the construction of the lesson plan was concluded, and the new vislet was published on a website, the TRT organized the redesigned intervention. The two teachers and two of their social science classes, consisting of 56 students in grade 8, participated. The classes were followed over six lessons apiece when the students worked with the vislet, gaining insights from the VA (within the primary transformation unit of the LDS model) and then translating these insights into KVs that were presented to the other students and assessed and graded by the teacher in the last lesson (the secondary transformation unit). The vislet included indicators showing statistical information about trade: General Net Income (GNI), imports, exports, and consumption in the world. This was one part of the social science theme 'Trade and Consumption'. Assignments in the vislet included interpreting and analyzing the information in the visualizations, discovering global trade patterns, and drawing conclusions about causes and consequences.

During the intervention the teachers regularly assembled the class for joint discussions, either focusing on interesting facts and possible conclusions to be made from the visualizations that the teachers wanted to highlight, or encouraging students to demonstrate the insights they had gained when working with the vislet. As mentioned, the teachers encouraged students to gather their insights when interpreting and analyzing the statistical information in the vislet. After a while, the students attended to this recommendation, and throughout the lessons they collected screenshots, reasonings, images, or short notes they later could
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use in their KVs. To guide the students when they were ready to start producing their KVs, the teachers demonstrated examples of what a KV could look like. The students presented their KVs during the last lesson in each of the classrooms.

After each lesson, the TRT engaged in informal talks reflecting about the learning activities with VA and KV and how the didactic design of the education was perceived this time around. When the intervention was completed, the two teachers participated in a focus group.

Presenting the results (Phase 7)
I analyzed the empirical data produced in relation to the redesigned intervention, and parts of the results have been presented at a scientific conference, in Paper IV, and in this comprehensive part of the thesis. More specifically, as one intention of the DBR process is to generate design principles (Anderson & Shattuck, 2012; Barab & Squire, 2004) the implications from the results in the two studies are presented in the thesis’ discussion chapter (corresponding to RQ3).

Analyzing—thinking with theory
The data analysis in this thesis is directed by material discursive analyses (Callon, 1986), and attention is placed on the interactions between the VA, KVs, students, and teachers. As described in the theoretical section, these interactions create various networks; i.e., assemblages of links formed by the actors (Law, 2004). Briefly this means drawing from a socio-material perspective during analysis, the ambition is to determine how the actors construct reading networks when multimodal and interactive texts are employed, how the actors construct writing networks, namely knowledge visualizations, and what critical issues play a part in didactic design. Therefore, the analysis is a process where theory is used to intervene, and where analyzing is “to think with theory” (Jackson & Mazzei, 2013).

To be more illustrative, in accordance with the chosen theoretical perspective, Law’s (2004) concept of “method assemblages” is one way to describe this way of thinking, or “plugging in” theory to data in the thesis. The concept illustrates a broad and boundless way of thinking about the analytical work, and where analytical methods that do not seek the definite, recursive, and stable are seen as appropriate. In fact, rather
than seeking stability within and among the data, analytical attention is
drawn to data that seems to be about difference rather than sameness
(Lather, 2010). What this meant for me more precisely during the ana-
lytical work has been guided by Callon’s (1986) three methodological
principles: a matter of style, generalized symmetry, and free associ-
ation. What they signify will be pondered upon in the following.

The first principle, a matter of style, implies that the researcher, in
an impartial manner, includes both the social and the material actors and
refrains from censoring any actor. As Callon (1986) describes it “No point
of view is privileged, and no interpretation is censored.” (p. 3-4). The ob-
jective is to allow all actors to be unstable without trying to fix their iden-
tity too quickly.

The second principle, generalized symmetry, entails a common vo-
cabulary when describing actors and actions in the data (Callon, 1986).
The repertoire chosen is up to the researcher, but it is important to use
the same terms in the descriptions and not alter the vocabulary when
moving from the social to the material actors. Hence, the analysis of in-
teraction between the visuals, the screen, teachers, the cursor, students’
gazes, voices, text, and so on, are presented with similar expressions.

The third principle, free association, means to refrain from all a pri-
ori distinctions between the material and the social, in order to not create
any disjuncture between the actors interacting in the networks. Accord-
goingly, in such analytical processes there are no pre-defined analytic grid
imposed on the actors, instead the actors are followed, making sure no
boundaries separate them. This manner, opposed to arranging the data
more conventionally; for example in themes and by using a coding pro-
cedure, entails a tentative and hesitative unveiling of the data. This par-
tial unveiling of the data may be seen as an enactment of crafting and can
assist in detecting both what is discovered, but also what might be over-
looked (Law, 2004; Taylor, 2016). It can be described as a process of as-
sembling how relations are entangled and constructed, but not by ar-
rangeing them into a pre-given list or fixed shape (Law, 2004).

How these principles have guided my way of “plugging in” data and
theory; i.e., my way of “thinking with theory” is described in the next
subsection.
“Plugging in” theory and data

Considering the implications from the theoretical perspective accounted for above, means that I have plugged in theory to think with the data (and used data to think with theory), (Jackson & Mazzei, 2013). All data—fieldnotes, focus group, and video captures—have been treated accordingly in the analysis. I have tried to follow, trace, and track how different actors connect to each other, form links, and interact; i.e., to follow the emerging network.

During the two studies, field notes were taken by researchers both during the TRT meetings and during the classroom events. These notes are annotations regarding background information related to the different settings where the studies took place. They also consist of reflection notes considering different statements, happenings, or events during the DBR process. Therefore, the field notes were used as complementary information about the overall process, rather than informing the studies of detailed in-depth analysis. However, the fieldnotes were re-read during and accompanied the work with crafting events.

The focus group was held with the two teachers taking part in the second study. It lasted for approximately 46 minutes and was recorded using a voice recorder. The recording was listened to, and parts of the interview were selected and transcribed in a text document. The transcription was read and analyzed in relation to RQ3 when trying to trace and identify critical issues that emerged in the didactic design elaborated upon in the lesson plans and discussed in the focus group.

The video captures are considered the most important empirical data for this thesis. The various steps of how the webcam recordings were analyzed are accounted for thoroughly in the following section.

Data management: To impose order and obtain a clear overview I arranged the video recordings in a tree-like matrix. This structure was used to arrange and separate the various recordings according to school, teacher, class, and date. The matrix was anonymized.

Watching: the first step in the procedure began, in an open-minded way, by merely watching the zoomed-in actions of the different actors. The intention was to commence as unprejudiced as possible, making an effort to perceive and follow the actors in an impartial manner. I tried not to refrain or censor any actor, thereby applying Callon’s (1986) first principle “a matter of style”. Therefore, to prevent unconsidered
interpretations in this initial phase of the analysis no annotations were written down at this point. According to Law (2004), this method of crafting assemblages entails the practice of not only noticing the obvious but also trying to detect and amplify signals of relations that otherwise would have faced the risk of being unnoticed. Hence, the analysis began by watching without making annotations.

Annotation: as the analytic phase continued, various networks became visible, some in a salient manner, and others in a more ‘silent’ and indefinite shape. At this stage I also began to note annotations of specific events, and the interactions and links that emerged between the actors in the data. Following Callon’s second principle “generalized symmetry” I used the same terms when explaining the actors’ actions. Massumi (2002) describes this type of analytical attention as an open-ended practice of sense-making, explained as a multisensory experience where perception, cognition, and affect are interlinked. Law (2004, p. 14) defines this as “a combination of reality detector and reality amplifier”. All annotations were structured the same way; they were dated and details of which capture and when in the capture the specific event were played out.

Selection: the next step in the process was to select pieces of the data in terms of specific events. Some enactments of socio-material relations were chosen, and others were not. This is a necessary aspect when applying a socio-material approach; i.e., “cutting the network” as explained by Strathern (1996). As explained, according to Callon’s (1986) third principle, free association, no selection criteria in the form of a coding system were used. Instead, the video recordings picked for a closer analysis were chosen according to Stafford’s (2001) concept of intensification, which is similar to what MacLure (2013) explains as “moments of wonder”. This can be described as when I as a researcher engage with the data, and something emerges—in this case in the video captures—that grasp and affect me. Accordingly, besides the logic related to the research questions, the analytical attention may also be affected by the entanglement of relations between the data and myself as a researcher. Consequently, the video captures and field notes picked out for analysis were chosen based on intense relational events characterized by moments of disconcertion, fascination, and curiosity; i.e., wonder (Stafford, 2001; MacLure, 2013).
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Transcription: the moments within the data—the selected pieces of video captures—were reviewed and transcribed. In this process I came close to the data, and I tried in the work to follow actors’ interactions and emerging network effects, trace actors’ relations, their relational materiality and performativity, and track whether and how translations produce durable networks (or not).

Crafting events: some of these transcripts were then turned into events demonstrating socio-material relations between the VA application, KV, teachers, and students. By using both written text and sometimes screenshots from the video recordings, the events are present in the papers as short descriptions of how heterogenous actors interact.

Ethical considerations

In a research process there are always ethical considerations. To reach ethical adequacy “one has to consider not only exceptional cases, but everyday decisions, and reflect not only on the conduct of others but also upon one’s own actions” (Burgess, 2005, p. 1). The code of the Swedish Research Council, (2017) has assisted the entire research process. In the beginning, an ethical vetting was made within the VISE project that this thesis is a part of. The ethical procedures described there have guided the research through the work. Throughout the two studies, recurrent ethical considerations and discussions about trustworthiness, honesty, respect, and accountability have been held by me and the other researchers in the VISE project, but also with the participating teachers and students. Moreover, to ensure the quality of the research, the aspects of trustworthiness and credibility have been addressed when designing the methodological and analytical procedures thoroughly, as described in the method section.

When developing the research procedures of planning, setting up collaboration with teachers, implementing an intervention in classrooms, and presenting results, I have strived to do so openly, fairly, and objectively. I have also aspired to treat teachers with respect, to listen to their thoughts and ideas, and remain aware of how our different roles might affect the relationships within the group. For teachers there is always a risk of exposing themselves in different ways; for example by revealing things one might not want to reveal in terms of professional practice or personality. Also, it can be revealed if the participating teachers
lack specific knowledge, dare to “let go”, or how they to learn new things. To fulfill individual protection for the participating teachers they have thoroughly been informed according to principles of research ethics. They were informed about the research process, about the project’s confidentiality, and how the research material would be used. After this they gave consent to participate.

Moreover, it is important to take into account that there is also a risk that students may risk exposure regarding ignorance, behavior, or social skills in the classroom. Such a risk can be ethically troublesome, especially related to the video captures, as unwanted or inappropriate behavior could be caught on film. However, this did not happen.

To be certain to fulfill individual protection for the participating students, both the students and their parents were informed according to principles of research ethics (information, consent, confidentiality, and how the research material was to be used). In the following section, a short description is given of how students and parents were informed about the studies, the consent procedure, and how the empirical data is stored.

**Information and consent**

Prior to the two studies and the intervention, all students and their parents received information about the study and told that participation was voluntary (see Appendix 3). Efforts to uphold participants’ anonymity were described and participants were also informed that their involvement in the study could be terminated at any time. Also, the participants were informed that all empirical data was only to be used for research purposes. Written consent to participate was collected both from the students and their parents. This was a challenging task that demanded a lot of time and effort but contributed to participation. In the first study, consent was given by 96 students (out of 97), and in the second study all 56 students gave consent.

**Storage of the empirical data**

Following the recommendation from the Swedish Research Council, I have declared how data have been collected and how data will be taken care of after the research study concludes in a data management plan. The data management plan is registered at the university.
A tree-like code key of all recordings has been produced, so it is possible to easily gain an overview of the entire material. To ensure correct storage of information regarding the schools and persons involved, their names have been anonymized, as the Swedish Research Council (2017) describes. Also, to grant anonymity at future presentations and publications all names of participants, if mentioned, are altered. When screenshots from the recordings are displayed, faces are blurred.

Three external hard discs with passwords are used to safely store the video recordings. The three researchers involved in the VISE project have one external hard disc each to ensure access to the recordings in case of technical errors on one or two of the hard discs. As the recordings have been analyzed, two of the hard discs will be deleted, and the remaining one will be stored according to General Data Protection Regulation (2018). All digitally produced lesson plans, notes, and students’ digital presentations are also stored on the external hard discs. The consent letters are stored in a locked cabinet at the university. The handwritten field notes and recordings of focus group interviews are stored in the same way.

Methodological reflections

When setting up a research study, as well as during the entire process, there are many aspects as well as choices to be made which guide the thesis in various directions. In this section I reflect upon trustworthiness, my roles as teacher and researcher, and DBR as the methodological approach.

Trustworthiness

Earlier I addressed trustworthiness in relation to ethical considerations. Here, it is reflected upon in relation to the studies at large. The concept of trustworthiness relates to the truth value and transparency of how a study has been conducted and, most importantly, it is vital in terms of how findings can be considered useful and honest (Cope, 2014). What exactly can be deemed trustworthy has been debated (Leung, 2015), but a common interpretation refers to it as adhering to the criteria of credibility, dependability, confirmability, and transferability, as outlined by Lincoln and Guba (1986).
The most important criterion, according to Polit & Beck (2014), is the *credibility* of the study, similar to the concept of validity in quantitative research. This has been adhered to in the thesis by using procedures in accordance with the theoretical framework; i.e., in accordance with how such studies usually are performed. Credibility also entails prolonged engagement with participants, peer-debriefing, and member-checking (Connelly, 2016). This was accomplished by applying the DBR approach during my own and the other researchers’ close collaboration with the teachers, several meetings with in-depth discussions, in the design of lesson plans, and in the jointly planned, realized, and evaluated intervention.

According to Pilot and Beck (2014), *dependability* refers to how quality can be assessed with confidence regarding data production, a focus of the analytical attention, and interpretation. How the data production in this thesis was organized and produced has been addressed in the method section, both in writing and by a model offering an overview. Also, by describing the applied analytical attention, as is done in the method section, I mean that I provide possibilities for others to assess the quality of the studies. By explaining what happens (in the networks) through thick detailed descriptions, credibility has been promoted (Shenton, 2004).

The third criterion, *confirmability*, refers to the neutrality or degree to which the procedure and methods in a study are consistent and possible to repeat. The studies in this thesis are deeply affected by the theoretical approach chosen. The networks I choose to follow, which actors I include, how I chose to cut the network, etc., means that it is not possible for another researcher to repeat these studies in exactly the same way. However, one way to consider these matters is to discuss your methods, analysis, choices, etc., with other qualitative researchers. Throughout the two conducted studies I was a member of the VISE project. We regularly worked together, discussed, and reflected upon procedures and findings. Moreover, all results within the project are presented in co-authored papers. Therefore, it is argued that the ambition to prevent biases of only providing my perspective on the research has been achieved. The collaboration strengthened the confirmability of my study. However, as a researcher, to be a part of creating knowledge, rather than uncovering it,
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entails that there is no method of guaranteeing an unbiased result (Gunnarsson, 2018; Hekman, 2010).

Furthermore, *transferability* means whether the results of a study may be generalized, or useful, to other contexts. In my view the presented results in the different papers relate to a common view and add knowledge to the scientific community of VL. By reaching the quality of work that corresponds to a scientific standard, the findings are presented in four different papers published in international journals. This is, I argue, a measure of transferability. However, what might limit the transferability are that the studies are relatively small in scale, deal with novel interactive visualization readers, and have been conducted at an early stage in students’ visual reading and writing practices. Moreover, my role as a researcher affects the research process and thereby not only the research results but also changes in the school practice. To set up the studies, demonstrate the technology, form a TRT, reflect and discuss about teaching with VA, create lesson plans, etc., in this process I am anything but ‘a fly on the wall’; instead I affect and am affected by other actors in a mutual process. The choices I make, what networks to select and highlight in the study, and how to define and delimit phenomena depends on me as a researcher (Højgaard & Søndergaard, 2011). So, certain steps are taken which others might not have chosen. Furthermore, my different roles in the VISE project are another concern. As mentioned in the beginning of this comprehensive part of the thesis, I first joined the project as a teacher, introducing the VA application in my classroom during social science lessons. A while later however, as I obtained a doctoral position connected to the project, my role and thereby my perspective changed. The switch of roles in the project have resulted in both pros and cons. One advantage was that I already knew the foundations and aspirations of the research team and was firmly convinced of what I wanted to explore. Another was that I was well acquainted with the educational practice and had an inside understanding of the teachers’ work. This facilitated, for example, communication with the teachers and knowing elaboration on lesson plans. However, sometimes it was hard for me to refrain from my preconceived notions as a former teacher. Nevertheless, this duality has been mostly favorable in my opinion. As stated by Barab and Squire (2004), to be so deeply involved in the entire research process, as DBR often leads to, might challenge the researcher in making
credible and trustworthy assertions. Working as closely as we did within the TRT, foremost the second TRT, means that we share a common knowledge, shaped during meetings and discussions that have been thoroughly documented. This close collaboration could also mean a possible blindness to aspects outside the group. As a counterweight to this, my participation in research seminars and doctoral courses were valuable and supported the broadening of my knowledge and the possibility of bringing new perspectives to the team.

**DBR as methodological approach**

The choice to apply DBR as a methodological guide means that it is necessary to work closely with teachers as experts on educational practice. A close collaboration can run smoothly and effectively, but it can also involve risks; for example personal disagreements slowing down the research process. The risk as it turned out in this thesis was that for teachers to learn advanced technology, and reflect and discuss with others during several meetings, meant work that all in all stretched over many days. Although there were economic guarantees covering the costs to engage supply teachers, there were none available to hire. Hence, some of the teachers expressed that they had to focus on their ordinary schoolwork and therefore only participated in the first study. Perhaps some of the teachers that withdrew also did so due to a feeling of insecurity about inviting researchers in their classrooms. However, although some teachers left after the first study, they have contributed a extensively this thesis. The teachers that continued in the second study engaged tremendously with their skills gained in the first circle, time and effort spent on meetings and work in between the meetings, together with allowing me access to their students and classrooms. Another methodological reflection is related to the iterative nature of DBR, which can result in difficulties of deciding when to stop. There is always a chance that something does not turn out as expected and it is tempting to initiate another round of the DBR phases. If collaboration works well, as was the case in these studies, one of the strengths with practice-based research is the opportunity to explore effects that are produced together with participating teachers and in practice. This means research might lead to changed practices, rather than research effects upon practice (Gunnarsson, 2018).
Stengers (2005) describes this as investigating what the practice can become, instead of describing what it is.

I conclude this section of reflections by articulating my opinion that the thoroughly described DBR process support the trustworthiness of the thesis. It is my belief that the theoretical approach of socio-material perspective allowed me to detect and analyze important patterns of how actors interact. By this, I could describe the highly complex reading practice where multiple actors affect and are affected by each other in the classrooms. Therefore, I view this study as methodologically solid and as contributing important knowledge related to all the three RQs.
Chapter 5

Findings

This chapter first addresses research questions one and two, through a summary of Papers II, III and IV. Then, the third research question is answered by a summary of Paper I together with a review of the results in Papers II, III, IV.

Characteristics of ‘reading’ interactive visualizations

As mentioned, both Papers II and III correspond to the first research question, as they map characteristics of reading interactive visualizations. Paper II mainly focuses on the initial connections between the visuals and the readers, and explains how relations and interactions come into being together with emerging visual literacy. Paper III focuses more extensively on how the reading process unfolds by following how the reading starts and develops.

Summary of Paper II

“Emerging Visual Literacy through Enactments by Visual Analytics and Students”

This paper generates knowledge about how reading visual interactive interfaces are constructed, and how students and interactive visualizations connect and interacts. ANT contributes the study's theoretical frame. Methodologically, the DBR approach guides the study and, accordingly, a close collaboration between researchers and social science teachers has directed the research design (Anderson & Shattuck, 2012; Easterday, Rees Lewis, & Gerber, 2016). The aim is to deliberate on what potential aspects of VL might appear when a VA and students interact in social science secondary classrooms.

Avgerinou and Pettersson (2011) express that to interpret information from visual sources requires VL. To read the interface of a VA further increases the importance of being able to read, or translate, visual information (Lundblad, 2013; Stenliden, 2014).
The results show various characteristics of reading interactive visual sources. First illustrated is how visuals and vision shape each other in the tight and intense socio-material relations between a VA, teachers, and students. In this kind of reading there are multiple possibilities for the visuals and gazes to connect. Foremost, the relations between the visuals and the students’ gazes are strong and performative, which tends to produce ‘quick’ or ‘locked’ vision. Quick vision is when a visual directs the student’s gaze, the movement of the eye that assists the student in quickly finding information. In opposition, locked vision is when a visual—for example a highlighted and moving bar in a bar chart—directs and holds the student’s gaze, supporting the student in focusing on, holding on to, and following the bar. Accordingly, the interlinked actors are performative as they work upon and influence each other.

Second, the actors’ performativity promotes enactments that either hinder or enable the reading of the interactive interface. The two kinds of vision produced for example by visuals’ movements, different highlighting effects, or various colors therefore effect the possibility of the interactions to be strong and durable. For example, a visual like an orange link can produce a quick vision, supporting the student to find information. What complicates the interactions is that an orange link may also produce a locked vision that hinders the student from continuing to read. As this happens, other information goes unnoticed and the possibility of proceeding with reading is weakened. When facing trouble—i.e., “trials of strength”—and interactions cease, actors like the teacher, another student, the cursor, or visuals, can act as “lines of force”; i.e., something that supports actors in reconnecting and continuing with the interactive reading. Hence, complexities in the reading process are demonstrated and interactions vary in force and duration depending on the relational materiality and performativity that affects how students and visuals interact, or not.

Third, the characteristics of the reading highlighted here can also be linked to several aspects of VL. For example, when certain visuals stand out and attract students’ vision this is ‘visual discrimination’. Such visual contrast leads to some visuals being seen while others are not noticed. ‘Visual association’ occurs when some visuals are associated with others; for example, when students relate a red dot in the scatter plot with the red spot in the map, thereby associating the information from both areas
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of the interface. This helps to ‘construct meaning’ from a visual message. For example, seeing the timeline display the economic development of a country assists students in relating to previously acquired knowledge of that country’s growth in textile industry. ‘Visual reasoning’ is present throughout the enacted interactions when reading during the lessons. Discussions and reflections as students and visuals connect demonstrate students’ understandings and reasoning in coherent ways. These kinds of VL aspects emerge and support students’ interactive reading.

In sum, Paper II contributes the insight that visuals and vision shape each other, pointing towards the importance of being aware of how the performativity of each single visual property might attract the eyes. It also shows the complexities of how the same visuals and visions, due to how they are combined, may either hinder or enable the reading of the interactive interface. Furthermore, this paper contributes with knowledge of different VL aspects that emerge when such reading takes place.

Summary of Paper III

“The Construction of Interactive and Multimodal Reading in School—a performative, collaborative and dynamic reading”

Paper III sheds light on how the reading process unfolds by following how the reading starts and develops. It focuses on exploring how interactions between a Visual Analytics (VA) application and students shape the reading practice of an interactive and multimodal interface in social science secondary classrooms. Also, this paper is theoretically guided by ANT metaphors and a DBR methodology. The aim is to produce knowledge of how the interactive and multimodal reading practice is constructed. Information-rich interfaces like a VA generate complexities concerning how to ‘read’ multimodal information on a screen and require a different type of reading (Bearne, 2003; Bowen & Roth, 2005; Serafini, 2012). In particular, the differences lie in the mixture of modes provided.

The results reveal that it is difficult for students to establish a starting point for reading this kind of interactive visualizations. At first there are hesitating movements and lose connections between students, visuals, and text. The interactions are transient and elusive and no actions that could count as ‘reading activities’ seem to occur. The cursor scrolls

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up and down, and students’ gazes neither focus on visuals nor on written text. However, although the interactions are hesitant and indecisive, the actors keep on trying to establish links to start the reading. This indicates that the interactive and multimodal interface, with a variety of visual actors, seems to induce a willingness among most of the students to keep on trying to read. Also shown in this paper, is that the performativity of visuals is strong and affects students’ gazes, encouraging them to stay focused. Thereby a starting point is found, and the reading activity is initiated. Most frequently, visualizations in the map, the scatter plot, or the bar chart become starting points. Written text, on the other hand, is merely passed over, and students’ gazes do not connect with it at all in the beginning. After a while the interactions become more coordinated, which stabilizes the reading network. For example, the cursor moves between visualizations and written text several times, and as these different semiotic carriers of information come into view it enables the actors to connect with each other.

As the reading network proceeds, a reading direction is slowly produced. Precisely as when finding a starting point, it seems as if visuals stand out and come into sight prior to the written text. Especially visuals such as color, highlighting, and movement attract students’ attention in a dominant way. This phenomenon of visual performativity seems to affect the reading direction so that written text is obscured; almost invisible. So, on one hand the performativity of visuals is supportive in the production of a reading direction, as students quickly connect with them. On the other hand, that same performativity may also hinder the connection between students and the written text. This often leads to difficulties for the students to comprehend their assignments, and after a while they realize the necessity to connect with both visuals and text. These findings clarify that to produce a reading direction merely based on interactions between students and visuals results in an ‘insufficiently’ constructed reading. It is shown that a combination of visuals and text supports an interactive and multimodal reading, which enable students to solve school assignments.

Also shown is that reading is collaborative; for example when the cursor’s arrow assists students’ gazes to follow written text lines or bars in a bar chart. Evidently, when collaborative interactions occur between all actors the reading turns from vague and insecure to systematic, swift,
and efficient. Different reading directions are produced on the interface and the reading supports students in tackling the assignments.

The results also demonstrate that the reading is affected by the fact that the surface can be transformed by various interactive features. Hyperlinks, zoom-functions, interactivity, changes to the statistical indicators or highlighting-effects, etc., all provide possibilities to change the composition of how the multimodal text is displayed. When the readable information is easily distinguishable and designed in a distinct way a successful and dynamic reading is produced. Demonstrated in this paper is the possibility to shift reading area. If the reading fails in some area; for example when the zooming is misdirected and reading in that area is not possible, the reading interactions shift to another readable area. Clearly, the possibilities provided by the interactive features contribute to a dynamic design of the reading surface.

Overall, Paper III contributes with knowledge that interactive and multimodal reading is established by interactions where actors search and find a starting point, produce a reading direction, and change the reading surface. The results clarify that reading is characterized as being intense, performative, collaborative, and dynamic. This knowledge contributes to equipping teachers and students with insights of how literacy in interactive and multimodal texts (LIMT) can support reading, and how that reading practice can be developed in schools.

Students’ insights translated to knowledge visualizations

The second research question focuses on how students’ insights from a VA can be translated to knowledge visualizations. The question will be answered by a summary of paper IV.

Summary of Paper IV

“Students’ Insights from Interactive Visualizations Arranged Multimodally in Knowledge Visualizations”

This paper corresponds to the second research question, which addresses how students’ insights from a VA are translated to knowledge visualizations. As in the other papers, this paper is theoretically guided
by ANT metaphors. Methodologically it follows the iterative phases in DBR and builds on the classroom intervention, planned jointly by myself and the teachers. The intervention continued during the second study and was re-planned in relation to the results and analyses from the intervention in the first study. Also, this time the now redesigned intervention employed the VA application Statistics eXplorer that visualizes official statistics (here General Net Income, imports, exports, and consumption) from the World Bank. The students were instructed to transform their insights into multimodal KVs that they would later present to the teacher and other students. The teachers specifically encouraged the students to refrain from written text, except where it was unavoidable and emphasized that these KVs were to be mainly visual presentations. The empirical material consists of zoomed-in webcam recordings (61.5 hours) from 12 social science lessons. The two teachers and their 56 students participated in the classroom interactions. Field notes were also taken.

The aim of Paper IV is to detect patterns in how these knowledge visualizations are produced and arranged multimodally.

It is known that interactive visualizations like VA applications support students in handling visualized, large, and complex data sets but that multimodal and interactive opportunities seem to ‘collide’ with schools’ common ways of encouraging students to demonstrate their knowledge through written text-based modality (Stenliden, 2014, 2015; Åkerfeldt, 2014a). Therefore, when working with multimodal technologies in schools, it is important to not only thoroughly develop students’ ability to read, understand, and draw conclusions from a visual mode, but also to develop their methods for how their insights can be reformulated and represented in multimodal knowledge formation (Baldwin, 2015, 2016; Bearne, 2009; Cope & Kalantzis, 2000; Purdy, 2014). However, there has been little empirical research on the specific ways in which understanding the practices of how such translation, or reformulation, might transfer and develop iteratively when moving from one kind of text to another, or from one form to another (Sefton-Green, 2021). Inspired by the field of knowledge visualization (KV), this paper explores what happens when students, working with official world statistics as displayed by a VA’s interactive visualizations, are encouraged
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to translate and demonstrate their insights into multimodal knowledge visualizations.

The results in Paper IV demonstrate the translation process when students’ insights from the interactive visualization, the vislet, are translated into KVs. Three patterns emerge as the KVs are produced: exploring, gathering, and inserting.

Initially, an exploration of the interface takes place through movements and connections among different actors; i.e., the students, the visuals, and the written text in the vislet. Students’ gazes and the cursor moves around the visuals and written text at the interface. The cursors click on different visuals, the students comment on and discuss what happens, interactive features like zooming are tried out—interactions where actors support each other in handling the technology as well as in initiating the work with the assignments. Links between the actors are established as the actors move around and connect with each other. Challenges may appear when the students are unable to connect to the VA; for example when the zooming fails. Then the exploratory interactions stop, and the emerging network is weakened and risks dissolution if the actors do not find a way to reconnect.

The second discernible pattern constitutes a gathering of insights. The actors now orient toward how to translate the insights drawn from the VA, and this is done by selecting and ‘storing’. The selected insights either come from reading and analyzing the interactive visualizations or from the teacher demonstrating and discussing something that attracts the students’ attention. At first, the students ‘store’ their visually gained insights by writing text in a text document. The selected insights—both visuals from the VA and verbal utterances by the teacher—are thus translated into written text. Despite frequent reminders from the teacher to gather screenshots of their insights, at first only written text is stored in the text document. However, bit by bit a shift is demonstrated in the interactions. After a considerable amount of text has been accumulated, visuals in the form of screenshots from the vislet are added to the text. It seems as if it takes time to change the students’ mental model of how to present insights as they, after a while, realize that visual insights do not necessarily have to be translated to written text but can be presented in the same mode. During the gathering of insights, some actors interact so strongly with each other that links with other visuals or written text are
sometimes weakened or interrupted. This may lead to insights only being gathered from one area in the VA, whereas other areas have become rather invisible, and can entail that the most relevant information is not selected.

The third pattern is when the insights are inserted and arranged multimodally in the KVs. More actors are integrated; and tabs of the overall topic instruction, the assessment matrix, the digital presentation program (the future KV) open at the interface. The insertion interactions are characterized by students’ gazes and the cursors quickly moving between all these actors inserting and arranging insights on slides in the presentation program. Written text from the text document, together with screen shots are copied and inserted into the presentation program, turning it into a KV. The results show that during this process the written text is translated to headlines and bullet lists, and combined in different ways with the visuals. Many actors are involved in designing the layout of the slides, thus shaping the KV. For example, visuals and written text change places, animations of the slides and their order are altered several times, and interactions are coordinated in a rather playful and experimental way. The inserted visuals can carry information that provides an overall picture, detailed insights, and demonstrate general patterns and/or specific information of outliers. However, if some visual information is obscured; for example if some bubbles in the scatter plot or countries in the map are missing due to a failed zooming, or due to blurriness, the visuals are difficult to comprehend. At times the interactions stop, and the students express that they do not know how to proceed, but then the cursor and students’ gazes move between the topics of instruction, clicking on interactive features, visuals take place on the interface, and the interactions commence again. Also assisting the production of the KV is that students discuss and demonstrate their work to each other, providing tips and tricks as a way to guide and help one another.

The KVs are also affected by the teacher’s instructions of how a message can be reinforced by adding visuals such as colored frames, circles, arrows, highlighting, underlining, etc. As the inserting and arrangement interactions continue, improvement becomes visible. The results demonstrate that what first appears as a visual playfulness is an important step in the process of developing and improving students’ visual abilities. Moreover, after further interactions back and forth between the vislet,
the text document, and the KV, some students skip the intermediary text document and insert the insights into the KV directly from the VA.

The multimodal KVs are arranged and rearranged over and over again. They are information-rich and characterized by visuals as carriers of information, and act as reinforcers combined with some written text (headlines and bullet lists) as a semiotic mode.

To sum up, this paper contributes to identifying and describing the patterns exploring, gathering, and inserting in the translation process. Also shown is how the multitude of actors taking part in a digital multimodal writing activity of producing a KV affect and change each other when transferring, relocating, reformulating, and re-presenting the insights from the VA to the text document, and finally to the KV. The results also show that it is important for teachers to allow and encourage students to explore, experiment, and play with the interactive features, visuals, and text on their own, as a way to improve the KVs. Equally important is that students are not left entirely on their own, as teachers’ guidance is crucial in several ways. For example, demonstrating functions and discussing insights in the VA, showing the use of visuals as message amplifiers, and emphasizing the importance of using visuals that “show the entire picture”; i.e., visuals that are not missing parts of vital information or are blurry.

Overall, this study contributes knowledge of how KVs are produced and arranged, and provides awareness of what might hinder or support students’ development of visual abilities when transforming insights multimodally.

Critical issues emerging in the support of students’ visual literacy

The third research question focuses on emerging critical issues important for the support of students’ visual literacy. The question will be answered by a summary of Paper I, together with a re-analysis of all papers, as well as an analysis of the focus group. As a reminder, in the early phases of the first study, the teachers had little experience of interactive visualizations and had never tried the Statistics eXplorer. In the second study, based on their gained skills and insights, the teachers elaborated upon a new and refined lesson plan.
Summary of Paper I

“Innovative didactic designs: visual analytics and visual literacy in school”

This paper provides findings about teachers’ development of didactic designs; that is, thoroughly conceived lesson plans in which VA and KV are combined in learning activities in school settings. Applying ANT as a theoretical stance assisted in the exploration of relations between students, teachers, the VA, and other actors (Callon, Law, & Rip, 1986; Latour, 1987; Law & Hassard, 1999). The DBR approach guided the study methodologically (Anderson & Shattuck, 2012; Easterday, Rees Lewis & Gerber, 2016). The aim is to clarify vital components emerging in innovative didactic designs that attempt to enhance students’ VL. In classrooms, there are often clashes between the use of powerful multimodal digital technology and traditional ways for students to produce and present but also for teachers to assess student knowledge (Stenliden, 2014; Åkerfeldt, 2014a). Clearly, as the digital (visual) resources are put to use in classrooms, they call for a pedagogy that takes account of both the process of making visual discoveries and various expressions of student knowledge; especially modes that embrace visuals and a visual vocabulary. In other words, modes that embrace the main components of VL theory: visual perception, visual language, visual learning, visual thinking, and visual communication (Avgerinou & Pettersson, 2011).

The results in this paper demonstrate that vital components in teachers’ didactic design plans consist of a mix of modes in the learning activities, a strong combination of spoken and visual instructions, and different organized opportunities for joint reflections. By including a mix of modes in the lesson plans, the teachers put effort into balancing performative, rapid knowledge formation with a deeper, more reflective way of learning (c.f. Fleischer, 2013). Highlighted are that combinations of visualizations and spoken elements are meant to constitute powerful tools for developing students’ VL. Opportunities for reflections are seen as supportive for developing visual discrimination, visual thinking, visual association, and visual reasoning. Another result is that different kinds of writing dominate the intended use of KVs. It is suggested in the lesson plans to use digital mind maps with written notes or to arrange written text graphically in maps. It seems that teachers’ inexperience of
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visual technology makes it difficult for them to promote expression and organization of visual elements in KVs.

Revisiting all papers: towards a didactic design synthesis for visual literacy

As summarized, the lesson plan in Paper I demonstrate vital components for a didactic design aiming to support VL which relates to the third research question. In Papers II, III and IV, the focus was primarily on reading and writing. To answer research question three more thoroughly, a re-analysis of all the papers is made together with an analysis of the focus group. Thereby, a focus on didactic design that centers the support of students’ visual literacy is made possible. This procedure offered insight into some critical issues that are presumed to affect teachers’ support of students’ VL. The identified issues will be described under the three following subheadings.

The unfamiliarity with visual reading and writing

So far, neither teachers nor students are familiar with reading and writing together with interactive visualizations. All papers in this thesis show that managing and maneuvering the advanced technology and commencing the reading are somewhat complicated in the beginning. For example, Paper III reveals the difficulties for students to establish a starting point and reading direction. At first there are hesitating movements and weak interactions between students, visuals, and text. Yet, they keep on trying to read, and after a while many students handle the visualizations with boldness. Students explore and try out different functions in a rather daring way, and teachers are more careful and hesitant. However, as demonstrated in Paper IV, when the teachers’ knowledge of the VA application increases and they learn to handle the interactive features, it is possible for them to pedagogically instruct and demonstrate important features in the VA for their students.

Moreover, teachers and students seem to be unaware of how visuals’ performativity affect the reading. Papers II and III illustrate how visuals and written text affect students’ gazes (or not) in this complex and dynamic reading surface. The teachers rarely give thorough instructions of how to manage the interactive features or how to gain insights from the various visualizations. The teachers seldom distinctly guide their students in the initial phase of the visual reading or writing processes.
Added to this, teachers’ insecurities seem to prevent them from leading joint discussions (as revealed in Papers II and III). However, when teachers have become more familiar with visual reading and writing themselves, they demonstrate interesting insights and lead joint discussions (shown in Paper IV).

Being unfamiliar with the practice of visual reading and writing, teachers are forced to rethink their practice and need to leave familiar territory. For example, when designing teaching it is necessary to be aware of the differences between the reading students are accustomed to and the interactive reading practice. As stated in Paper IV, multimodal and interactive texts seem to ‘collide’ with schools’ common ways of encouraging students to demonstrate their knowledge by written text-based modality, so it is desirable for teachers to become more familiarized with visual reading and writing engagement in development work. The challenging and time-consuming process of initiating teaching with interactive visualizations requires teachers to prepare to put a lot of effort and enthusiasm into exploring and planning for teaching with interactive visualizations.

The teachers also bring up the unfamiliarity when talking about reading and writing visualizations. This is expressed by one of the teachers:

…it is chaotic, you do not know the structure. Everything comes at once and you have no strategy to begin with.

They refer to it as “a new way to read and a new way of presenting knowledge” that is difficult for some students, as they are used to the ordinary way of reading usually expected in school. Furthermore, they say that when you are insecure yourself, reading a screen also is difficult for them. Moreover, the teachers express that if they themselves lack knowledge, the students become insecure. However, the teachers declare that it becomes easier to support the students when you have worked with this type of visualizations for some time. One of the teachers says:

We learn them to read [written text in books, authors remark], we simply cannot leave them in this. We must guide them, demonstrate!
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The teacher mentions that the students need support during the reading process. But, as the students work and show each other, they are inspired. Another teacher expresses the complexity in reading or writing with visuals but also how this kind of reading could have a positive impact on the students:

...images swishing here and there...they understood how to do, everyone used it, and some students blossomed.

To summarize, the unfamiliarity results in a necessity to rethink how to read and write, of what an interactive text entails, where to begin, how to maneuver, how to proceed, how to know what visuals to use when demonstrating knowledge, and for teachers how to teach all this when you are unaccustomed to any of it yourself. What is also clear in the analyses is that students require support in their understanding of the interactive data visualization features, as they need to learn what they can show and what visuals they may choose.

A questioning of the written
As students and teachers construct reading of the interactive and multimodal interface in a vislet, the written text’s privileged position is challenged. It is shown (Papers II and III) that the performativity of visuals is strong and affects students’ gazes in remaining focused, while written text is often passed over or even neglected. Paper III examines how a starting point is found, and how a reading direction is produced, thereto it is demonstrated that visuals stand out and come into sight prior to the written text. In particular, visuals such as color, highlighting, and movement attract students’ attention in a dominant way. The strong visual performativity seems to affect the reading direction so that written text is obscured; almost invisible.

On the other hand, there appear to be a ‘resistance’ from both teachers and students to leave the tradition of the written as the main mode for presenting insights. The first lesson plans, analyzed in Paper I, underlined a mix of modes to be used and especially pointed out that students’ insights from interactive visualizations were to be presented visually. As demonstrated, teachers encouraged their students to refrain from written text and emphasized that the KVs should be mainly visual. But then they instructed the students to write their findings in text documents and, in the assessment phase, the students had to answer study
questions in *written text* before doing a *written test*. So, producing KVs based on visuals was not realized in the classrooms in the first study (Paper I). Hence, to refrain from using written text when producing KVs is difficult. Also, Paper IV illustrates that students at first gather visual insights and translate them to written text in a text document. It takes some time before the students let go of the written and instead insert gathered visuals directly in the KV. It seems as if the dominance of written text is a communicative practice that is a challenge to modify. Evidently, teachers and students are facing conflicting conceptions of how knowledge is usually presented and how it can be done differently. However, when the teachers have developed their skills in handling the interactive visualizations, together with improved visual abilities of their own, their guidance on how to present insights visually become much more resolute and distinct (Paper IV). At first, students are often uncertain of how to translate their visual insights into KVs and hesitantly begin to insert their insights into the KVs. However, this changes as the teachers thoroughly exemplify how a KV may appear and how visuals may be used as reinforcers of a message. Then, the students start to produce their KVs with increased confidence. At this point several of the students begin to skip over the text document or notebook as an intermediary and instead begin to translate their insights from the VA directly into the KV. Hence, as teachers’ instructions and demonstrations specifically underline visual literacy abilities, this highly affects the students’ presentations. In addition, it is revealed that teachers allowing their students visual playfulness when producing the KVs as well as to move around in the classroom, showing their KVs to each other is supportive when students insights are translated into a KV (Paper IV). Therefore, different ways of visualizing insights are spread among the students, which is beneficial for many.

In the interview, the teachers revealed that some students panicked at first when they were advised to refrain from written notes on paper when presenting their KVs, but that they managed this very well. According to the teachers, none of the students failed, in comparison to when they demonstrated their knowledge in written tests. The teachers commented that here the students had to build up their results over a long time, and then show and demonstrate what they have learned, and not only through bullet lists. This, according to the teachers, lead to students
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interacting directly with their presentations. The teachers explained that the students were used to having a written text document in between.

To sum up, when reading, visuals’ performativity strongly affects students’ gazes in staying focused, while written text is often passed over, therefore it is difficult for students to solve their assignments. When demonstrating knowledge in KVs, both students and teachers find it hard to leave the mode of written text.

The interactivity and its dynamics

There are innumerable ways to read/navigate and communicate information by a VA. This phenomenon, addressed in Papers II, III and IV, means that teachers and students have multiple opportunities to interact with the VA. Where, what, and how interactions take place during the construction of reading and when producing KVs differs among students. Also, the interactivity includes the possibility to change the actual reading surface, which in turn affects what information can be ‘read’. This means that teachers’ pedagogical overview becomes fragmentary, as the possibilities to know what specific information their students have read are limited. This, compared to students reading from books, leads to a teaching situation where teachers lack control over what subject content their students have processed. Moreover, the numerous opportunities to find information in a dynamic reading area makes it impossible for teachers to be ‘experts’ on all the content displayed on the interface. Thereby it is also impossible to predict what issues students will address in an openly held discussion. As demonstrated in Papers I, II and III, this uncertainty and lack of content control seem to prevent teachers from leading joint reflections on interesting insights.

Furthermore, the possibilities of dynamic interactions between the reader and the various modes and readable areas in an interactive visualization complicate the construction of reading. Paper II illustrates how the same visuals and students’ visions (quick or locked), due to how they are interlinked (or not) either hinder or enable the reading of the interactive interface. Challenges appear when students, visuals, and written text are unable to connect, which weakens the reading and writing network, but as demonstrated in Papers II, III, and IV the actors often find a way to reconnect. Usually when the interactions stop, the cursor and students’ gazes move around on the interface—the map, the scatter plot, the topic instruction, and clicking on interactive features, which enables
the interactions to start over. Hence, visuals and vision shape each other, and the result is a changeable reading process depending on which actors connect. However, dynamic possibilities to change the reading surface might lead to inserted visuals in the KVs, which can be difficult to comprehend, for example if they fail to provide an overall picture, lack detailed insights, or do not demonstrate general patterns. This may, for example, occur due to a failed zooming when gathering insights via screen shots. If the visual is blurry, if some visual information is obscured or even missing, the interactivity and its dynamics challenge the reading and writing.

In the interview, the teachers mention that when reading static diagrams on, for example, climate or rainfall, the teaching is more focused on specific content. In cases where students had to find facts on their own it is a non-steered and open practice. Regarding different reading directions, the teachers expressed that when they themselves became more skilled, they asked the students questions like:

Where have you found this? What did you do to get there?

Reported by the teachers is that this type of reading and writing requires clearly expressed frameworks but within those frameworks, openness is possible.

Altogether, this suggests that it is helpful for teachers to consciously align pedagogy and technology to develop visual skills. By elaborating on how the critical issues identified here can be taken into account in classrooms, it will be possible to present additional vital components of how teachers can design education that supports students in developing VL. This will be done in the next chapter.
Chapter 6

Discussion

This research expedition in social science classrooms set out on a quest towards visual literacy in school and during the maneuvering along societal and educational challenges several insights have emerged. Of significant societal importance in this post-truth era, and one of the reasons for writing the thesis, are the changed circumstances of how we can make sense of the world. The risks of a blurred border between truth and lies, a questioning of facts, and disinformation campaigns have increased as contemporary society faces an unprecedented information overflow together with the power of technological developments (Andre & Lavicza, 2019; Journell, 2017; McIntyre, 2018; Tandoc et al., 2018; Wikforss, 2017). One way for educational practice to meet such challenges, as revealed in this thesis, is by providing a way for students to obtain a worldview based on official statistics through a VA application as the Statistics eXplorer. Illustrated is that such interactive visualizations can assist students in choosing relevant data and trustworthy information, as well as gain insights and develop their abilities to handle and communicate them to others. This means that schools can support students in acquiring a fact-based view of the world by implementing tools like VA (Andre & Lavicza, 2019; Jern, 2010; Lundblad, 2013; Prodromou, 2017; Rosling et al., 2005; Watson, 2017), and thereby that such visualizations offer an opportunity to counter falsehoods.

However, this thesis also shows educational challenges deriving from implementing advanced visual technology in schools. Foremost, to read interactive visualizations and to write knowledge visualizations, challenges our assumptions of what reading and writing usually is and puts pressure on schools to adapt by altering communicative practices. Exploring how reading and writing ‘could be otherwise’ (Woolgar & Lezaun, 2013), meaning how reading and writing can be performed in a visual context, this thesis reveals shifting practices. In such visual reading and writing processes, it is essential for students to become visually literate. Consequently, teachers’ roles are vital when aligning pedagogical strategies in a didactic design that support students in developing VL.

This discussion chapter first addresses educational challenges related to the double aspect of visual literacy. This means that initially the
results of what characterizes the development of reading interactive visualizations and how students’ insights are translated to KVs will be discussed. Critical issues that emerged along the research expedition will thereafter be addressed in relation to a didactic design to support students’ visual literacy in such classrooms. Hence, the discussion that follows encompasses the results in relation to the overall aim: to map what characterizes ‘reading’ of interactive visualizations and ‘writing’ knowledge visualizations accompanied by implications for the didactic design in such classrooms. Further, earlier research and implications for students and teachers will be addressed. In the concluding remarks, as a closure of the discussion chapter, I return to the arguments for embarking on this research expedition and further elaborate on the educational and societal challenges.

Shifting communicative practices

As pointed out in the introductory chapter, digital technology and the information overflow, put forward a shift in how to process and communicate information in schools which has been explored in the different papers. Here, I first give an account for and discuss the results of what characterizes the development of reading interactive visualizations and then how students’ insights from a VA are translated to knowledge visualizations. The intention is to discuss how the results contribute knowledge in relation to didact design of educational practices. Additionally, contributions made possible by the socio-material perspective and DBR will be discussed.

Characteristics of an interactive reading—a complex yet achievable socio-material endeavor

The analysis in the conducted studies (Papers II and III) demonstrate how multiple actors are involved in a relational material practice when reading interactive visualizations. Five main characteristics of reading interactive visualizations unfolded in the analysis; they are intense, performative, complex, collaborative, and dynamic.

There are intense interactions between many actors, foremost between students and different visual features. The interactions include, for example, quick changes of the interface, emotional outbursts,
Diagram switching, reinforcing gestures, bars moving rapidly, concentrated gazes, bodies leaning closer to the screen, text boxes appearing and cursor movements. Reading is shaped by the actors’ performativity. For example, visuals in the VA application such as highlighting, movement, and color strongly affect students’ gazes while written text often becomes subordinate and sometimes even ‘invisible’. What happens then is that some areas on the interface are read, while others are not. By this the performativity might weaken, dissolve, or strengthen a reading network. In the analysis it is shown that in the interactions, mainly visuals and vision shape each other, but that a combination of visuals and text is more supportive when reading interactive and multimodal texts. Moreover, to read interactive visualizations are characterized of being highly complex since there are multiple possibilities for visuals, written text, and students to connect. Depending on which actors in the reading process that connect and how they interact with each other might either challenge or promote reading. It has been shown that strong performativity of visuals and the interactivity can act as both trials of strength, hindering the reading, and lines of force, that enable the reading (Paper II). Therefore, it is vital to be aware of how visuals, written text, and students’ gazes connect, thereby influencing the reading process. The results of this thesis contribute knowledge about how interactive reading is established through interactions in which actors search for and find a starting point, produce a reading direction, and change the reading surface. The reading process is characterized as being non-linear, and the absence of a given starting point cause obstacles to the establishment and maintenance of a strong reading network. Furthermore, the reading also includes establishing a reading direction, which is enabled through collaborative interactions. In addition, the reading is also, beyond being non-linear, characterized by being dynamic. Depending on what information the actors interact with, the reading surface can be changed, and different areas are navigated, while others are passed. Additionally, there are several VL aspects that emerged in the analysis when students read interactive visualizations, such as visual discrimination, visual association, constructing meaning, and visual reasoning (Paper II). The reading process often develops from vague and indefinite to systematic and efficient, as VL abilities are improved. In addition, it is revealed that these VL abilities need to be learned and practiced.
The results presented here raises various, interesting, and urgent aspects of reading of relevance to society at large and educational practice in particular. The latter will be discussed here, and in the concluding remarks of this chapter I will address the points pertaining to a wider, societal level.

In line with the work of several other scholars (e.g., Bearne, 2003, 2009; Serafini, 2012, 2017; Walsh, 2008, 2010, 2017), this thesis shows that the intensified use of screens displaying both texts and visuals noticeably changes the concept of reading. As a reading network comprised of students, visuals, and written text in the VA began to emerge, initial interactions were hesitant. Most likely, this can be related to students’ earlier established conceptions of what reading (written text) usually consists of in school. Now, in terms of reading an interactive and multimodal text, it was crucial to pay attention to visual elements and how they were arranged (Burmark, 2002; Kress & Van Leeuwen, 2006; Samara, 2007; Watzman, 2003; Walsh, 2017), as well as be cognizant of the interactive features on the interface. Reported by Behnke (2016) is that even visuals in social science textbooks may be difficult to read, depending on the design and layout influencing the visual attention. In the reading surface of the VA, visual attention could be steered toward a range of visuals all of which could display development over time through a moving timeline. Yet, although the students were unaccustomed to the VA, this was rather quickly managed by them as they, often in a persistent and fearless manner, started exploring the interface. I assert that reading development; i.e., finding a starting point and reading direction, was made possible because of the strong relational materiality and performativity of the multitude of actors, as shown in Paper III. Also, the interactive features in the VA, the different modes in such a multimodal text, and its strong effect on students gazes often produce intense, collaborative, and dynamic interactions, and thereby a willingness to construct the reading.

As shown in the results of Papers II and III, the actors are entangled in the reading practice. While other researchers express that the reader has a choice of where to read, what to read, or to design their reading by selecting and giving attention to what is in line with their interest (Bearne, 2009; Kjällander, 2011; Kress, 2010; Serafini, 2011, 2012, 2014; Walsh, 2006, 2017), this thesis shows that this is not entirely up to the
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reader. Papers II and III, focused on emerging VL and reading, demonstrate a more complex practice, where the relational materiality and performativity strongly affect the reading actors. I stress, based on these results, that it is the reading network that designs what and where it is possible to read. From my perspective, it is no longer adequate to say that reading is merely a socially- or culturally constructed practice (Carter, 2006; Diaz, 2007; Purcell-Gates, 2020). Instead, I agree with Burnett et al. (2020) and Dezuanni (2015) in that it is a socio-material reading practice. Dezuanni (2015) even argues that a sociocultural approach is inadequate for gaining a complete understanding of emerging literacies when individuals interact with digital technologies:

Failing to recognize material processes risks telling only part of the story of how digital media literacies may be assembled. (Dezuanni, 2015, p.420)

The analysis demonstrates that the practice of reading interactive visualizations accentuate and strengthen the view that it is a socio-material enactment, as earlier expressed also by others (Pennycook, 2018; Kümerling-Meibauer, 2015; Mackey, 2016). This thesis contributes knowledge that supports the claim by Gourlay and Oliver (2016) that when writing “it’s not all about the learner” (p.77), when it demonstrates the characteristics of interactive reading. Based on the described results, I argue that it is vital for teachers and students to be aware that how reading is designed depends upon which relations and interactions the heterogeneous actors manage to establish reading networks.

The results in this thesis also point towards the necessity of being an active reader and employing certain strategies in this changed reading practice. Not only do the actors work together, but they also work upon each other, coordinating actions. The fact that when interacting with various modes, readers must be more active and employ other strategies concur with earlier research (Coiro, 2014; Hamat et al., 2010; Serafini, 2011, 2012). The visuality and interactivity induce students to be active readers, and as the results demonstrate, they continued to put effort into trying to construct the reading, although they faced challenges. As shown, this occurred as the performativity at times challenged the reading. In this thesis, several aspects of what might hinder or enable interactive reading are demonstrated in detail. When this happened, as the
reading network faced trials of strength and risked dissolvement, the actors continued to interact, and through different lines of force the network was often strengthened, and thereby the reading could continue. This willingness to succeed in reading, to try and try again, thus finding new actors to interact with, is in line with what Brownell (2020) reveals about how students, through a remediation process, learn to use multiple communicational tools and practices, Comber’s (2016) idea of students discovering of resources by playing, questioning, and conveying ideas; and also Firat’s et al. (2022) writing on students’ willingness to experiment. As illustrated in Paper III, in relation to the changed reading practice, it is vital to develop strategies on how to handle the interactive features, how to maneuver and navigate the interface, and how to change the reading area; i.e., learning the ‘How, What, and Where’ to read. Observing how students engaged in visuals such as captioned images, maps, tables, and timelines in social studies text, Roberts and Brugar (2017) found that none of them understood all aspects of all four devices and therefore needed explicit instruction and scaffolding. In comparison to a static text, when students reading an interactive text ‘failed’ in one area of the interface (the map, the bar chart, or the scatter plot) the information can be read in another area (Paper III). I stress that, for teachers and students it is essential to gain knowledge both of how one can be affected by and affect other actors, and the importance of experimenting actively combined with these strategies in a visual information process, such as reading interactive visualizations.

One of the arguments highlighted in the introductory chapter is the need for further knowledge of the shifting communicative ways generated by digital technology, and specifically interactive visualizations. Given the results of Papers II and III, one conclusion is that further knowledge of how the reading process develops and what VL is, are crucial for the educational practice. As demonstrated, the reading process often developed from vague and indefinite to systematic and efficient as VL abilities were improved. Hence, my argument would be that for students in an increasingly visualized world, this kind of reading is also crucial to learn, precisely as much as learning to read written text. This is in line with Börner et al. (2016), Glazer (2011), Saddiqa et al. (2019) and Schönborn and Anderson (2010). And, further, for students to learn and practice VL abilities, teachers must learn to do so, as well.
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Interactions between students and the VA that produced emerging VL abilities such as visual discrimination, visual association, visual reasoning, and constructing meaning, all occurred in the reading networks. Those aspects were detected when students collaborated in pairs, and, for example, related to previously acquired knowledge, associated information from various areas on the interface, talked and reflected. Yet, such VL was, in the first study, seldom noticeable on a classroom level. However, by applying the iterative phases in DBR methodologically it was clearly demonstrated that when the teachers in the second study were more familiar with VA and VL, they frequently allowed students to demonstrate findings and held joint discussions and reflections; i.e., supported their students to develop VL. Except for improved technical skills, this type of teaching also seems to require teachers be willing to let go of what I would refer to as ‘content’ control, and be open for possibilities to, in real-time, discuss earlier unknown insights together with their students.

Hence, relating to the first part of the VL definition, it is obvious that students are capable of reading/decoding/interpreting visual statements; i.e., assembling meaning from visuals to extract information and interpret data (Avgerinou & Pettersson, 2011; Brumberger, 2019; Lee, 2017). In conclusion, on the basis of the result of the papers in this thesis, I suggest that in order to be able to reason, associate, and construct meaning when reading interactive visualizations, both teachers and students need to learn the reading process. Although it may be a complex endeavor, it is achievable when performed in close collaboration between students, teachers, and visualizations. In the next section on the writing aspect of VL, translating insights to KVs, will be discussed.

Translating visual insights to knowledge visualizations—an entangled visual enterprise

When students’ insights from working with interactive visualizations are translated to knowledge visualizations, a multitude of actors are involved in the process. At first, they are all dispersed, but during the translation process they are reassembled in the final KVs. The networks consist of visuals and written text in the VA, students, the teachers, the cursor, the keyboard, the digital presentation program (the future KV), tabs of the overall topic instruction, the assessment matrix, etc. The actors change
and affect each other, which in turn transfers, relocalizes, reformulates, and re-presents the presentation of the insights. The visualizations in the VA are translated to, for example, maps and scatter plot bubbles with layers of arrows, frames, etc., as highlighters and reinforcers of insights. The written text is still present, although in a minimal way, as it is translated into bullet lists, key words, and headlines. Three specific patterns emerge when insights are translated: exploring, gathering, and inserting. In the beginning of the translation process, some interactions are hesitant and even stop for a while, but later in the process strong networks are established and the exploring, gathering, and inserting actions are swift and straightforward. Exploration of the VA’s interface takes place through movements and connections among, for example, the cursor (moving, zooming, and scrolling), the map with colored countries, students’ gazes, and unfolding text boxes. Students’ gathering of insights commences through selecting and ‘storing’ information, to begin with in the mode of written text. After a while, text documents decrease as intermediaries between the VA and KV as the insights are translated directly from the VA to the KV. The layout of the KVs is arranged and rearranged several times by the students as they insert their insights. The analysis also illustrates that it is important for teachers to allow students to interact rather freely with other actors, as for example, trying out and experimenting with visual functions on their own. Such visual playfulness appears to be supportive in the development of visual abilities. Furthermore, it seems to be inspiring for students when teachers demonstrate functions in the VA together with examples of what a KV might look like. The results demonstrate that multimodal arrangements like KVs are generally information-rich, that the visuals are either carriers of information or used as reinforcers of the message, and that written text is used as a semiotic to complement the visuals.

All together, these results (Paper IV) demonstrate how visually gained insights from a VA are translated into a multimodal KV by interactions between heterogeneous actors. When analyzing my material, it was evident that the translation moments (problematization, interessement, enrollment, and mobilization) allowed me to follow, in detail, how visuals and written text were transferred, relocalized, and re-presented. I stress that to translate insights, a range of complex interactions by a multitude of actors is required.
In accordance with Kress (2003), and Åkerfeldt (2014b) describing that digital writing is non-linear and includes a lot of moving and editing back and forth by the writer, the results presented in this thesis show that students, when exploring, gathering, and inserting in the KVs quickly move between the VA, slides in the digital presentation program (their future KV), and tabs of the overall topic instruction and the assessment matrix; and that they experiment, arranging and re-arranging recurrently. This confirms what was earlier expressed by Williams and Beam (2019); namely that digital writing is a complex undertaking of simultaneous planning, writing, and reorganizing the written. When performed in a visual context, these literacy abilities are described by Serafini (2017), as VL transactions with multimodal ensembles comprised of visual images, and different design elements, as well as written text. Based on the results in my study, I argue that it must be added that such translations are even more complex when interactivity is also a component. I assert that interactivity and its dynamics complicate the writing process at first, but then promote the production of KVs. As demonstrated, initially, some interactions are hesitant and even stop for a while (Paper IV), and it is possible to see that it might be difficult for students to produce visualizations. Firat et al. (2022), concluded that it is harder for students to generate their own visualizations than it is for them to interpret graphs, but experimenting with different modes is motivating and promote engagement. However, later in the translation process, strong networks are established and the exploring, gathering, and inserting actions are swift and straightforward. Bresciani and Eppler (2015) explain similarly how the users of interactive technologies are invited to interpret, design, and produce visualizations. In my two studies it is also shown that interactivity produce a willingness to continue because students’ gazes strongly connect with the writing surface. In my view, what engages and affects is related to relational materiality and the performativity of all actors. So, while others depict the writing process as steered by the writer, I underline that, precisely as is the case with the reading process, the material perspective adds a depth of comprehension to the writing process.

An intriguing result of the conducted studies is the resistance to abandoning written text as a mode for demonstrating knowledge in school. Both teachers and students find it difficult to leave the written
text. Probably, as shown by Stenliden (2014) the clash between school practice and visual communication is deeply embedded. This is in line with what many research studies highlight; namely how student’s multi-modal productions challenge teachers’ traditional assessment practices (e.g., Baldwin, 2016; Magnusson & Godhe, 2019; Silseth, & Gilje, 2017; Sofkova Hashemi, 2013; Åkerfeldt, 2014a). Hence, called for are teachers willing to rethink institutional norms and dare to leave written text as the main mode for assessing school assignments.

It likely takes extensive effort and practice to alter teachers’ and students’ conflicting conceptions of how knowledge is usually presented and how it can be done differently. But, as illustrated, producing information rich KVs is doable (Paper IV). Factors of major significance are teachers’ decisive demonstration of what a KV looks like, how visuals also can act as reinforcers of a message, and to allowing students visual playfulness (Paper IV). Presumably, if playing with visuals had been stopped by teachers, the students’ development of VL would likely have been hindered. The analysis in Paper IV demonstrates that a mix of working on their own, and talking about and demonstrating their visualizations to each other, together with moments of teachers guiding are beneficial when producing a KV.

As shown in Paper IV, when both teachers and students had learned more about producing KVs, writing process could also be described in a similar way as the reading process. This is in line with Walsh (2017), who asserts that in digital contexts it is often impossible to see reading and writing as separate; instead they frequently occur together. Precisely as the analysis revealed (Papers II and III) multiple actors are involved in a relational material practice, and the same applies when writing KVs. Equally, the five main characteristics of reading can also be identified in the translation process; as mentioned they are intense, performative, complex, collaborative, and dynamic (Paper IV). However, there is one difference to be found, and it concerns the written text. In the reading process, written text is almost invisible, and it takes a lot of time before students connect to, for example, a text box with a written assignment (Papers II and III). On the contrary, as mentioned earlier in this section, during the writing process written text begins firmly in focus when presenting insights, and both teachers and students find it hard to leave the written. However, during the writing process, their attention is more
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steered toward inserting visuals into the KVs. Presumably, this is related to school practice and assessment procedures. Precisely as argued by Insulander et al. (2021) and Åkerfeldt (2014b), in my view, this can be related to the curriculum, existing school traditions, and to tools for assessment not being adjusted toward an interactive and multimodal text.

Relating to the second part of the VL definition, it is illustrated (Paper IV) that there were many informative and visually permeated KVs produced in the classrooms. By that it is possible to assert that interactions between students and visualizations have illustrated how to write/encode/create visual statements; i.e., to create and communicate a message to others (Avgerinou & Pettersson, 2011; Brumberger, 2019; Chevalier et al, 2018).

I underline, however, that it takes time and effort for teachers (and students) to rethink their practice and be willing to leave the familiar territory of written text. For this to happen, I claim that it is crucial for teachers to rethink the institutional norms regarding the written, adjust their teaching toward an interactive and multimodal practice in general, and new technologies and VL in particular. Hence, important is attuned practices as well as accepting that playing the role of an expert with full content control is impossible when teaching with interactive visualizations. Instead, the teachers' role in this type of teaching might be better considered to be a mix of instructor, guide, and collaborative partner when students produce visualizations.

Consequently, this thesis displays what Alper et al. (2017), Schönborn and Anderson (2006, 2010) and Stenliden (2014, 2015, 2018), all have indicated; i.e., it is not enough to introduce new technology, it must be accompanied by adapting new pedagogical practices.

Vital components in didactic design for visual literacy

When VA and KV are employed in classrooms, the critical issues earlier accounted for—the unfamiliarity, the questioning of the written, the interactivity and its dynamics — are challenging for students and teachers. Throughout the studies within the thesis, realized during the DBR process, the close collaboration with the teachers has made it possible to distinguish how they have iteratively elaborated upon lesson plans, implemented interactive visualizations, and developed their teaching; i.e., addressed these challenges. As intended when applying the DBR process
(Anderson & Shattuck, 2012; Barab & Squire, 2004) to generate design principles, these insights are presented in this final stage of the thesis. The design principles stem from a synthesis of the critical issues. They lay the ground for a didactic design framework for visual literacy in school consisting of several vital components. The framework is divided in two parts: prerequisites and guidelines for teaching.

The **prerequisites** highlight the importance for teachers to:
- acquire knowledge of different aspects of VL, meaning how students, visuals, and written text in visualizations interact
- strive for sufficient technical competence to feel confident enough to give adequate demonstrations and instructions
- plan for a combination of spoken and visual instructions which supports activities in the classrooms
- plan for a mix of modes in the learning activities

These **guidelines** are sorted into four teaching elements: instruct about VL, demonstrate methods, arrange joint activities, and encourage student initiatives. For a teacher it is important to:

**Instruct about VL:**
- in accordance with characteristics for interactive visualizations inform about general VL abilities (i.e., talk about visual reading, writing and other abilities such as visual reasoning, association, discrimination, constructing and communicating meaning)
- in correspondence to the general process of writing a KV, explain how the interface can be explored, how insights can be gathered and directly inserted, and how visuals can be arranged in a KV
- in relation to the multimodal character of an interactive visualization, explain that both written and visual modes are important, and neither are to be ignored.

**Demonstrate methods that:**
- explicitly display how visual reading and writing can be constructed; i.e., specific methods of how to become visually literate, thereby not only teaching content aspects related to what is displayed
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- show different ways of navigating and adjusting the reading surface, how to find a starting point and reading direction, and demonstrate how relational materiality and performativity might hinder or assist students to read
- expose technical features in the interactive visualization, here the dynalinked function, how to zoom and change indicators in the map, scatter plots, and bar charts, how to reset, etc.
- reveal examples of explorations, and how visual insights can be gathered from a VA, inserted and arranged in a KV, and that it is not necessary to first transform visuals to written text in an intermediary document

Arrange joint activities by:
- preparing exercises for shared exploration of different interactive features and functions
- organizing joint reading and writing activities
- organizing opportunities for joint discussions and critical reflections that explicitly support visual discrimination, visual association, and visual reasoning
- promoting students to demonstrate where, what, and how they have read and verbally express their insights to others
- encouraging students to show their work in progress, share ideas, and assist each other when producing KVs

Encourage student initiatives that:
- support collaboration; allow students to walk around in the classrooms, looking at other students KVs and demonstrating their own
- allow experimentation and visual playfulness in the production of KVs to support creativity and development of VL

This framework will enable teachers to support students’ ability to read and to produce visualizations by balancing fast, performative, and interactive visual information against a slower, more reflective, and thought-out way of translating gained insights into a compatible, attuned, and modifiable mode. It is essential to make room for discussions together with the students in the classrooms, and, as suggested by
Schönborn and Anderson (2006, 2010), critical and meta reflections are of great importance. Therefore, adequate attention for the visual information is encouraged. This pedagogical strategy also counteracts students’ ambition to quickly transform their insights into written text (Stenliden, 2014). In addition, joint discussions support students in learning how to demonstrate knowledge visually by preventing them from being left too much on their own.

If teachers are made aware of VL abilities themselves, they will have a greater chance of supporting their students in reaching a higher level of visual and critical thinking, analytical reasoning, and reflection. Such abilities are needed, as expressed by Bresciani and Eppler (2015), Chevalier et al. (2018), Glazer (2011), Roberts and Philip (2006), and Schönborn & Anderson (2006, 2010), in collaborative tasks, including information visualizations, where visuals may support sense-making and understanding.

Thus, to successfully construct reading of interactive visualizations there is an imperative for employing VL, and therefore, this should be taught in schools today. It is an intriguing demand, and raises the question of how the teachers can learn more about how to support their students in developing VL. What is needed then, by the teachers, is time and engagement in development work. The list of vital components focusing on the implications of technology use can promote teachers’ VL competencies and operational skills, as well as pedagogic processes and practices; although gaining such skills and practices is reported as challenging by Elf et al. (2018), Björk Gudmundsdottir and Hatlevik (2018), Brevik et al. (2019), Schönborn and Anderson (2006) and Tondeur et al. (2021). Literacy skills such as these are essential today, as expressed by Börner (2019), and for students to learn it is of course advantageous if teachers are familiar with the concept and how to teach it. Demonstrated in this thesis is a need to develop this literacy practice, which means that teachers’ professional development becomes a central aspect for planning and realizing this type of didactic design for supporting VL. Saddiqa et al. (2021) suggest that ways of promoting teachers’ pedagogic visualization skills may be to organize workshops, training, and seminars. Lantz Andersson et al. (2022) and Voogt et al. (2015) have shown benefits for teachers in participating in educational design research projects where they are included in the whole process as co-contributors and co-
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designers. Participating in such research projects may increase engagement, individual and collective developments, and the envisioning of an intention to take action, which may lead to intentional and transformative action; i.e., a changed way of teaching. Based on the results in the thesis (all papers), DBR is a fruitful methodology to augment teachers’ abilities in relation to VL and interactive visualizations. As the teachers in these two studies took part in various meetings, the opportunities of discussing and trying out VA and KV and learn about VL made it possible to design and carry out teaching that supported students’ VL. In the first study, knowledge about teaching with a VA and KV was unknown to the teachers. Still, they willingly planned for didactic design, opened their classrooms during the intervention, and faced problems that emerged during the first study. Then, in the second study, when the teachers had gained further expertise in technical features of the VA, together with insights of emerging VL abilities, during various TRT-meetings, several of these vital components became visible in the jointly designed lesson plan.

Therefore, evidently it is vital to begin by attending to the two mentioned prerequisites; i.e., for teachers to both learn to handle the technology as well as to develop knowledge of VL abilities. However, I argue that this is not adequate if teachers are to be seen as key agents for designing a digital school practice, as emphasized by researchers, educational policies, and reforms (Caena & Redecker, 2019; Erstad et al., 2021; Lantz-Andersson et al., 2022). Even though collaborative studies performed by both researchers and practitioners increase, far from all teachers participate in such professional development. Instead, pedagogic processes and practices of teaching to support students’ development of VL ought to be both included in schools’ contemporary agenda for teacher development as well as incorporated into higher educational teacher training. Furthermore, I agree with Chevalier et al. (2018), that it is a paradox when visualizations are increasingly introduced in schools, but curricula hardly mention how to develop knowledge of interpreting or creating them.

However, various efforts in the research community are made to enlighten, educate, and improve teachers’ pedagogic practices and didactic design. As mentioned earlier, the use of, for example, the TPACK model (Nilsson & Lund, 2022; Willermark, 2018) can aid in designing
principles to teach abstract concepts, guided activity, reflection, pre-training, etc. (Alper et al., 2017; Moreno & Meyer, 2007), active learning to develop higher-order thinking (Schweitzer & Brown, 2007), guidelines for supporting VL (Schönborn & Anderson, 2006). The vital components proposed in this thesis, when teaching interactive visualizations, adds to that corpus of educational frameworks, and it is my hope that they will specifically contribute to supporting teachers toward VL in social science classrooms. Yet, since the framework focuses on a broad scope of visual literacy, foremost related to reading and writing visualizations, it is most likely applicable to other school subjects as well.

Concluding remarks

In this section I return to the societal and technological aspects challenging education and our assumptions of reading and writing. Those challenges were the arguments for conducting this thesis. At this final stage, considering the results, I return to the illustrated challenges from earlier. However, this time, the figure in the introductory chapter is turned the other way around. This time, the figure starts in the social science classroom, where the shifting communicative practices have become obvious in this thesis and thereby it is also possible to draw conclusions and portray the shifts as opportunities for school to contribute to contemporary societal challenges (Figure 15).

![Figure 15](image-url)

This thesis has shown how reading and writing in a visual context can be ‘otherwise’, what characterizes it and how it is performed. When VA technology that offers official statistical data is introduced in classrooms this is one way for school to enhance the possibilities for students to explore relevant and trustworthy information. These technological
developments increase the chances to navigate through large amounts of visualized data. It is clear that even though it is a complex undertaking in several ways, students are capable of reading the interactive visualizations in a VA and creating and communicating the information to others by writing KVs. Nevertheless, when implementing VA, the communicative practices shift, as illustrated in this thesis. The text is altered and the reading and writing practices are changed. There is no doubt that the shifts exert force on former assumptions of reading and writing. If school is to benefit from the VA opportunities, the assumptions of literacy must be broadened and also include aspects from VL. Furthermore, it is important to realize that problems of information overflow can be met by visualizing the information, thereby increasing capacity for interpreting the represented information, hopefully making it understandable. Also, it is important to assure that the visualizations build on relevant and trustworthy facts. Otherwise, the opportunities from using interactive visualizations are withdrawn. Working with the visualized information in a VA, students can engage in societal complexities related to a vast information flow in digital contexts, and in a critical manner review information and facts, as emphasized in the curriculum (The Swedish National Agency for Education, 2022). Accordingly, besides developing students VL and social science content knowledge, interactive visualizations provide opportunities for students to obtain a fact-based worldview. Considering that many students most certainly meet unfounded interpretations, perceptions, and opinions instead of relevant facts (de Pablos & Lytras, 2019; Lewandowsky et al., 2017; Visvizi & Lytras, 2019), the results in this thesis point at possibilities for schools to implement the VA technology and thereby, as one way, enable students to face falsehoods, skewed stories, and conspiracy theories (de Pablos & Lytras, 2019; Lewandowsky et al., 2017; Sismondo, 2017; Visvizi & Lytras, 2019). If we fail to properly provide our students with relevant technology, central values such as democracy will be threatened, as highlighted also by Farkas and Schou (2019), Sismondo (2017) and Van Dyk (2022). The relationship between society and technology is complex and can challenge how people create their world views (Visvizi & Lytras, 2019). Therefore, it is critical not only for students’ own knowledge-building but also for society at large that students learn both the double aspect of VL and to master VA technology.
The results of this thesis contribute with knowledge of how teachers and students can work with interactive visualizations based on trustworthy information. However, it is not enough to introduce new technology, it has to be accompanied by adopting new pedagogical practices. For most teachers this requires a professional development which in itself can be a rather complex task, as discussed above.

If taking the results from this thesis seriously it is urgent for school to seize the educational opportunities as a means to facing the societal challenges. Hopefully, by employing the means and methods presented through this research expedition, it is possible to support teachers and their didactic design for visual literacy. Nonetheless, for that to happen it is not only a question of teachers embracing and opening up for shifting communicative practices. In contemporary society different prevailing assumptions of what literacy is, how it should be understood and how it should be taught, create strong opinions and tensions between groups of politicians, media, higher education, school authorities, parents, teachers and students, where some want to reduce or even prevent the use of digital resources in school. Instead, if various stakeholders in society realize the potentials of an expanded understanding of literacy, teachers may be supported and constitute a positive force supporting their students towards visual literacy.

Future research

This thesis contributes with mapping what characterizes ‘reading’ of interactive visualizations and ‘writing’ knowledge visualizations as well as implications for the didactic design in such classrooms. However, designing the research process, conducting the intervention, and producing the data occurred at a stage when teachers and students in schools had none or limited experience of using interactive visualizations. The students are novel readers of the interactive and multimodal text (Statistic eXplorer), and teachers are unfamiliar with teaching this type of reading and writing. Hence, it would be of value to continue study how VL develops in relation to a situation where teachers and students are more experienced in using interactive visualizations.

Also, in relation to VL and school practice, relevant further research is how the VL framework, suggested in this thesis, can function as a guide for teachers’ didactic design when supporting students’ development of
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VL. Perhaps the VL framework can be elaborated on and complemented with further or even more specific guidelines?

Another interesting area to investigate further would be to focus more in depth on the subject social science and specific content issues. For example, as we live in an unstable and changing world with increasing migration, it would be valuable to implement, use and study the effects of using interactive visualizations as a resource to broaden and deepen students’ knowledge about how social and economic factors influence, for instance, people’s reasons for leaving their countries.

One more interesting and important aspect related to teachers’ and students’ use of interactive visualizations relates to constraints concerning assessment. One possible way forward could be to explore how the assessment practice is affected as students produce interactive and multimodal texts, in this thesis referred to as KVs. Apparent from this thesis is that there appears to be a ‘resistance’ from both teachers and students to leaving the tradition of the written as the main mode for presenting insights. This has also been addressed by other researchers, but exactly how students’ multimodal productions challenge teachers’ traditional assessment practices and how to address it are hitherto rather unexplored.
Chapter 7

Sammanfattning

I detta avslutande kapitel sammanfattas bakgrund och syfte med denna sammanläggningsavhandling, liksom dess metod, resultat och diskussion. I avhandlingen ingår förutom denna kappa fyra artiklar.

Bakgrund


Det finns numer informationsteknologi som har utvecklats just för att erbjuda metoder för att hantera stora mängder data och information. En sådan teknik är "visual analytics" (VA) vilken bygger på ett tvärvetenskapligt vetenskapsområde baserat på informationsvisualisering, kognition och perception (Thomas & Cook, 2005). Genom att visualisera data på ett genomtänkt och användarvänligt sätt erbjuder denna typ av verktyg metoder att utvinna och förstå stora mängder information. Bland information som visualiseras kan mönster, tendenser och samband lätt upptäckas (Andrienko m.fl., 2011). Även elever kan bearbeta, förstå och lära av visualiserad information som presenteras med hjälp av VA (Ho m.fl., 2011; Jern, 2010; Saddiqa m.fl., 2019). Exempel på VA-verktyg


Det är inte bara läsprocessen som förändras när interaktiva datavisualiseringar introduceras i skolan. Även skrivprocessen förändras när den görs digitalt och multimodalt (Clarke & Svanaes, 2012; Ghandoura,
Sammanfattning 2012). Tidigare studier har visat att även om Statistics eXplorer är användbart för både lärare och elever i samhällsvetenskapliga ämnen i skolan så uppstår andra problem (Stenliden, 2014). Ett sådant var elevernas ambition att snabbt omvandla sina kunskaper från sin interaktion med ett VA, till skriven text. De slutsatser som de kunde dra från den visuella informationen och uttrycka verbal var ofta av högre kvalitet än innehållet i den skriven text som eleverna presterade. Det vill säga, de ofta korrepta, slutsatser och intressanta reflektioner som eleverna gjorde krävde att eleverna representerade sina kunskaper också med fler modaliteter än endast det skrivna ordet. Användningen av VA i skolan, bestående av ett snabbt och interaktivt gränssnitt, "krockade" med den praxis som ofta råder i skolan: att visa kunskap skriftligt (Stenliden, 2014).


visuell litteracitet både ett fokus på att kunna 'läsa' (navigera igenom och tolka) visuell information och att 'skriva' (produiera och kommunicera) egna visuella representationer, i den här avhandlingen.

Syfte och frågeställningar

I denna avhandling undersöks visuell litteracitet i grundskolan när interaktiva datavisualiseringar används. Studien genomförs tillsammans med lärare på högstadiet och deras elever i årskurs 7, 8 och 9 under samhällsorienterade lektioner. Syftet är att bidra med kunskap om visuell litteracitet genom att kartlägga vad som kännetecknar läsning av interaktiva datavisualiseringar och skrivande av kunskapsvisualiseringar. Även implikationer för didaktisk design i SO-klassrum utforskas. Mer specifikt är avhandlingens forskningsfrågor:

1. Vad kännetecknar läsning när elever och visuella analysverktyg interagerar?
2. Hur överförs elevers insikter från visuella analysverktyg till kunskapsvisualiseringar?
3. Vilka aspekter framkommer som viktiga i didaktisk design för att stödja elevers visuella litteracitet?

Sammanfattning

Metod

Eftersom kunskaper om och användning av interaktiva datavisualiseringar ännu inte är så vanlig i skolor, var en förutsättning för studien att etablera ett nära samarbete med lärare som var intresserade av att prova VA i sin undervisning. Ett sådant samarbete inleddes med inspiration från ”Design-based research” (DBR), (Easterday m.fl., 2018; Wang & Hannafin, 2005). Samarbetet mellan lärare, med expertkunskap kring skolpraktiken, och forskare, med erfarenhet av och expertis kring den valda VA-applikationen samt olika kunskapsvisualiseringar, syftade till att gemensamt utforma en intervention i SO-klassrum på högstadieskolor. Interventionen genomfördes sedan i två olika studier som ingår i avhandlingen.


Uti från resultat från första studien (som redovisas i artikel I, II och III) och diskussioner inom lärrarforskarteamet konstaterades behovet av ytterligare en studie och en förbättrad didaktisk design. Två av lärarna uttryckte intresse för att fortsätta arbetet och att planera för en fortsättning av interventionen. Sammanfattningssvis, allteftersom det empiriska materialet analyserades, lade resultaten från interventionen i den första studien grunden för en om-designad fortsättning av interventionen. Ett nytt lärrarforskarteam (om)bildades bestående av två lärare, från en skola, och mig som den enda forskaren. I den andra studien var jag mer aktiv och involverad i både skapandet av interaktiva datavisualiseringar anpassade för det aktuella innehållet, så kallade vislets, och i processen att didaktiskt utforma utbildningen.

Den andra studien pågick mellan oktober 2018 och februari 2019. En ny lektionsplanering, med uppdaterad design, arbetades fram
gemensamt inom lärarforskarteamet och interventionen fortsatte, denna gång under 12 lektioner i två samhällsvetenskapliga klassrum med totalt 56 deltagande elever från en skola. Det empiriska materialet bestod även denna gång främst av inzoomade videoinspelningar, men även vidvin kelinspelningar av hela klassrummen samt fältanteckningar. Denna gång genomfördes också en fokusgruppsintervju med lärarna när lekt ionsarbetet var avslutat.

Analysen av det empiriska materialet, som till övervägande del bestod av webcam-inspelningarna, styrdes av materiell diskursiv analys (Callon, 1986). Fokus lades därför på interaktionerna mellan VA, KV, elever och lärare och de nätverk som uppstod mellan aktörerna (Law, 2004). I analysen granskades videoinspelningarna, och de nätverk jag valt att lyfta fram i relation till forskningsfrågorna har jag transkriberat på ett sådant sätt att alla aktörers handlingar tydliggjorts. Dessa finns presenterade i de olika artiklarna som så kallade "event" och är där även tydliggjorda med hjälp av skärmklipp. Den första studien behandlas i artikel I, II och III och den andra studien i artikel IV.

Resultat och diskussion

Resultaten gällande den första forskningsfrågan (om läsning) visar på vilket sätt de olika aktörerna i nätverket är involverade i läsandet av interaktiva datavisualiseringar. Fem specifika kännetecken som utmärker interaktiv läsning identifieras. Läsningen är; intensiv, performativ, komplex, präglad av samarbete och dynamisk.

Det är intensiva interaktioner mellan många aktörer i nätverket, främst mellan elevers blickar och olika visualiseringar. Interaktionerna inkluderar till exempel snabba förändringar av gränssnittet, känslomässiga yttringar, diagramväxling, förstärkande gester, grafiska staplar som rör sig snabbt, koncentrerade blickar, kroppar som lutar sig närmare skärmken, textutor som dyker upp och markör-rörelser. Läsningen formas av aktörernas performativitet. Till exempel påverkar olika inslag i VA-applikationens visualiseringar, som rorelse och färg, starkt elevernas blickar medan skriven text ofta blir underordnad och ibland till och med "osynlig" och därför varken upptäcks och än mindre bearbetas. Genom detta kan performativiteten försvaga, lösa upp eller stärka ett läsnätverk. Dessutom kännetecknas läsning av interaktiva datavisualiseringar av att vara komplex eftersom det finns flera möjligheter för

Resultaten med koppling till den andra forskningsfrågan, som rör skrivande, visar dels att många aktörer är involverade, dels att tre specifika mönster - utforskning, insamling och infogande uppstår. Det sker i skrivprocessen när insikter ska överföras från ett VA till en KV. Här bestrår nätverket av visualiseringar och skriven text i ett VA, elever, lärare, markör, tangentbord, ett digitalt presentationsprogram (som används för KV), dokument med elevernas arbetsuppgift och aktuell bedömningsmatris, etc. Aktörerna i nätverket förändras och påverkar varandra, vilket i sin tur återverkar på hur insikter från VA överförs, omlocaliseras, omformuleras och åter-presenteras i en KV. Visualiseringarna i studiens VA är i elevernas KV omvandlade till exempelvis kartor och punktdiagram kompletterade med visuella element som pilar, ramar etc., de senare för att förstärka elevernas insikter. Skriven text finns fortfarande kvar, om än på ett minimalt sätt i form av punktlistor, nyckelord och rubriker.
Utfordrandet av de interaktiva datavisualiseringarna sker genom rörelser mellan olika visualiseringar, zoomningar och scrollande samt kopplingar mellan till exempel en markör, en karta med färgade länder, elevers blickar och textrutor som visas på skärmen när markören passerar över exempelvis ett land på en karta. Insamlingen av insikter börjar med att information väljs ut och ”lagras”. I början sker lagring genom anteckningar i ett textdokument. Efter ett tag minskar dock användandet av textdokumentet som mellanled mellan VA och KV och insikterna transformereras allt oftare direkt från VA till KV. När de sedan infogas görs det genom att layouten av elevernas KV arrangeras och om-arrangeras flera gånger. Avhandlingen visar att när elever ges möjlighet att interagera fritt med andra aktörer, som till exempel att prova och experimentera med visuella funktioner på egen hand, så utvecklas deras VL-förmågor. Vidare framgår att när lärare demonstrerar funktioner i VA tillsammans med exempel på hur en KV kan se ut påverkas elevernas arbete med KV positivt.


För att besvara den tredje forskningsfrågan, om didaktisk design, gjordes en om-analys av de fyra artiklar som är inkluderade i studien tillsammans med en analys av lärarens resonemang från fokusgruppen. Det resulterade i några kritiska aspekter som har bäring på lärarens stöd till elevers utveckling av visuell litteracitet. Under de två studierna, då undervisning med VA och KV genomförts i klassrum, har framför allt tre kritiska aspekter visat sig vara utmanande för elever och lärare: ovanan vid dessa typer läsning och skrivande, ifrågasättandet av det skrivna samt interaktivitetens dynamik.
Sammanfattning


Interaktivitetens dynamik innebär att det finns oändligt många olika sätt att läsa, navigera, skriva och kommunicera. Detta medför dels att lärares möjligheter att skapa pedagogisk överblick över vad eleverna läst försvåras, dels att lärarnas möjlighet att vara 'experter' på ämnesinnehållet också utmanas.

Utifrån de tre kritiska aspekterna; ovanan vid läsning och skrivande, ifrågasättandet av det skrivna samt interaktivitetens dynamik, utformas i avhandlingen ett ramverk för didaktisk design med särskilt fokus på visuell litteracitet i en skolpraktik. Ramverket är uppdelat i två delar, förutsättningar och riktlinjer för undervisning. Förutsättningar handlar om vad lärare i förväg behöver för kunskap om visuell litteracitet, visuell teknik och hur en kan undervisa om detta. Riktlinjerna är indelade i fyra undervisningsmoment; instruera om visuell litteracitet, demonstrera metoder, arrangera gemensamma aktiviteter samt uppmuntra elevinitiativ. Dessa handlar om hur lärare konkret kan designa en undervisning som stödjer elevers utveckling av visuell litteracitet. Det är väsentligt att

Avhandlingens resultat visar vad som kännetecknar läsning och skrivning i relation till elevers arbete med interaktiva datavisualiseringar. När VA, som i detta fall innehåller en stor mängd officiella statistiska data, introduceras i klassrummen är detta en möjlighet för skolan att förbättra förutsättningarna för elever att utforska relevant och pålitlig information. Resultaten i de båda studierna visar att, även om det är ett komplext uppdrag att arbeta med VA, kan eleverna läsa de interaktiva datavisualiseringarna och skapa och kommunicera sina insikter till andra genom att skriva en KV.

Denna avhandling visar också att när interaktiva datavisualiseringar implementeras, förändras de kommunikativa praktikerna. Texten ändras och läs- och skrivvanor ändras. Det råder ingen tvekan om att förändringarna påverkar tidigare uppfattningar om läsande och skrivande. Om skolan ska dra nytta av de möjligheter VA bland annat innebär måste tolkningar om vad litteracitet är breddas och också omfatta centrala aspekter för visuell litteracitet. Vidare är det viktigt att inse att utmaningar kopplade till stora informationsöverflöden kan mötas genom att i skolan uppmärksamma att informationen kan visualiseras på läsarbeteligt sätt, och därigenom öka förmågan att tolka stora informationsmängder. Genom att arbeta med visualiserad information i ett VA kan elever engageras i, ofta komplexa, samhälleliga utmaningar och på ett kritiskt sätt granska information och fakta, vilket inte minst betonas i läroplanen (Skolverket, 2022). Följaktligen, förutom att utveckla elevernas visuella litteracitet och samhällsvetenskapliga kunskap, ger interaktiva datavisualiseringar elever möjligheter att utveckla vad jag kallar en faktabaserad världsbild baserad på tillförlitlig information. Resultaten i denna avhandling visar på möjligheter för skolor att implementera interaktiva
Sammanfattning

datavisualiseringar och därigenom, som ett av flera sätt, göra det möjligt för eleverna att möta lögnar, fake news, skeva berättelser och konspirationssteorier (de Pablos & Lytras, 2019; Lewandowsky et al., 2017; Simondon, 2017; Visvizi & Lytras, 2019) genom att kunna läsa interaktiv multimodal information i ett VA.

Det räcker dock inte med att introducera ny teknik, den nya tekniken måste åtföljas med anpassning av nya pedagogiska metoder och didaktiska arbetssätt. För de flesta lärare kräver detta en professionell utveckling som i sig kan vara en komplex uppgift där det exempelvis måste finnas möjligheter för lärare att utveckla sin egen visuella litteracitet. Men, det är inte bara en fråga för lärare att omfamna och öppna upp för förändrade kommunikativa metoder. Ofta skapar olika antaganden om vad litteracitet är, hur den ska förstås och hur den ska läras ut, spännings mellan olika grupper i samhället. Emellanåt uttrycks starka åsikter av föräldrar, skolmyndigheter, högre utbildning, och inte minst av politiker och media, där vissa vill minska användningen av digitala resurser i skolan. Om i stället flera intressenter i samhället inser potentialen i att anamma ett brett perspektiv på litteracitet, så kan det, tillsammans med utgångspunktarna för och resultaten i denna avhandling, utgöra en positiv kraft för lärare i arbetet med att stödja sina elever att utveckla visuell litteracitet. Skolan bör, menar jag, spela en central roll i användandet av relevanta informationsverktyg vilka kan bidra till att avslöja det falska och oklara och skapa möjligheter för alla elever att bygga kunskap från pålitliga källor.
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Appendices

Appendix 1 - Lesson plan template in the first study

UNDERVISNINGSPLAN

Namn: Klicka här för att ange undervisande läsare.
Var: [E-post] [Telefon]
När (preliminärt): till datum
Årskurs: Klicka här för att ange årskurs.

Ämnesområdet undervisningen handlar om:
Klicka här för att ange text.
Centralt innehåll som undervisningen kopplar till:
Klicka här för att ange text.
Kunskaper/mål med undervisningen – vad skall eleverna lära sig
Klicka här för att ange text.

Titel på Vislet som ska användas i undervisningen:
Klicka här för att ange text.
Beskriv helt kort innehållet i den Vislet som ska användas i undervisningen och vilka frågeställningar som berörs:
Klicka här för att ange text.
Beskriv kort och övergripande hur undervisningen är tänkt att organiseras – iscensättning (se modellen för ”design av en formell lärsekvens”).
Klicka här för att ange text.
Beskriv de instruktioner, uppgifter, aktiviteter och resurser som planeras för att användas i den ”första transformationscykeln”

1. Klicka här för att ange text, skriv något om hur lektionerna kommer att organiseras, vilka instruktioner som kommer att ges till eleverna, vilka uppgifter de ska
utföra, hur är det tänkt att de ska genom för dessa/vilka aktiviteter och vilka resurser är det tänkt ska finnas att tillgå (kan vara analogt eller digitalt).


3. Klicka här för att ange text, skriv något om hur muntliga resonemang, som utgår ifrån arbetet med Visleten, kommer tillstånd, i par, i helklass, akvariomodellen, din roll som lärare i detta, etc.

Beskriv de instruktioner, uppgifter, aktiviteter och resurser som planeras för att användas i den "andra transformationscykeln".

1. Klicka här för att ange text, skriv något om hur lektionerna kommer att organiseras, vilka instruktioner som kommer att ges till eleverna, vilka uppgifter de ska utföra, hur är det tänkt att de ska genom för dessa/vilka aktiviteter och vilka resurser är det tänkt ska finnas att tillgå (kan vara analogt eller digitalt).

Klicka här för att ange text, skriv något om hur den tänkta bedömningen av elevernas kunskaper kan komma göras, hur skall eleverna visa sina kunskaper, etc.

2. Klicka här för att ange text, skriv något om det är något annat du vill tillägga angående tankar kring eleverna, deras sätt att visa sina kunskaper eller något om bedömning.
Appendix 2 - Lesson plan template in the second study

Lektionsplanering (kopplad till lärsekvensmodellen)
Resurser:
Syfte:
Institutionella mönster
Forskningsmässigt:

Iscensättning:

Första transformationscykeln:

• Vad kan eleverna träna på/upptäcka i visleten?

• Lektionens innehåll:

• Formativ bedömning:

Andra transformationscykeln:

• Hur ska eleverna visa kunskap? Kunskapsvisualisering...
  Kombination av text, muntligt resonemang och bilder/visualiseringar. Fokus på visuella kommunikationen, hur kan eleverna med hjälp av bilder/visualiseringar förklara och berätta om...

• Summativ bedömning, kunskapskrav:
Hej, om deltagande i en forskningsstudie inom VISE!
Vi vill fråga er elever och föräldrar om deltagande i en forskningsstudie. Deltagandet innebär att eleverna under ett antal ordinarie lektionstillfällen får prova att jobba med ett verktyg som heter Statistics eXplorer.
Studien syftar till att utveckla kunskaper om hur elever läser och tolkar interaktiva statistikvisualiseringar och hur lärare kan organisera sin undervisning där interaktiva visualiseringar utgör undervisningsmaterial.
Tanken är att låta eleverna använda Statistics eXplorer, ett digitalt verktyg, för att prova visuella analyser av olika typer av befolkningsstatistik samt att låta dem använda olika kunskapsvisualiserings när de redovisar vad de lärt sig. Vi kommer att följa undervisningen med videoinspelningar.
En del av eleverna får dessutom prova så kallad eye-tracking. Vid eye-tracking registreras elevernas ögonrörelser – var på skärmen de tittar, i vilken ordning samt hur länge deras blick befinner sig på olika punkter. De får då åka in till Campus Norrköping där sådan utrustning är placerad.
Studien genomförs i samarbete mellan Institutionen för samhälls- och välfärdsstudier (ISV) och Institutionen för teknik och naturvetenskap (ITN) på Linköpings universitet. Projektet kallas för VISE, en förkortning av Visual Storytelling in Education. Via följande länk adress finns mer information om projektet [http://vise.academy](http://vise.academy)
Vår förhoppning är förstås att detta känns spännande och att elever alla vill vara med! Naturligtvis är deltagandet frivilligt och kan också avbrytas när som helst. För frågor går det givetvis bra att vända sig till någon av oss per telefon eller mail:

Jag (elev) ___________________ Vill delta i studien
Vill inte delta

Jag (vårdn.havare) ______________ Tillåter deltagande
Tillåter inte
Bästahälsningar,

Ulrika Bodén  Linnéa Stenliden  Jörgen Nissen
Doktorand  Lektor  Docent
Linköpings universitet  Linköpings universitet  Linköpings universitet
070-0850990  070-0850705  073 414 1036
ulrika.boden@liu.se  linnea.stenliden@liu.se  jorgen.nissen@liu.se
Appendix 4

Focus group interview guide   Fokus grupp - samtalsguide

Nu har det gått en tid sedan ni och eleverna deltog i projektet. Vad har ni för tankar kring det som hände? Elevernas arbete med att analysera, tolka och presentera visuell information... Handel, handelsmönster.

**Interaktion med applikationen**

- **Läsa en interaktiv skärm.**
  - Vad tänker ni att man som lärare kan göra för att stötta elevers läsande av en VA, interaktiv skärm?
  - Jämför med att läsa en lärobok/ ”vanlig” websida – vad kan det få för betydelse för dig som lärare?

- **Tolka och analysera information.**
  - Hur kan lärare hjälpa eleverna att förstå informationen i en vislet?
  - Finns sådant som är lätt/svårt för elever?
  - Hur kan elever stödjas i deras arbete med uppgifterna i texturutan?
  - Hur fungerar det att använda olika funktioner? Zoom, tidslinje, ändra indikatorer osv

- **Det interaktiva gränssnittet.**
  - Hur påverkar de interaktiva möjligheterna elevernas lärande? Jämför med vanliga kartor, diagram, färdiga länkar.

- **Vilken betydelse får detta för dig i planerandet av dessa lärlaktiviteter?**

**Kunskapsvisualisering**

- Hur presenterar elever vanligtvis sina kunskaper? (skriver text, bildspel, mindmap, affisch, muntlig redovisning, film, ljud, annat) Likheter/skillnader med VA och KV?
Elever som gör kunskapsvisualisering.
- Tankar kring hur elever "samlade" det som skulle användas vid redovisning? Jämför med hur de vanligtvis gör.
- På vilket sätt behövde elever stöd i att göra sina kunskapsvisualiseringar?
- Instruktionen att inte använda text, hur gick det för eleverna? Lätt/svårt? Utmaning?
- Utifrån instruktionen att använda visuella tecken för att tydliggöra, hur gick det? Jämför med andra redovisningar de gjort?
- Vad gör en kunskapsvisualisering tydlig/otydlig/intressant/lätt eller svår att förstå?

Presentation av kunskapsvisualisering.
- Hur upplevde du elevernas kunskapsvisualiseringar?
- Hur kan man spinna vidare på de samband, orsaker och konsekvenser som eleverna lyfte fram?

Didaktisk design
- Skillnader mellan första och andra omgången vislet-arbete?
- Hur tycker du att arbetet på lektionerna fungerade? Kommentarer utifrån lektionsplaneringen och hur lektionerna gick.
- Vad kan förbättras?
- Viktiga didaktiska överväganden är viktiga att göra när det gäller denna typ av läraktiviteter?
- Hur påverkar dessa läraktiviteter din roll som lärare?

Bedömning
- Hur bedömer du oftast elevernas kunskaper? Vad är vanliga bedömningsunderlag?
- Tankar kring den formativa bedömningen?
- Hur var det att (summativt) bedöma elevernas kunskapsvisualiseringar vid redovisningstillfället?
- Hur blev dessa bedömningar jämfört med andra?

Vilka (ul)förmågor behöver elever för att kunna tolka, analysera och presentera visuell information?
Tycker du att eleverna genom detta arbete har utvecklat sådana förmågor? I så fall, på vilket sätt?
Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

https://doi.org/10.3384/9789180750233


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