# Handling socio-scientific controversy: students' reasoning through digital inquiry

# Handling socio-scientific controversy: Students' reasoning through digital inquiry

Anne Solli

GÖTEBORGS UNIVERSITET
ACTA UNIVERSITATIS GOTHOBURGENSIS

ISBN 978-91-7346-999-9 (print)
ISBN 978-91-7346-499-4 (pdf)
ISSN 0436-1121

Doctoral thesis in Education at the Department of Education, Communication and Learning, University of Gothenburg

The thesis is available in fulltext online:
http://hdl.handle.net/2077/58396

Distribution:
Acta Universitatis Gothoburgensis, Box 222, 405 30 Göteborg, or to acta@ub.gu.se

Photo: Stefan Larsson

Print: BrandFactory AB, Kållered, 2019

# Abstract


| | |
|---|---|
| Title: | Handling socio-scientific controversy: Students' reasoning through digital inquiry |
| Author: | Anne Solli |
| Language: | English with a Swedish summary |
| ISBN: | 978-91-7346-999-9 (print) |
| ISBN: | 978-91-7346-499-4 (pdf) |
| ISSN: | 0436-1121 |
| Keywords: | science education, socio-scientific reasoning, controversy mapping, digital tools, SSIs, video analysis |



The ambition of this dissertation is to develop knowledge of students' reasoning and digital inquiry about socio-scientific controversies (SSCs) in science education contexts. Motivating this research is the vast access to information on SSCs that have become readily available to us through network-based digital media and the challenge of selecting, analyzing and evaluating claims from various disciplines and perspectives. The dissertation is grounded in sociocultural and dialogical perspectives which imply that students' reasoning is investigated as being embedded in activity and shaped by the framings, demands, and traditions constituted through practice. The overarching research questions concern how student reasoning is 1) contingent on institutional, social and material contexts, 2) mediated by mapping tools developed within Science and Technology Studies (STS) when SSCs found online are investigated, and 3) the kinds of communicative competences displayed when students investigate SSCs digitally. Empirical material was collected in two different educational institutions. At a technical university, data collection was focused on group work on genetically modified (GM) food in an introductory biotechnology course (study I). At a science program in an upper secondary school, the focus was on group work on handling SSCs by using digital mapping tools (study II, III, IV). The data comprises several ethnographic sources including video-recordings, field notes, documents, as well as artefacts produced by students. The findings are presented in four studies: Study I reports on how students came to understand how to articulate an appropriate argument in a techno-scientific community exhibiting the features of biotechnological discourse, a

community-specific use of language that legitimates the epistemic and moral authority of science and marginalizes GMO opponents. Study II reports on how students recirculate a message from a scientific study that has been widely spread online that claims that GMO causes cancer in rats. It shows how such 'appeals to science' gained their meaning and rhetorical power as a discursive resource intrinsic to different Communicative Activity Types (CATs). Study III reports on how students' unfolding discourses on socio-scientific controversies (SSC) can be fruitfully analyzed by using dialogical theories. The findings illuminate how students discursively manage the multivocality and multimodality inherent in SSI online and reveal a set of discursive means that the students use to handle the many perspectives involved when communicating about an issue. Study IV reports on how a digital network visualization tool together with other mediational means such as a task provided by teachers, supports students when analysing data found online. The analysis shows how tool-mediated activity provides means for students to work out what is relevant and useful in a corpus of online data, categorizing online material in terms of criteria such as institutional status, trustworthiness, and position of a controversy. Overall, this dissertation points to the importance of learning not only to make what appears to be well-founded knowledge claims by appealing to science, but also the need to understand how science is used rhetorically in different contexts in order to develop appropriate contextualized responses to complex issues in a pluralist, democratic society in the Internet age.

# Contents

# Acknowledgements

Jag är glad för allt stöd jag fått under arbetet med avhandlingen. I det följande vill jag tacka ett antal personer som har varit viktiga för hur arbetet har kommit till, genomförts och stöttats.

Först vill jag rikta ett stort tack till de *lärare, elever* och *studenter* som låtit mig filma och analysera deras samtal.

Sedan mina *fina handledare*, *Åsa Mäkitalo* och *Thomas Hillman*. Tusen tack för otröttliga insatser! Från början till slutet har ni visat att jag kan lita på att ni finns där som stöd. Tillsammans har ni visat på så mycket kompetens att jag har känt mig priviligierad att få ha *er båda* till mitt förfogande. Jag är glad för att ni har hejat på och osentimentalt visat mig hur man hanterar utmaningar. Ni har styrt upp när det behövts, utan att jag behövt göra våld på en pockande, egen och till tider knappt hörbar röst. Ni har stöttat utvecklingen av den rösten, det hade inte gått annars.

*Mark Elam* har fungerat som en slags STS mentor under projektet. Tack för att du introducerade mig till *Åsa* och LETS-studio. LETS har erbjudit inspiration och möjlighet att diskutera kontroverskartläggning med forskare som *Tommaso Venturini* och *Christopher Kullenberg*. Jag är också tacksam att få ha arbetet tillsammans med ett antal kollegor i LETCOM projektet: *Mathias von Feilitzen, Patrik Lilja, Reka-Izabella Csonka* och *Sandra Ferraz Freire*.

Slutseminariumsdiskutant *Per-Olof Wickman*. Din konstruktiva, kritiska läsning hjälpte mig att utveckla kappatexten och gav mig några häftiga funderinger gällande tillhörighet och avståndstagande. *Maria Andrée* hjälpte mig att utveckla och tänka kritisk kring min sista artikel (II). Tack så mycket.

Jag är väldigt tacksam för att ha fått möjlighet att delta i text-seminarierna inom SDS som leds av *Åsa Mäkitalo* där kollegor med intresse för samtals-analys med sociokulturellt och dialogiskt perspektiv diskuterat texter och där jag fått värdefull respons på mina ofärdiga utkast. Till dessa ingår förstås *Roger Säljö* samt *Per Linell*, *Thomas Hillman, Janna Meyer Berling, Martin Göthberg, Annika Lantz Andersson, Sylvi Vigmo, Elin Nordenström, Ewa Skantz Åberg, Tina Kullenberg, Louise Peterson, Katka Cerna, Markus Nivala, Giulia Messina Dahlberg, Anna-Lena Godhe* och *Ann-Marie Eriksson.*

*Doktorandkollegor*, ni har var och en på kurser och i fikarum varit del av en gemenskap som betytt mycket för mig. Särskilt tack till mina ”dialogism-kamrater” *Janna Meyer-Beining och Martin Göthberg* för ovärderligt stöd. Jag kommer sakna våra fikastunder, och ja, även våra ”debriefingar”.

Vill även rikta ett tack till mina medförfattare på studie I, *Frank Bach* och *Björn Åkerman*. Jag vill även tacka kollegorna på IDPP och Nate-gruppens seminarier för kommentarer gett utifrån ett ämnesdidaktiskt perspektiv.

Tack till *IPKL's administratörer* med hjälp att hålla ordning och hitta mig till rätta: Tack särskilt till *Doris Gustafsson* för uppvisat tålamod och all hjälp med stort och smått och *Desirée Engwall* för stöd med ACTA-mallen i stressat slutskede. Tillsammans med studierektorerna *Annika Lantz Anderssons* och *Mona Lundins* stödjande samtal gav ni alla förutsättningar för att bli klar.

Tack till alla snälla *vänner och systrar* som bjudit in till roliga semestrar, trevliga måltider, utflykter, bad, fest, samtal och skratt och har satt arbetsrelaterade utmaningar i perspektiv. Utan er vore livet mycket tråkigare och otryggare. Mine foreldre *Harald* och *Kjersti* - takk for støtte og omsorg. Jag uppskattar att er uppfostran inte hade rättänkande ”präktighet” i fokus, utan jag kände mig alltid trygg i att tycka olika. Jag fick ta farvel med far i höstas. När jag ska försvara avhandlingen är han ändå med mig, han gillade rejäla ordväxlingar och stod alltid på min sida. En viktig person och personlig fond för detta avhandlingsarbete är min *farmor Helga.* Hon fick som de flesta på sin tid slå sig till tåls med sjuårig folkskola, goda studieresultat och lust att läsa vidare till trots. Hon behövde på egen hand ta ansvar för sig och familjen, bidrog till en bättre värld genom hållbara vanor och mer eller mindre ensamt fostrande av söner till ambitiösa studenter och snälla fäder. För hennes del tror jag inte mer utbildning hade spelat någon roll för att hon skulle göra mer ”rationella” eller ”ansvariga” val i sitt liv. Mer utbildning hade gett henne större möjligheter att realisera något av det hon drömde om; att få ett mer välbetald arbete, ett mer självständigt liv med möjlighet att påverka samhällsutvecklingen och helt andra möjligheter att på olika sätt möta världen.

*Oda, Truls, Embla, Niki.* Store älskade barn, jag är så glad att ni finns! Ni erbjuder så många förfriskande perspektiv och kloka funderingar.

*Stefan min man.* Tack för allt du tar om hand. Tack för din generösitet. Tack för att du fortfarande vill ha diskussioner med känsla och skärpa <3

Masthugget i januari 2019
*Anne Solli*

# 1 Introduction

## 1.1 Handling socio-scientific controversies (SSCs) in the Internet age

The interest of this doctoral dissertation is in exploring how students in interaction and within the educational contexts in which they learn and act, handle controversial social issues generated by innovations and developments in science and technology. While many such innovations and developments may be helping to make a better future, the emergence of risks, ethical concerns, and environmental problems also reminds us of potential dangers (Irwin & Wynne, 1996). Innovations such as nuclear technology, cloning and genetical modified foods have drawn public attention to their uncertainties and limitations yielding dilemmas and controversies (Irwin & Michael, 2003) Contemporary citizens in industrialized countries are faced with handling a complex knowledge-intensive world where current developments in science and technology are a prominent part of the socio-political landscape (Levinson, 2006). Through network-based digital media, we have access to information and experiences to an extent that was inconceivable only a few decades ago rendering knowledge claims from different fields and actors readily available to us (Säljö, 2010). In digitalized societies we are offered a vast array of useful and contradictory claims and arguments on any given issue, and it is challenging to select, analyze and evaluate information amongst various disciplines, perspectives, genres, and modalities (Lemke, 2006; Mason, Junyent, & Tornatora, 2014; Walraven, Brand-Gruwel, & Boshuizen, 2009).

The ability to navigate and critique the content available via media and information and communication technologies (ICT) becomes ever more important and requires new and complex skills (Mason, Scrimin, Tornatora, Suitner, & Moè, 2018). This navigation becomes even more significant when debates and conflicting views with regard to social, political and economic issues related to health care, climate change, and food production concern communities of people worldwide. Such controversial issues, which I will refer to as socio-scientific controversies (SSCs) are often identified as requiring serious attention through different forms of expertise and public

deliberation in a democratic society, making them relevant for educative purposes in a broad sense. Educators can thus play an important role by attending to SSCs and by arranging activities where students are invited to explore and discuss their complexity, including differences of opinion, otherness, and plurality (Biesta, 2007). In such activities, students need not only to reproduce knowledge, but construct and create, select, analyze, and critically review it (Säljö, 2010).

Within the field of science education there is an established research area called socio-scientific issues (SSI) that explores the teaching and learning of social *dilemmas* with conceptual or technological links to science (Sadler, 2004a, 2011; Kahn & Zeidler, 2016). SSI education is assumed to serve as a pedagogical strategy with such goals as developing responsible citizens capable of applying scientific knowledge and developing (scientific) habits of mind including acquiring skepticism, and evoking critical thinking (Zeidler & Keefer 2003; Zeidler, Sadler, Simmons & Howes 2005). In the extended summary of this dissertation I choose to use 'SSC' instead of SSI when I describe the controversies that the students in the included studies discuss for two reasons. First, SSIs can include issues which are not controversial in the sense that they do not involve several actors with different interests and affiliations[1]. Second, unlike the focus of this dissertation, the point of departure for the 'SSI framework' is promotion of the development of a specific morality and ethics which is argued for by advocates of the approach as being distinct from the framework associated with the academic field of science, technology and society (Zeidler et al. 2005). Despite the decision not to use the term, the schoolwork investigated in this dissertation is closely aligned with an SSI education framework.

With this work, I aim at studying how students handle controversial issues in science education by exploring and understanding how students handle and reason on SSCs through interaction within educational contexts, mediated by the cultural tools available. One such cultural tool, Internet search as a way to get to know more about an unfamiliar topic, is a routine way to identify and access information (Walraven, Brand-Gruwel, & Boshuizen, 2009). Digital technologies are now an integral feature of schools as is the pervasive use of the Internet (Johnson, Bulfin, Nemorin, & Selwyn, 2018, Livingstone,

[1] Examples of such SSIs include curing nearsightedness with laser (Ekborg et al , 2016) and dealing with personal dilemmas concerning Cystic fibrosis and inheritance (Sadler, 2011)

Mascheroni, Staksberg, 2018). Access to information in science education has dramatically increased over the last few decades by means of the introduction of digital devices and Internet access in classrooms. For example, students regularly search the web for school assignments instead of using books and libraries when they need to prepare essays or presentations (Mason et al., 2018; Walraven et al., 2009). Conducting online search tasks has become a routine activity to identify and access information on a wide variety of topics such as vaccinations, climate change, nuclear energy, and genetically modified organisms (GMOs) (Hsu, Tsai, Hou, & Tsai, 2014; Tsai, 2018). Key to such activities are the abilities to navigate and critically assess content with the supporting strategies necessary for handling the abundance of information available through ICT (Chung & Neuman, 2007).

Given the challenges of handling information online and the curricula in many jurisdictions that explicitly require schools and universities to address issues of information and scientific literacies[2], educational institutions are faced with the challenge of helping students to develop the digital competences[3] required to constructively handle complex and controversial issues encountered (Almqvist & Östman, 2006; Furberg & Ludvigsen, 2008). In order to tackle these problems, a variety of tools and procedures have been proposed for the analysis of SSCs including digital mapping tools (Venturini, 2010c, 2010b; Venturini & Latour, 2010) such as those used in the studies of this dissertation. As a class of digital tool, these mapping tools provide means to explore, manipulate and visualize networks of online data and to work out what is relevant and useful when exploring a controversial issue from a corpus of online data (Jacomy, Venturini, Heymann, & Bastian, 2014). The maps they

[2] In the Swedish curriculum, in line with science curricula in many other countries, there is a focus on scientific literacy as formulated in the 21st Century Science project: "we... expect a scientifically literate person to be able to: appreciate and understand the impact of science and technology on everyday life, take informed personal decisions about things that involve science, such as health diet, use of energy resources, read and understand the essential points of media reports about matters that involve science; reflect critically on the information included in and often more important omitted from such reports; and take part confidently in discussions with others about issues involving science" (Retrieved June 15, from http://www.nuffieldfoundation.org/twenty-first-century-science/scientific-literacy)

[3] The Swedish government announced the introduction of comprehensive curricular changes in March 2017 designed to strengthen the role of schools in developing digital competences (Regeringskansliet, 2017). These changes to the curriculum in 2018 stress the development of not only abilities to use digital technologies and understand the effects of digitalization for individuals and society, but also to cultivate critical and responsible relations to these technologies.

generate are used as both instruments to explore a controversy and as tools to present it to others (Venturini, 2010a).

Concerns have been raised that current generations of school children and college students are often doing little more than taking search-engine results as gospel (Selwyn, 2011) and about the availability of, amongst other phenomena, faked data, conspiracy theories, creationism, and health scares (Banaji & Buckingham, 2013). In addition, there is concern about expectations in contemporary society for young people to consume information before being able to properly evaluate its worth. Recently, a substantial amount of empirical research on young people and Internet use has moved the discourse away from universalizing assumptions about 'Internet use' (Livingstone, Mascheroni, & Staksrud, 2018) and a social shaping approach to understanding 'the Internet' has allowed researchers to problematize technological determinisms and to critically discuss concerns regarding young peoples' Internet usage. Still, in depth studies concerning the relationship between education, the Internet and citizenship are rare (Choi, 2016; Choi, Glassman, & Cristol, 2017).

## Socio-scientific reasoning and democratic citizenship

The question of democratic citizenship is high on the agenda of policy makers and politicians around the world and education is frequently being mobilized as a way of contributing to the formation of responsible citizens and promotion of 'good citizenship' (Biesta, 2011). Biesta and Lawy (2006) have shown that the overriding concern of social and educational policy has been to nurture and guide young people towards a pre-described outcome. This emphasis upon social engineering, upon the 'manufacture' of compliant yet 'active' citizens remains a fundamental component of the mainstream discourse of citizenship and citizenship education It reveals the extent to which current policy and educational practice have been informed by the idea of citizenship-as-achievement.

The notion of citizenship-as-achievement is founded upon the assumption that citizenship is a status that individuals can achieve. Ideas about the role of education in the promotion of good citizens are based on several relatively complex claims concerning knowledge. These claims concern knowledge about what a good citizen is, what a good citizen needs to learn, and how individuals can learn to become good citizens (Biesta, 2011). However, there

is a tendency within policy, practice and research to see such claims as relatively uncontested (Levinson, 2010), a view that Biesta claims is "reinforced by research that operates symbiotically with policy" (2011, p.142). A focus in curricula and policy documents on individuals' knowledge and their ability to reason and come to decisions on complex issues without consideration for how they are part of larger collectives, implies that there is an obvious link between obtained knowledge and responsible citizens (Ideland, 2016). With the introduction of the concept of citizenship-as-achievement, Lawy and Biesta (2006) argue that to fully understand what it means to be a citizen in a democratic society is to recognize that citizenship is a relational concept which is necessarily located in a distinctive socio-economic, political and cultural context. They argue that the aim of citizenship education has been to 'engineer' a particular citizen and to measure the achievement of that aim against predetermined and taken-for-granted criteria of efficiency and effectiveness. Similarly, the dominant approach in science education research to understanding students reasoning on SSCs has been reported to be typically situated within the individual-psychological tradition where an individual's reasoning and decision making is studied in isolation (Bencze & Alsop, 2014; Roth, 2014)[4]. Further, in research on digital media literacy, an emphasis on the individuals' responsibilities to be considerate has been argued to undermine the value of conflict and dissent for the advancement of democracy, resulting in the "decontextualization of citizenship" such that an overt attention to considerate youth obscures the social conditions surrounding young people. Thus, instead of empowered media-literate citizens exercising their communicative entitlements, the emphasis becomes one of dutiful citizens, as part of a "moralizing discourse" (Livingstone et al, 2018).

We are only beginning to understand how students could be learning to participate as citizens in the digital age with increased opportunities to choose Internet based resources for educational purposes and the accompanying challenge to support students in developing competences required for digital participation. Many educators are attuned to creating space for students to

[4] Obviously there are also studies that take a more social and contextual approach to students' reasoning on complex issues (Almqvist & Östman, (2006) and Arvola Orlander and Lundegård (2011), including studies in a related field, education for sustainable development (ESD) (Rudsberg & Öhman, 2015; Rudsberg, Öhman, & Östman, 2013). I will return to such studies in the literature review section in chapter 2.

discuss the kinds of dilemmas that socio-scientific controversies entail yet our analytical understanding of what it implies for students to navigate their way through such complex issues online is insufficient (Choi et al., 2017; Klosterman, Sadler, & Brown, 2012; Wise & Schwarz, 2017). This in turn renders it not only difficult to evaluate how students manage to grasp such issues, but also to understand in more general terms what it means to engage in deliberations based on the masses of information available online.

## Socioculturally embedded reasoning

Considering the relevancy of the issues and the few empirical studies of students' unfolding activities when searching and evaluating material about SSCs on the Internet in science education settings, in this dissertation I will attend to students' locally embedded reasoning and how it is mediated by digital mapping tools designed to support the analysis of controversies. By conducting studies of student activities, I offer empirical examples for discussions of practices and contribute to understandings of socio-scientific reasoning as a sociocultural activity.

Investigating student reasoning on SSCs where complexity is salient, the science unstable, and the issues contested among many different stakeholders, I aim to contribute to earlier work in this area that take as its point of departure that student actions must be understood in relation to their circumstances (Almqvist & Östman, 2006; Furberg & Ludvigsen, 2008; Nielsen, 2012; Orlander Arvola & Lundegård, 2012; Rudsberg, Öhman, & Östman, 2013; Säljö, Jacobsson, Lilja, Åberg, & Mäkitalo, 2011). The process of dealing with SSCs is not only a process of making meaning of scientific concepts, processes and argumentation *per se*, but is also a process of dealing with, and making meaning of, institutional demands, values, and expectations. The approach I adopt entails studying reasoning as socioculturally embedded and contingent on social, institutional and material conditions (Linell, 2009; Säljö, 1999, 2010; Vygotsky, 1978; Wertsch, 1998). A premise is that dialogue not only takes place in interpersonal dialogue, but also at the level of sociocultural practices and institutions. Another premise of this sociocultural approach is attention to studying social interaction with artefacts, considering the interdependencies between students and artefacts such as digital technologies. With this approach, I will show how students in interaction, by using mediating tools, use, evaluate and reflect on knowledge claims

concerning SSCs. This analytical perspective reveals the particulars of the discursive activities in which students engage with SSCs online and in a classroom context.

## 1.2 Aim and research questions

Considering the availability of information, the relevance to multiple disciplines, and the transformation of knowledges there are challenges to addressing SSCs within the established educational subjects. The overarching aim of this dissertation is to explore how students in interaction and within the institutional contexts in which they learn and act, handle SSCs. The aim is pursued by asking the following overarching research questions:

1. How is student reasoning contingent on institutional, social and material contexts when investigating SSCs?
2. How is student reasoning mediated by mapping tools developed within Science and Technology Studies (STS)?
3. What communicative competences are displayed when students investigate SSCs digitally?

These questions are investigated in the empirical context of an introductory biotechnology course at university, and in an upper secondary school as students worked with new digital methods developed for the analysis of the increasingly interconnected nature of controversial issues online to explore SSCs under the curricular umbrella of science in society. To be able to follow and observe student activities, the empirical material for this dissertation includes video-recordings, field notes, documents as well as student generated material such as written reports and controversy maps generated by digital tools.

This dissertation includes four studies focused on various ways in which student reasoning on SSCs is embedded in social, institutional and material contexts. In Study I, the focus is primarily directed towards how students and a professor state and support claims regarding opposition to Genetically Modified Organisms (GMOs) appropriate within the biotechnology community. Study II examines how students' appeals to science (reusing online claims) play out differently in various school project activities. Study III adopts a dialogical approach to understand how students handle the multiple perspectives inherent in SSCs online, investigating how individuals are in dialogue with both others present in the classroom (situated interaction) and

at the level of communities and institutions. Finally, Study IV investigates how students' collaborative exploration and ordering of the complexity of a controversy is co-constitutive of the digital mapping tools in use.

## 1.3 Outline of the dissertation

This dissertation has two major parts. Part 1 acts as a framing for the reading of the four empirical studies that make up Part 2. It positions the studies in their theoretical and methodological context and discusses questions that are raised and the contributions and implications that can be drawn from the empirical work. Following the introduction, the next chapter provides a presentation of relevant studies in research fields related to SSCs and online information seeking about complex issues. Chapter three deals with the theoretical framing of the dissertation by introducing the central notions of the dialogical and sociocultural perspective on communication used to study SSC reasoning as a social and contextual phenomenon. Chapter four deals with the research design, accounting for the pedagogical settings in which the empirical material was generated and how the studies were designed and conducted. Then a summary of the four empirical studies is given in chapter five. This chapter summarizes each study including its specific focus, main findings and arguments. Chapter six offers a synthesized discussion of the findings from the studies in response to the overarching research questions of this dissertation. Finally, chapter seven is a Swedish language summary of the dissertation.

# 2 Literature review

This chapter positions the dissertation in relation to previous research in two main areas. I seek to develop knowledge about how students' reasoning on SSCs is mediated by contextual features and the kinds of communicative competences that are displayed when investigating SSCs digitally. Therefore studies of reasoning on complex social issues in science education, and studies of information seeking online are reviewed. The selected studies serve as a point of departure for positioning my own approach by means of discussing claims on students reasoning within two theoretical perspectives. From one of the perspectives, understanding is developed through analyzing the claims of individual students while omitting their context. From the other perspective, focusing on social practices, approach studying situated interaction taking contextual features into account. Synthesizing relevant studies conducted from these perspectives, the review should be seen as a background and rationale for the decisions made in this dissertation.

## 2.1 Handling complex social issues in science education

Throughout the history of science education, long before the introduction of the Internet, scholars and practitioners have called for the contextualization of science content through the exploration of socially relevant issues. Early proposals for alternative school curricula that included such issues were inspired by university Science-Technology-Society programs. They were formally initiated in the late 1960s and responded to a perceived crisis in responsibility related to, for instance, the environment and nuclear energy. Preparing students to engage in discourses and decisions related to societal dilemmas and controversies has been a sustained interest first in the area of STS instruction (Aikenhead, 1985; Solomon & Aikenhead, 1994) and more recently in the socio-scientific issue (SSI) movement (Sadler, 2011; Zeidler, 2014; Zeidler, Sadler, Simmons, & Howes, 2005). Many science educators in the international community include SSI in science classrooms to encourage the development of social consciousness and to develop "scientific habits of

mind" (Zeidler, Sadler, Applebaum, Callahan, 2009, p.75) and functional scientific literacy[5] (Zeidler & Sadler, 2010). A practical, broadly conceptualized scientific literacy includes informed decision making and the ability to analyze and evaluate information, dealing with moral reasoning and ethical issues, acquiring skepticism, maintaining open-mindedness, recognizing multiple forms of inquiry, accepting ambiguity, and searching for data driven knowledge (Zeidler et al., 2005). Responses to calls to include approaches involving science and society have reflected the political and intellectual tensions inherent in science education and varied from acceptance and project implementation to rejection because of a perceived need to return to "basics" (Sadler & Dawson, 2012). Adherents of a more traditional science education approach, focused on scientific content and principles and typically aimed at preparing students for future studies in science and technology, has often been seen to push against more societal or humanistic approaches to science in schools (Aikenhead, 2007). This conflict is likely to be a contributing factor in the emphasis placed on positive outcomes in the work of researchers of SSI education who seek to convince such stakeholders as the science teacher community and policy makers that these issues should be included and continue to have a profound role in science curricula.

In Sweden, curriculum guidelines state that students are required to critically evaluate information and to use scientific knowledge to formulate and evaluate arguments in current issues in society (Ekborg et al., 2016). Schools are to strive to ensure that all students increase their abilities to formulate independent standpoints based not only on empirical evidence and critical analysis, but also on ethical considerations[6]. Furthermore, students are to develop their ability to make decisions on SSIs. This is in accordance with the kinds of scientific literacy stressed in science curricula around the world (Ottander & Ekborg, 2012). However, that these issues are included in the curriculum in many countries does not necessarily imply thorough handling of them in classrooms. The Swedish Schools Inspectorate has reported that physics classrooms were more focused on science content knowledge and less

[5] I will not go into the discussion of various ways to define scientific literacy , but will use the term scientific literacy to mean that the objective of science education is "learning from science", i.e. how science can be used by students in their own life, regardless of whether they are going to pursue careers in science or not (Wickman, Liberg, & Östman, 2012)

[6]https://www.skolverket.se/undervisning/gymnasieskolan/laroplan-program-och-amnen-i-gymnasieskolan/gymnasieprogrammen

on the nature of science and using science (Skolinspektionen, 2010). Their report recommends that physics teachers connect more often to current issues in society, but the concern reveals the tension of whether or not students will be able to learn enough science if they "rather discuss their own values and societal problems and forget the scientific content"[7] (Ekborg et al., 2016, p. 26).

Although not dominant in the literature on socio-scientific issues, incorporating complex social issues into science education has been problematized (Feinstein & Kirchgasler, 2015; Levinson, 2001, 2010; Roth & Désautels, 2004). The argument has not been that science education should return to basics, but rather that there is a concern that complex issues might not be handled adequately within science classrooms. The availability of information, relevance to multiple disciplines, the transformation of knowledge, and the use of increasingly sophisticated technologies highlights a range of issues challenging to address within established educational disciplines (Levinson, 2010). Some concerns regard the most appropriate location for such issues within the school curriculum when they could be places in social science, humanities or science, for example. Levinson and Turner (2001) found that science teachers addressed social aspects of biomedical science infrequently and with a lack of confidence. Although humanities teachers showed greater willingness to engage pupils in such discussion, few teachers of any discipline addressed ethical aspects of scientific advancements. The authors suggest that science teachers might not have appropriate training to address such complex issues and non-STEM teachers might not have the content knowledge required to teach them (Levinson & Turner, 2001). In addition, the argument has been made that students might develop scientistic attitudes from learning about these issues in science classrooms (Feinstein & Kirchgasler, 2015; Roth & Désautels, 2004). Feinstein and Kirchgasler (2015) have showed how universalism, scientism and technocentrism are common themes in the scientific discourse around sustainability in the Next Generation Science Standards in the US, and are concerned that students who are taught to think about sustainability issues in the science classroom may potentially not be adequately prepared to see its ethical and political dimensions. It has also been claimed that emphasizing the discussion of the applications of science and scrutinizing the production of

[7] My translation

knowledge obscures the connection that science has to financing, industry, and the military (Roth & Désautels, 2004). Roth and Désautels (2004) suggest that instead of framing goals in science education in terms of scientific literacy, a more viable approach begins by framing a more general project of democratic citizenship and asks what kind of scientific literacy can contribute to this project. Their argument is illustrated with data from a three-year ethnographic study where residents in a community dealt with a contested water supply issue, irrespective of science background interacted with and questioned scientists and politicians in a public hearing. They went on to argue that educating for citizenship presupposes participation in democratic processes.

Most curricula arguments for treating science and society issues in science education are seemingly uncontentious. They may claim that science helps students become informed citizens, capable of using science and technology productively and wisely with others in order to solve the numerous global problems humans now face (Levinson, 2010). Levinson (2010) argues that the reality of democratic participation in schools is in tension with the dominant discourse in science curricula and calls for making the role of scientific knowledge more explicit. Oft-repeated rhetoric about the significance of science in policy statements about the sciences as a necessary ingredient in the development of an informed and engaged citizenship has also been questioned by Feinstein (2011). Although not questioning the relevance of science for citizens to engage in reasoning about socio-scientific controversies, science has indeed increasingly become a subject that citizens need to cope with (Osborne & Dillon, 2008), Feinstein's (2011) argument is that we need to approach claims about its usefulness for citizenship *empirically*.

Similarly, most of the literature on SSIs takes the premise that introducing SSIs in classrooms is positive and productive as a point of departure. Negotiation of SSCs is typically associated with preparing students to make informed decisions (Sadler, Barab, & Scott, 2007; Walker & Zeidler, 2007; Zeidler, Osborne, Erduran, Simon, & Monk, 2003; Zeidler, Sadler, Applebaum, & Callahan, 2009) and act as responsible citizens in the future (Pedretti, 2003; Berkowitz & Simmons, 2003). SSIs have also been used by researchers as a vehicle to explore activism within science and technology education (Bencze & Alsop, 2014; Hodson, 2014). The idea is that by engaging directly with local issues, students gain experience of the ways in which competing social, political and economic interests impact on decision-

making. Through participation in community projects, students are understood to gain access to ideas, experiences, people, institutions, and sociopolitical structures that build both individual and collective capacity to address SSI and environmental issues in political ways with the "goal to engage in the struggle for greater freedom, equality and social justice" (Bencze & Alsop, 2014, p.5). Before reviewing this science education research literature further, I will address the most common theoretical approaches taken to understand SSI reasoning.

## 2.2 Different theoretical approaches to understanding SSI reasoning

Whether reasoning is seen as individual or social evidently has major consequences for understanding how students learn to reason about SSIs. In science education, three different epistemological positions underpinning research about teaching and learning have been identified: the disciplinary perspective, the personal ways of knowing perspective, and the social practice perspective (Kelly, McDonald, & Wickman, 2012). Studying epistemology as social practice, entails seeing it as constituted through situated interaction. The aim is to describe actual epistemological practices and report on how people proceed in action to accomplish certain purposes (Kelly et al., 2012). Such studies of social practices where students reason on complex issues draw on sociocultural, ethnographic, and pragmatist studies of learning as talk and action in science classrooms. In this review, examples of such studies include Nielsen (2012), Rudsberg & Öhman (2015), Furberg & Ludvigsen (2008), Almqvist & Östman (2006). The sociocultural perspective views social and cognitive processes as intertwined. This implies that students' actions and activities are embedded in historical and institutional settings, where norms and values are part of students' argumentation in particular knowledge domains. It is in the relations between institutional aspects of the setting and the actions performed by students that the activity of learning is generated (Wertsch, 1998).

An alternative to the social position is a more individualistic view most akin to the personal ways of knowing perspective referred to by Kelly et al (2012). This approach can be recognized in a considerable amount of SSI research. Research on SSIs and the developing of scientific literacy often associated with such issues, has been mostly based on the assumption of

knowledge as individual (van Eijck, 2012), and has focused on individual decision making (Bencze & Alsop, 2014). The analytical foci of such SSI studies have often been on students' conceptions of scientific concepts and phenomena and how they are related to the conceptualization of controversies and the development of argumentation skills[8]. These studies have made important contributions to understanding the abilities students develop when taking part in SSI education. A prominent aim has been to understand how students' make informed decisions in the future as citizens. Consequently, as a part of these studies, students are often asked about their opinion and the kind of choices they would make in an imagined situation as a school activity. This kind of activity is referred to as 'decision making' in the SSI literature (Hogan, 2002; Liu, Lin, & Tsai, 2011; Sadler, 2004b). Many of the studies conducted to date report on how students, having engaged with SSIs and then been tested or interviewed individually, have developed aspects of scientific literacy such as applying scientific knowledge (Zohar & Nemet, 2002) or appraisal of multiple perspectives (Kahn & Zeidler, 2016; Sadler et al., 2007).

In the following, I will present a review of selected studies of particular relevance to this dissertation that report on students reasoning when working with SSCs and complex issues in science classrooms. The criteria for selecting these studies can be seen as a strategic selection to 1) illustrate how claims in the articles reflect that individual students/teachers are the units of analysis, and 2) examine studies that have investigated classroom interaction by taking contextual features into consideration in order to provide a more comprehensive background for this dissertation and situate the contribution of the research approach taken in this dissertation to the field.

## 2.3 Studies of reasoning on complex issues

In this section I will report on studies of reasoning on complex issues in science education, mostly from the field of SSI studies but also from a related field, education for sustainable development (ESD). In particular, research on learning outcomes related to the inclusion of SSIs in school science has received considerable attention. In the Second International Handbook of Science Education (Fraser, Tobin, & McRobbie, 2012), the chapter on SSIs,

[8] Although certain authors such as Sadler (2009) argue for a sociocultural perspective on SSI education his epistemological assumptions remain as reflected in methodology, analysis and reporting of the results, where the individual is the unit of analysis.

"Context for the promotion of key learning outcomes" (Sadler & Dawson, 2012) reports on studies that support the integration of SSIs in school science. Sadler and Dawson's review reports on the development of four types of learning outcomes: science content knowledge, nature of science knowledge, interest and motivation, and argumentation. In the following I will review studies focused on the role of knowledge in and about science and studies on argumentation as well as unfolding reasoning in classroom contexts. Since my focus on students reasoning in the classroom does not extend to the issues of interest and motivation, I will not report on such studies. The chosen research is particularly relevant since I investigate how students engage in argumentation when stating, questioning, and supporting claims regarding SSCs, and how they appeal to scientific claims in SSC reasoning. The following sections will therefore introduce a number of issues that have been raised in the field and are relevant for the work undertaken in this dissertation.

## The role of science knowledge

Questions of how or whether science content knowledge[9] is useful for citizens in everyday activities extends the SSI literature (Feinstein, 2011). As already argued in 1993, canonical scientific knowledge must be connected to economic, social and other value positions in order to make scientific knowledge useful in everyday actions for citizens (Layton, Jenkins, Macgill, & Davey, 1993). Layton and colleagues (1993) had sought out groups of citizens who were, or had recently been, in situations where they had been in need of some scientific knowledge. Individuals were interviewed about the knowledge they had acquired in order to cope with their particular circumstances. The outcome of these case studies was a set of criteria that scientific knowledge should meet to be relevant for citizens. These criteria are: obvious relevance, helpful and useful, trustworthy source, relatable to other social knowledge, in a communicating language form. Irwin and Wynne (1996) echo these findings with nine other cases of public involvement with science-related issues where scientific arguments, presented as value-free, played an important role in the framing of the discussion of these issues. This was seen as problematic since the scientific framework was not considered to be value-free, being

[9] Although rarely defined, generally science content knowledge seem to refer to stable, canonical knowledge or the products of science such as the basic school book understandings of structure and function of DNA for instance when it comes to genetically modified foods.

determined by social as well as technical factors. In these cases, many members of the public did not share the assumption that scientific knowledge is superior to the social knowledge with which they were more familiar. In situations such as parents dealing with children with Down's Syndrome, scientific genetic knowledge was looked upon as a potential resource for practical problem-solving, yet it typically did not match this requirement. The kind of medical information offered was seen to be essentially irrelevant and of little practical benefit since it was validated and standardized by a scientific community seeking to contribute with knowledge about the natural world while the parents sought knowledge about what needed to be done within their own particular situation.

Studies of the role of science in students' socio-scientific reasoning have been categorized in two groups (Nielsen, 2012): The first group of studies focuses on the presence and quality of science content (e.g Fleming, 1986, Grace & Ratcliffe, 2002; Sadler & Donnelly, 2006). One recurring finding amongst these studies is that students rarely invoke science content knowledge in conversations about socio-scientific issues and that students generally rely on ethical, economic and social factors rather than on scientific factors (Nielsen, 2012). The other group of studies focuses on the extent to which students' science knowledge, or knowledge about science, determines the quality of socio-scientific discussions (e.g., Bell & Lederman, 2003; Lewis & Leach, 2006; Ryder, 2001; Sadler & Zeidler, 2005b).

An example of how scientific knowledge is assumed to have a privileged position in understanding controversial issues can be found in a recent study in the International Journal of Science education (Cinici, 2016). In the rational for providing science teachers with training and discussion of GMOs, the author claims that "many studies show that ethical issues, values and beliefs rather than knowledge and understanding appear to be at the heart of the non-acceptance of GMOs" while referencing researchers who have voiced the need to educate the public to interpret information about GMOs from a scientific perspective. Further Cinici (2016) makes the inference that in order to make more informed decisions about SSIs, students need to appreciate the basic science and scientific enterprise underlying the issue.

The importance of understanding basic science in order to be able to engage competently in SSI reasoning was the focus in a study by Sadler and Zeidler (2005b). In their study, the ways in which science content knowledge influenced the negotiation and resolution of complex scenarios based on

genetic engineering were examined. Two groups of students representing what was termed as divergent levels of content knowledge participated in individual interviews during which they articulated positions, rationales, and rebuttals in response to gene therapy and cloning scenarios. A mixed-methods approach was used to examine the effects of science content knowledge on the use of informal reasoning patterns and the quality of informal reasoning. Participants from both groups employed the same general patterns of informal reasoning. Participants shown to have a more advanced understanding of genetics, demonstrated fewer instances of reasoning flaws as defined by a priori criteria and were more likely to incorporate science content knowledge in their reasoning patterns than the others. This investigation indicated that science knowledge or knowledge about science influenced socio-scientific discussions and that such knowledge influenced the quality of socio-scientific reasoning under the circumstances studied.

In the rhetoric that states that SSI activities contribute to enabling students, as citizens, to make decisions informed by science, great value is placed on the use of science as evidence and on evidence-based decisions (Sadler, 2006; Zeidler, Sadler, Simmons, & Howes, 2005). The idea that socio-scientific activities are valuable because they develop students' evidence-based reasoning is found throughout the canons of the socio-scientific framework (Nielsen, 2013a). It is taken for granted and seems intuitively reasonable that an informed socio-scientific decision draws on science. However, what it means to successfully invoke scientific knowledge in socio-scientific deliberations is unclear, especially given the varied theoretical perspectives through which SSI reasoning is understood. Studies that have analyzed the use of scientific knowledge in classroom discussions report contradictory results. Some studies of student discussion conclude that students use scientific knowledge as a factual background in order to give authority to an argument and to establish a shared starting point for a discussion (Nielsen, 2012; Orlander Arvola & Lundegård, 2012). In contrast, other studies have shown that students seldom include scientific knowledge in classroom discussions (Albe, 2008b; Christenson, Chang Rundgren, & Höglund, 2012), and that when it is included it is not used critically (Walker and Zeidler 2007). Rudsberg & Öhman (2015) maintain that there is a need for targeted classroom-based research on the role of scientific knowledge in SSI discussions since few studies have analyzed the role of knowledge in student discussions through in situ studies of ongoing activities in educational

practices. The studies reviewed in the following have investigated when students do use scientific content in discussions and the role that such usage has in the process of socio-scientific reasoning in the classroom.

Nielsen (2012) used normative pragmatics to take the local relevance of utterances into perspective when investgating the role scientific facts play in socio-scientific discussions, drawing on Goodwin's (2002) notion of framing as an aspect when individuals influence the decisions of others. Students received written material on gene therapy with descriptions of the procedures and its history. They discussed in small groups in order to decide on future legislation regarding human gene therapy and were reported to invoke science in order to give speakers' utterances a certain authority or to highlight the particular quality of an argument. Thus, students were reported to draw on science information in their socio-scientific deliberations, making selective use of science in attempts to frame specific aspects of gene therapy as the salient aspects and to make it appear that these aspects call for certain positions to be taken with regard to human gene therapy.

Orlander Arvola and Lundegård (2012) highlighted how science content becomes relevant to student experiences when investigating the argumentation of 15-year-old students on the topic of abortion in a science classroom. The study reports on how the students' unique voices caused displacement of the science content, with arguments made without providing explicit scientific justifications. Instead, the authors argue that students had to transform the problems involved in an argument into choices they could live with. Students rarely used scientific language, but did so when they considered it necessary to clarify their own standpoint. The findings indicate that while students may not use much science in socio-scientific argumentation, they can engage in socio-scientific argumentation in ways that are meaningful for them and use science in specific ways that suit their argumentative goals.

In the field of education for sustainable development, Rudsberg and Öhman (2015) have shown how knowledge plays a crucial role in discussion about climate change in a Swedish upper secondary school. Their argumentation analysis combines Toulmin's argument pattern (Toulmin, 2003) and pragmatic meaning analysis (Wickman & Östman, 2002) to show how adding new knowledge is necessary if students are to form arguments and move discussions forward. The analysis was not limited to scientific knowledge, but included the kinds of knowledge that appeared to be important for the students' argumentation. Such a pragmatic perspective on

knowledge implies that knowledge acquires meaning in the activity at hand, meaning that it can have different roles in different situations. The authors report on how knowledge can enhance the quality of a discussion and give it new directions. They identified two general functions of knowledge in the students' discussions: knowledge functions as data to justify claims and knowledge was consistently part of a collective process among the students that aims to understand the problem at hand. The analysis also resulted in descriptions of different categories in which knowledge served specific functions. Specifically, it served to clarify and correct previous arguments, but also served to provide evidence for counterarguments. Moreover, using what was understood as relevant knowledge had the function of highlighting conflicting interests, contributing to an emphasis on the complexity of climate change issues. Findings showed how by re-actualizing previous knowledge, students created complex chains of reasoning that involved critical reflections on the relations between the economy, politics, and the environment.

A particularly relevant line of research in science education termed Nature of Science (NOS) has focused on developing knowledge about the epistemology of science, or science as a way of knowing that refers to the values and assumptions inherent to scientific knowledge (Bell & Lederman, 2003). As part of this line, it has been proposed that individual understandings of NOS are related to discussions of SSIs, but few have investigated the connection (Sadler & Dawson, 2012). Walker and Zeidler (2007) investigated students' development of NOS understandings in the context of an SSI-related intervention in high school in the US where they designed a curriculum based on genetically modified foods such that NOS themes were highlighted and that assessment of NOS ideas was embedded in the learning activities. Students' views on the nature of science were expressed in their answers to interview questions and in a written questionnaire the examined the role of empirical evidence in science, the social and cultural factors implicated in the generation of scientific knowledge, and the creative aspects of science. Through this self-reported data and investigation of the features of argumentation in classroom debate, the authors concluded that students particularly developed NOS ideas in the areas of the tentative/developmental and creative/subjective aspects of science. However, when presented with an opportunity to apply these understandings in an SSI debate, students did not invoke NOS ideas. The authors concluded that the SSI-based instructional unit promoted exploration of NOS ideas with some learning gains, but that

students ultimately did not develop frameworks for NOS robust enough for applying the ideas in more general decision-making opportunities in the school context. With their approach to understanding discourse, this follows from Walker and Zeidler's (2007) observation that when certain resources are not drawn on in discussions, it reflects insufficiently "robust frameworks".

One reflection from reviewing studies of SSI reasoning is that while it is claimed that SSI education aims to stimulate and promote individual intellectual development in morality and ethics (Sadler, 2004; Sadler & Zeidler, 2004; Zeidler et al, 2005), such outcomes are rarely the focus of studies (Dawson & Sadler, 2012). Rather, studies are more often focused on finding ways to give students scientific knowledge and ways of reasoning to enable "the development of rational and analytic thought and discourse (Zeidler, Osborne, Erduran, Simon, & Monk, 2003, p.108) for "making rational and informed decisions" (Simmons & Zeidler, 2003, p. 83). This way of approaching knowledge versus values or what could be understood as the rational versus the irrational has a long history (Wickman, Liberg, & Östman, 2012) and is clearly in focus for several of the studies conducted with the premise that (socio)-scientific reasoning can cure the irrationality when stances are taken in SSCs (Cinici, 2016; Simonneaux & Simonneaux, 2009). The findings of these and other studies of students reasoning including the role of science knowledge plays in argumentation and discussions suggest a need for continued negotiation of what educators and researchers mean when we say that students need to learn science in order to engage in discussion and come to decisions in relation to SSCs. By focusing on how science students SSC reasoning is contingent on contextual features and digital tools, I intend to complement and add to the knowledge assembled through studies of reasoning in the classroom.

## Argumentation and classroom interaction

Although a considerable amount of SSI research have been devoted to understanding the role of science knowledge in discussions, there is also an interest in understanding the kind of procedural competences that is developed (Byhring & Knain, 2016; Sadler, 2011). For instance, how students are handling the complexity of SSIs have been an area of concern to several scholars (Zeidler & Kahn, 2016; Sadler; Barab & Scott 2007; Byhring & Knain, 2016) Byhring & Knain (2016) have explored how students in school

science construe complexity in SSI through language resources by investigating multiple voices as the presence of intertextuality. Byhring and Knain (2015) used Systemic Functional Linguistics (SFL) to identify how handling of complexity was construed by the interplay between students' roles in the discourse and resources in language for making multiple voices present. Through an exploratory analysis they aimed at contributing to the research on development of teaching practices to cope with SSI by showing how students' construe low and high complexity in unfolding discourse. They identified how in a high-complexity event, students take on different roles and use modality and projection as grammatical resources for opening up for different positions, multiple voices, and various contextual resources. Byhring and Knain (2015) argue that handling complexity is demanding, and "explicit scaffolding is necessary to prevent a potentially complex challenge from being treated as a simple one" (p. 1).

During the past three decades, the potential role of argumentation for learning in formal science education has been a significant focus of research. This attention follows from the general realization that argumentation, the coordination of evidence and theory to support or refute an explanatory conclusion, model, or prediction, is a critically important epistemic task and discourse process in science. The value of developing argumentation and small group discussion skills has been particularly emphasized when dealing with issues involving uncertain or controversial science (Christensen & Fensham, 2012; Erduran & Jiménez-Aleixandre, 2008).

A number of scholars have highlighted the importance of learning to argue in discussions about SSIs (Nielsen, 2013a). Toulmin's argumentation model (2003) has been particularly widely applied in studies that investigate whether or not students and teachers develop more advanced argumentation patterns through analysis of differences in the use of argumentation elements such as data, warrants, qualifiers, and rebuttals to back claims (Dawson & Venville, 2010; Erduran, Simon, & Osborne, 2004; von Aufschnaiter, Erduran, Osborne, & Simon, 2008). In the following review, I will examine several recent studies of the unfolding of student argumentation and discourse on SSIs in science classrooms that are of particular relevance (viz., Byhring & Knain, 2014; Nielsen, 2012; Orlander Arvola & Lundegård, 2012; Rudsberg, Öhman, & Östman, 2013; Rudsberg & Öhman, 2015; Åberg, Mäkitalo, & Säljö, 2010, Albe, 2008a).

Rudsberg et al. (2013) analyzed the discourse of two students in upper secondary school when taking part in a classroom discussion on the possibilities of solving environmental problems where they combined a transactional perspective on meaning making based on pragmatic philosophy and an argument analysis based on Toulmin's argument pattern. Two ways in which students' arguments develop during classroom discussions were identified: learning to specify the conditions for one's claim and learning to find new solutions. It was concluded that the complexity of the students' arguments increased as a result of taking part in the discussion, that the quality of their arguments developed over time, and that the knowledge used in their arguments became more nuanced and developed in terms of complexity. An important conclusion was that increase in the quality of arguments and the quality of the knowledge content used occurs simultaneously.

Albe (2008a) investigated argumentation with a class of 11th grade students involved in the study of health effects related to the use of cell phones through a micro-ethnography with a focus on the rhetorical aspects of discourse. She analyzed student argumentation through analysis of audio recordings and transcripts. Her results indicate how SSIs provide for student engagement in collaborative argumentation. Students challenged one another to explain views and considered the perspectives of others. In the study, scientific evidence appeared to be the key element enabling students to make an enlightened decision. Scientific proof was seen by the students to be a 'revelation of nature' and empirical evidence was perceived as 'an ideal of truth', a key element which resolves controversy. Students appeared to expect scientific certainty and request more science in order to be able to make a well-founded decision on a SSI. Albe (2008b) suggests that "naïve epistemological representations" limit student argumentation and that, "students' work on socio-scientific controversies should be accompanied by an examination of the way in which scientific knowledge is produced within a community and, in particular the role of controversy in the process" (p. 86).

Furberg & Ludvigsen (2008) report on a study of ways secondary school students make meaning of socio-scientific issues in ICT-mediated argumentation settings. Their theoretical argument has as its point of departure in the analytical distinction between 'doing science' and 'doing school,' as two different forms of classroom activity. In the study, they conducted an analysis of students working on the subject of genetics with a web-based groupware system. The analysis identifies how the students'

orientations were directed towards finding scientific explanations, exploring ethical and social consequences, and towards 'fact-finding'. Students' different orientations seemed to be productive because they urged them to engage in ongoing discussions and explicit meaning-making. Furberg & Ludvigsen's findings suggest that in order to obtain a deeper understanding of ways students' make meaning of socio-scientific issues in ICT-mediated settings, it is important to not only address how students perform the activity of 'doing science', but it was seen to be equally important to be sensitive to how students orient their talk and activity towards more or less explicit demands embedded in the educational setting. In other words, how students perform the activity of 'doing school.'

In their study of 14-15 year olds working on the topic of climate change, Mäkitalo, Jakobsson & Säljö (2009) show that disparate and conflicting framings are common in student discussions and in interaction amongst students and teachers. Their study highlights how important the framing and development of perspectives are for the student engagement with different aspects of a problem. When tackling problems, students were seen having to interact in contextually relevant ways, whether it was as an accountable student being able to explain the greenhouse effect or as a concerned citizen justifying a position.

Drawing on the contributions of the studies discussed above in terms of understanding the role knowledge of science plays for reasoning while identifying the weakness that there has often been a lack of consideration for the contexts in which claims are made in research in this area, the current study investigates how science plays a role in reasoning using a sociocultural and dialogical approach. This approach entails exploration and understanding of how students handle and reason on socio-scientific controversies (SSCs) through interaction within institutional contexts and mediated by the cultural tools available to them. Since students, as citizens, are expected to learn how to participate in dialogue about ongoing SSCs, it is necessary to consider one of the most prominent arenas where such public debates take place—the Internet. One prominent sociocultural activity to study, concerns the common use of web browsers for finding information on unfamiliar topics. Therefore, I will now proceed to introduce and review studies of ways students handle information encountered on the Internet. These studies are not primarily located in the field of science education, but rather in the fields of technology

enhanced learning, computer supported collaborative learning and digital literacy.

## 2.4 Students handling of online information

In science education, approaching information in the media has primarily been used as a way to contextualize scientific concepts, demonstrate their relevance, or increase student interest (McClune & Jarman, 2014). However, the importance of also learning about the media itself has also been recently highlighted (Belova & Eilks, 2016). Learning through and about media is suggested as a way to develop students' capabilities to critically approach and use science-related online information (Belova & Eilks, 2016). Yet, McClune & Jarman (2012) detected teachers' strong preference for traditional media types, such as printed newspaper articles, over digital media in science education. Although it was suggested that the Internet would be an invaluable resource for teachers to expose students to diverse perspectives on current scientific reports and claims during the early days of its introduction to schools, many schools (in the US) quickly sought to ban access or to filter sites to prevent students from visiting unreviewed materials (Linn, 2003). Similarly, it has also been argued that students should not spend time surfing through "a plethora of sometimes misleading information" (Zeidler & Nichols, 2009). Rather Zeidler and Nichols (2009) recommend that students should spend their time reading and evaluating the multiple perspectives of a given socio-scientific issue from sources that teachers have selected and classified as either reliable or as potentially false or unscientific. Thus, students would be confronted with mixed evidence from unsound sources and perspectives, and learn to assess the validity of varied claims and data (Linn, Davis, & Bell, 2004). Others have argued that the library also offers controversial material and have called for increased attention to evaluating the evidence available there. The result of this initiative was a series of research programs to prepare students to interpret persuasive messages in relation to school science (Linn, 2003).

The Science Controversies – On-line Opportunities for Partnerships in Education (SCOPE) programme studied how students explore science in the making. The SCOPE materials[10] prompted students to critically evaluate news

[10] (http://scope.educ.washington.edu/ )

accounts of 'personally relevant topics' (Bell, 2004). For example, to make decisions about the cultivation and consumption of genetically modified foods, students compared the risks from traditional agricultural practices such as hybridization with the risks of genetic modification. They also weighed issues of economics, world hunger, and individual health. In addition, students studying this controversy learned to distinguish comments from scientists in the agricultural industry, environmental protection groups, and researchers supported by government grants. Using this learning environment to guide student inquiry was reported to promote knowledge integration about the nature of science (Linn, 2003).

With the introduction of digital devices and the Internet to classrooms over the last few decades, access to information in science education has increased dramatically and conducting online information searches has become a common task (Halverson, Siegel, & Freyermuth, 2010; Hsu et al., 2014; M.-J. Tsai, Hsu, & Tsai, 2012; Walraven et al., 2009). An example of a recently conducted study taking a cognitive approach (Hsu et al., 2014) examined the role of different levels of scientific epistemic beliefs (SEBs) in students' online information searching strategies and behaviors. Students' self-reported online searching strategies were evaluated and their search behaviors were recorded by screen-capture videos. The authors report that those students with more sophisticated SEBs tended to employ more advanced online searching strategies such as self-reflection and self-monitoring in relation to the goals and process of searching. When students search on the Internet about complex issues such as socio-scientific controversies they may be confronted with multiple sources of information that provide different and conflicting perspectives. This implies that they need to develop knowledge and skills to distinguish helpful resources from unhelpful or intentionally deceptive ones while allowing for uncovering of how particular knowledge claims may serve the interests of different claimants. The media literacy field is developing capacity and frameworks for examining Internet media use in education but the more traditional content disciplines have been slow to respond to this challenge with the field of science education as a typical example (Klosterman et al., 2012).

Studies of young children, university students and adults searching for information on the web have reported on the difficulties they encounter (Walraven et al., 2009). In particular, effectively and critically retrieving, evaluating, selecting, judging, and integrating information gathered from the

Internet is a challenge (Wu & Tsai, 2011). Studies have reported on how students tend not to base their evaluation and selection of sources on clearly articulated criteria (e.g., I see this is the official website of Greenpeace) and instead draw on intuition (Walraven et al., 2009). An early study reported that teenagers used information without thinking about the purpose of a site (Fidel et al., 1999) and it has also been reported that students find it hard to express how they evaluate and select information (Lorenzen, 2001) and that a majority of students admit to rarely checking information (Beljaarts, 2006 Dutch language study cited in Walraven et al 2009).

Navigation and critique of the content available via ICT has been shown to require students develop supporting strategies for handling the abundance of information (Chung & Neuman, 2007). Studies of the search behaviors of upper secondary science majors that have been conducted generally indicate the need for more guidance and support for students when they search for SSIs online (Hsu et al., 2014). The provision of such guidance necessitates approaches for helping students to both explore and order information, and to conceptualize and unpack controversies. While there is little research to date based on direct observation studies of students collaborative handling of online information, studies that address how to support students engaged in seeking information online are of relevance to the present dissertation project, particularly those dealing with science related complex issues (viz., Lin & Tsai, 2012; Stadtler & Bromme, 2007; Wiblom, Rundgren, & Andrée, 2017; Wu & Tsai, 2011). For students working on such issues, it is challenging to select and examine high-quality relevant sources. For example, Wu and Tsai (2011) tested the learning outcomes of guided online searching on the topic of nuclear power usage. Students who were instructed to search for information related to different perspectives such as technology, ecology and economy were reported to outperform an unguided group in terms of reasoning capabilities and conceptual understanding. Similar results were reported by Stadtler & Bromme (2007) who studied students searching for information on a medical topic. Students who received metacognitive prompts where they were asked to reflect on how well they understood the information and to indicate the sources of that information, outperformed control groups in terms of knowledge about sources, and produced more arguments relating to the sources of information. Also structuring the search process, the use of a social bookmarking application to support productive behavior has been investigated by Lin & Tsai (2012). The application enabled asynchronous

Internet exploration and students who exhibited an active engagement including searching, making bookmarks and commenting on the bookmarks of others were reported to exhibit a 'deep' level of cognitive engagement and tended to become aware of valuable online resources for the assignment (Lin & Tsai, 2012). In a design-based study, Wiblom and colleagues (2017) addressed students' opportunities to develop and practice their capabilities to critically approach online health information. The participating students were given an online retrieval task that included searching for and evaluating health-related online sources. The students were introduced to an evaluation tool designed to support critical evaluation of health information online. Without using the evaluation tool, students struggled to gain an overview of the vast amount of information available and negotiate trustworthiness. Guided by the evaluation tool, critical reasoning was practiced to handle source subjectivity and to sift out scientific information. However, irrespective of the kind of support students receive, the normative framing of the school context plays a role as reported in a recent study by Forte (2015). The study reports on high school students' information assessment practices in science as they help build a collaborative online information source (Forte, 2015). One finding was that although the design of the activity in the study was aimed at supporting open collaboration through the construction of a textual artifact, specific established school norms such as invoking the teacher as an expert authority figure still became relevant as students framed tasks in institutionally sanctioned ways.

Amongst the range of studies that have explored information seeking activities, few have considered the collaborative, discourse mediated nature of the search engine use that is common in classroom contexts (Knight & Mercer, 2014). Some research has explored collaborative information seeking in educational contexts (viz., Lin & Tsai, 2012; Wu & Tsai, 2011), however still fewer studies have been based on direct observation of students' online activities. In one study that has taken this approach, Knight and Mercer (2014) investigated the role of exploratory dialogue in collaborative classroom-based search engine tasks. Their results indicate that the success of groups in such tasks is related to the use of educationally productive dialogue and exploratory talk rather than other factors.

In an earlier study, Almqvist and Östman (2006) examined small groups of students (13-14 year olds) as they worked with an assignment that required the selection of information in science education. Specifically, the assignment was

to use the Swedish Schoolnet, an early network and curated web portal organized by the Swedish National Agency for Education, to help them write three sentences about what they felt was the most important aspect of the greenhouse effect. The main purpose was to have them evaluate information on the Internet. To illustrate the Internet's significance for students' meaning making in empirical terms, the authors did not proceed from a preconceived notion of technology and its relation to human action. Rather, they drew on Wittgenstein's theories on language and how knowledge, certainty, and doubt are all tied to language games, implying that these actions take place within a specific practice, with specific objectives, and that it is in this practice that they have meaning. The findings show that students merely copied the information they found online. In addition, the findings show that while the mode of reinforcement of the texts used by the students may have provided little opportunity for doubt or learning how to doubt, the students' intentions for the assigned task determined the result of the interaction, i.e. copying from the first page they encountered. The authors claim that if students had intended to search for multiple explanations of the greenhouse effect in order to choose the most important aspects, the findings would probably have been different. In other words, given the particular circumstances studied, based on the curated school website used and the assignment given, it was reasonable that students did what they did. Thus, the internet came to be used simply as a source of information that could be written down in order to finish the assignment. The authors showed that the students did not evaluate the information they encountered on the websites they visited and suggest that the students' lack of evaluations were understandable due to the institutional circumstances that prevailed during the students' meaning-making (Almqvist & Östman, 2006).

In this dissertation project I acknowledge the relevance of the studies discussed above in terms of both recognizing the need to provide students with supporting strategies when engaging with online information (Lin & Tsai, 2012; Stadtler & Bromme, 2007; Wiblom et al., 2017; Wu & Tsai, 2011) and the importance of institutional settings when analyzing what students attend to (Almqvist & Östman, 2006; Forte, 2015). Drawing on these insights, I investigate what students are doing when engaged with information online by use of a visualization tool to represent the information encountered in a condensed and more readable form. Digital technology is now used throughout educational institutions as a means to support learning – either as

a learning tool in its own right (i.e. as a means of supporting learning activities and tasks) or as an information tool and as a means of accessing information (Selwyn, 2011). While previously limited to demonstrating the coproduction of science, technology and society through the medium of individual cases studies, new data collection and visualization tools offer the opportunity to depict broader 'landscapes' of controversy without sacrificing attention to the smallest details of conflict and disagreement (Marres & Rogers, 2005; Venturini & Latour, 2010). Key amongst these new tools are those developed as part of the Forccast[11] project that have been used in this dissertation project. While activities for schools using these tools involving partners in both schools and universities have been created and published, to date, research reporting on students working with them in schools has, to the best of my knowledge, not been published.

## 2.5 Summing up

Reflections from the reviewed literature have informed the goal of this dissertation which is to develop knowledge about students reasoning regarding socio-scientific controversies in light of their material, institutional and cultural contexts. Studies of individual student reasoning have made important contributions to the field and to our understanding of how students deal with SSI reasoning and scientific content knowledge *per se*. However, to be able to gain a rich understanding of the complexity of students' reasoning in a particular learning environment, a more holistic view is also needed. The socio-cultural and dialogic perspective taken in the present dissertation involves including the significance of context where reasoning takes place. The dissertation aims to add to the existing body of research on a number of levels which I have aggregated into two points:

First, I observe student actions in situ taking contextual features into consideration in analysis. Others have been arguing for the need for more studies of processes through in situ studies of science education settings in general (Rudsberg, 2014), and the importance of studying learning processes by studying social interaction and institutional dimensions has been

[11] http://controverses.org/en/controversies. Forccast is a project hosted by SciencesPo and includes fourteen higher education and research institutions. Among its partners are institutions from both schools and university, and institutions specialized in social and engineering sciences in France and abroad.

underscored (Wickman et al, 2012). By taking various contexts and mediating tools into consideration when analyzing students SSC reasoning, I aim at contributing with a complementary approach to earlier research approaches in this field where claims students have made have often been seen to be a reflection of what the students were able to or a reflection of what they believed irrespective of context. I aim at contributing to studies that understand socio-scientific reasoning as sociocultural activity implying that claims must be analyzed with reference to the contexts in which they were generated (Almqvist & Östman, 2006; Furberg & Ludvigsen, 2008; Mäkitalo, Jakobsson, Säljö, 2009). I will do this by analyzing the details of the students' interactions with others and tools integrating aspects of socio-cultural and dialogical perspectives (Linell, 1998a; Säljö, 1999; Wertsch, 1998)

Second, there are currently few empirical reports on the classroom practices associated with working with online material in science education that has not been selected by teachers (Klosterman et al., 2012). Similarly, there are relatively few studies based on direct observation of how students collaboratively handle information they have found online (Knight & Mercer, 2014). This gap in earlier research is of relevance to both the science education field as well as to fields dealing with understanding how computers support collaborative learning. A recent position paper suggesting future directions for the field of computer supported collaborative learning argues for the necessity of research addressing the handling of the multiplicity of perspectives and uncertainties of information in the Internet age (Wise & Schwarz, 2017). It is suggested that in relation to these issues, an emerging goal is to help people effectively engage in the process. The pervasive use of the Internet and its application in formal educational settings is relatively new, and in depth studies concerning reasoning on SSCs mediated by digital tools rare.

# 3 Dialogical and sociocultural perspectives on reasoning

In this chapter, I present some of the basic premises and objectives of the theoretical perspective chosen in this dissertation to analyze reasoning on socio-scientific controversies (SSCs) in science education settings. I draw on both dialogic and sociocultural frameworks to be provided with ways of understanding and formulating students work with SSCs in various educational contexts, interacting with mediating tools and in dialogue with others[12] . These frameworks provide opportunities to approach the empirical material as situated, institutional, and cultural, while making it possible to take the dynamics of the students meaning making into account. The theoretical approaches also offer particular benefits for gaining insight into students reasoning on SSCs where complexity is salient, the science unstable ("in-the-making" to use Latour's expression (1987)), and the issues contested among different stakeholders. A premise of a dialogical framework that is key for my work is that dialogue not only takes place in interpersonal dialogue, but also at the level of practices and institutions (Linell, 1998a; Wertsch, 1998). A premise of a sociocultural approach important my work is the attention to studying social interaction with artefacts, taking into account the interdependencies between students and digital technologies (Säljö, 1999, 2010). Adopting theses key premises, drawing on concepts from sociocultural and dialogical traditions of researching social interaction, this dissertation shows how students in interaction with mediating tools, use, evaluate, negotiate, and reflect on knowledge claims concerning SSCs. Thus, the analysis reveals the particulars of the discursive activities in which students engage with SSCs taking classroom contexts into account.

In addition to introducing the approaches to communication and discourse that have guided this research, a number of concepts that are relevant for

[12] This dissertation presents one possible approach to using dialogical theories when analyzing students SSC reasoning. There is a variety of other applications of these theories in educational research, some of which provide ideas for best teaching practices (Knight & Mercer, 2014) or certain forms of dialogic teaching (Wegerif, 2011). The dialogic framework that is adopted for this dissertation does not promote any particular instructional strategies for classrooms.

understanding specific aspects of the interaction I observed will be presented. Each concept provided a different perspective on how students handle SSCs. Voice (Vološinov, 1973) allowed me to study students engaging in dialogue where multiple perspectives are salient (study III). Accountability (Buttny, 1993; Mäkitalo, 2006) as well as Linell's notion of Communicative Activity Types (CATs) (2010) provided means to analyse how students use 'appeals to science' as discursive resources in conversations (study II). The foundational concepts of mediation and cultural tools (Säljö, 1999; Wertsch, 2007) from sociocultural theory allowed me to understand students' work with digital tools to make SSCs legible in study IV. Finally in this chapter, I will present and discuss the discourse analytical approach taken in study I, where participants reasoning in a biotechnology course was studied, based in a discursive psychology tradition having a main focus on the 'theories' or Discourse models (Gee, 2005; Gee & Green, 1998) which were seen to play out within conversations and texts.

## 3.1 Reasoning as social, dynamic and contextual phenomenon

The contextual nature of people's meaning making has been articulated by several theorists in many disciplines, including those working in the approach chosen in this dissertation. Reasoning is, from the perspective I take in this dissertation, always imbedded in a particular form of discourse or genre (Bakhtin, 1986) and always implies participants' contextualization (Rommetveit, 1974). Accordingly, students' actions and activities are embedded in historical and institutional settings, where norms and values become central aspects in their argumentation and reasoning. Seeing education as a dialogic process, where teachers and students interact in settings that reflect the values and social practices of schools as cultural institutions (Mercer, 2004), students are understood to orient their activities and talk towards the more or less explicit expectations, values, and activities embedded in the particular educational setting. This does not mean that actions are determined by their contexts, only that they are more or less structured by them. It is in the relation between institutional aspects of the setting and the actions performed by students that learning activities are created (Furberg & Ludvigsen, 2008).

In the studies of my dissertation, I refer first and foremost to the works of Linell (1998a, 2009, 2010). Linell's approach is based on empirical studies of talk-in-interaction that make them particularly relevant and useful for my studies of reasoning in situ. I understand students' SSC reasoning as interdependent with other's experiences, actions and utterances. Not as the product of autonomous individuals who can decide everything for him or herself (Linell, 2009). In the discourse on developing socio-scientific reasoning and competences useful for citizenship, there is an implied cultivation of the free-flowing rationality and 'pure intellect' of individuals (Lemke, 2001; Rommetveit, 2008). A focus on individuals' knowledge and their ability to reason and come to decisions on complex issues without consideration for how individuals are part of larger collectives, including the sense in which individuals take sides in social and cultural conflicts, implies that there is an obvious link between knowledge and responsible citizens. Following this line of argument, the dominant approach to understanding students reasoning on SSCs in science education research is typically situated within a psychological tradition where the individual's argumentation is studied without considering contexts (Bencze & Alsop, 2014). Language as a central aspect of science learning has been of increasing interest to science educators for at least two decades (Roth, 2014). In the shift from social psychology, the unit of analysis changed from the individual to culture or a cultural dimension (discourse). Whereas researchers can use a cultural lens for understanding, teachers are confronted with the task to educate and test individual students and might not find such a shift useful or meaningful. Even when students are engaged in collaborative settings, the institutional requirement of evaluating learning at the individual level orients the endeavor of educators to the individual.

The position taken in this dissertation is an alternative to attributing claims to individual speakers. When I study students working with digital tools on a computer, reading website texts, talking to each other, or writing an essay in a university course, I view them as involved in communicative actions in interaction with others and contexts, both in the immediate situation and with knowledge and contributions of others who are not present. In dialogism, relations between the individual subject and the other(s), and between the individual and the world are *primary*, rather than derived from a world of 'rational' subjects and 'verifiable' objects (Linell, 2000). So underpinning the studies in this dissertation is an understanding that the basic constituents of

discourse are interactions and communicative projects – not utterances by autonomous speakers (Linell, 1998a). In this way, studying human reasoning through a dialogical perspective entails regarding interactions, activities and situations as primary. Language takes on a specific meaning from the context in which it is used, while simultaneously helping to construct what we take that context to mean and be in the first place. This implies the need to consider sequences of connected talk and action, not simply individual utterances. Bakhtin (1986) argues that "in reality any communication […] addressed to someone or evoking something, has a particular purpose; that is, it is a real link in the chain of speech communion in a particular sphere of human activity or everyday life" (p. 83). Bakhtin views language as a social activity, because any language act is a response to other acts, both those that preceded it and those that will follow (Bakhtin 1981). The meaning of an utterance derives not from the content of its words, but rather from its interplay with what went before and what will come later. Speakers and listeners are not viewed as separate entities; the speaker expects a response either directly or delayed and these expectations form how and what the speaker says. According to the dialogical tradition that I take as my point of departure, the speakers' relations to others play a decisive role and are not compatible with product-centered, individualistic models of communication.

## 3.2 A Bakthinian approach to issues of public debate

When students explore socio-scientific controversies (SSCs) they are faced with heteroglossia, different genres, stakeholders, and media resources online. The dialogical approach for understanding how students handle the multiple perspectives of SSCs is beneficial, since a range of stakeholders in society create tensions that make these issues salient to the public. It conceptualizes the individual as infused by the inherent tensions of such debates, rather than reduce the analysis to the individual level of scientific reasoning. Debates about SSCs are conducted through a mixed stream of multimedia resources and genres such as those examined by the students in this dissertation. From a Bakhtinian perspective (1981), dialogue is central and is considered to operate on multiple levels. According to Bakhtin, professional jargons (the discourse of biotechnologics, physicians, politicians, etc.) are one aspect of this stratification of discourse. They are not only defined by lexical aspects, but

represent particular forms of interpretation of the world. So, as Bakhtin puts it, a professional jargon, as does any discourse, constitutes a specific point of view on the world (Grossen, 2010):

> " [A]ll languages of heteroglossia, whatever the principle underlying them and making each unique, are specific points of view on the world, forms for conceptualizing the world in words, specific world views each characterised by its own objects, meanings and values. As such they all may be juxtaposed to one another, mutually supplement one another, contradict one another and be interrelated dialogically"
>
> Bakthin, 1981, p. 291–292

The words we select in any specific situation have an otherness about them; they belong to specific speech genres, they bear the traces of previous utterances. They are also directed towards specific others, to specific addressees. It is this sense of otherness in language that is fundamental and that explains Bakhtin's dialogism. As Bakhtin writes in his essay on speech genres:

> "In reality any utterance in addition to its own theme, always responds (in the broad sense of the word) in one form or another to others' utterances that precede it…. The subject of his speech itself inevitable becomes the arena where his opinions meet those of his partners (in conversation or dispute about some every day event) or other viewpoints, world views, trends, theories, and so forth. World views, trends, viewpoints and opinions always have verbal expression. All this is other's speech, and it cannot but be reflected in the utterance. The utterance is addressed not only to its own object, but also to others' speech about it"
>
> Bakhtin, 1986, p. 94

Fundamentally, Bakhtin argues that human life is inherently dialogic and that we are constantly in dialogue with both our immediate surroundings as well as the past and the future. That any discourse, written or spoken, is inherently dialogical means that an utterance is always oriented to what has already been said by others and simultaneously formulated in anticipation of some kind of response. While it is made to make certain meaning potentials relevant in the unfolding of dialogue, its concrete sense is inevitably shaped by its response. It is other-oriented and other-dependent. Debates about controversies that are conducted through a mixed stream of multimedia resources and genres are in this context seen as unfolding over time (Vološinov 1973). The analyses in this dissertation of how students engage in dialogue about controversies focus

on their joint discursive activity within the educational setting. As students engage in making sense of a controversy together, their utterances contain elements of previous utterances and disputes from the debate online, and are elsewhere oriented towards their peers or teachers in situ, anticipating an active responsive understanding.

Adopting a dialogical approach to students' interactions allows for examining how the individual is in dialogue with interlocutors and contexts (Grossen, 2010; Linell, 1998a, 2009), both in the situation and socioculturally. Rather than analyzing individual retrospective accounts as student beliefs about these issues, one dialogical approach that I take in study III invites an analysis of students' discursive management of multiple perspectives, a multivocality which is not only recognizable in ongoing public debates, but also part of our internal dialogue when confronted by controversial issues in our everyday lives (Bakhtin 1986; Linell 1998, 2009).

## 3.3 Voice as perspectives on an issue

In dialogism, the perspective of the other is seen as an inherent feature of an utterance and the complexity of voices within utterances and how the utterances of individuals are co-authored through the voices of others have been theorized (Bakhtin, 1981; Vološinov, 1973). Study III investigates how students draw on ideas, opinions, and perspectives attributed to other people to bring in multiple perspectives and the complexity of an issue. Debates on controversial issues involve struggle between different stances and interests and involve several voices. Interlocutors who talk about controversies to make sense of them and explain them to others are in dialogue both in the immediate environment and with other contexts. Their utterances are largely reconstructions of the voices of other individuals or groups. While an utterance may incorporate several perspectives, opinions, stances, and voices, some forms of discourse attempt to hold one and only one perceptive on its topic. These forms of discourses are conceptualized as one-voiced or mono-perspectival (for instance, some scientific texts can be described this way). Individuals' utterances may thus host many voices with some more personal while others rely on social languages associated with a type of activity or genre. This gives relevance to two main notions of voice as a perspective on a topic. One is the notion of a generalized voice and perspective on a topic that is tied to the social language of a particular group, such as scientists or

environmentalists. The other draws on several different voices, whether these voices are taken from other individuals or they are generalized voices. A single perspective on an issue can accordingly be voiced by many persons, and one person can house several perspectives. Hence, there is no one-to-one correspondence between person and voice if we are to speak of voice in the sense of perspective on a topic or issue (Linell 2009).

When speakers use other's ideas, positions, and utterances, the analytical notion of reported speech becomes relevant (Vološinov, 1973). Individuals' contributions to a conversation can involve references to or quotes from other people's utterances and even dialogues between different voices can be embedded. However, reported speech involves drawing on others' words while shaping them for one's own purposes (Vološinov, 1973). This double-voiced quality makes reported speech interesting for analysis. For instance, a speaker may use quoted utterances from other people for her own purposes while simultaneously attributing them to somebody else. There are also subtle and complex ways in which speakers can comment on the utterances they report, for instance by adopting a slightly ironic tone while simultaneously appearing to simply reproduce them.

Studying reasoning of socio-scientific controversies entails studying how participants in the study encounter groups of people and traditions with views that are different and maybe in tension with their own. This introduces oppositions, disagreements and different evaluations (otherness). The others introduce other and maybe disruptive perspectives bringing in experiences and knowledge other than those that might have been expected and students may see things differently from points of view that are strange and unfamiliar to them. Ideas encountered online, for example, are not ready-made, but are instead accomplished and completed in dialogue with others. However, the individual may gradually acquire an ability to introduce 'virtual others' in his or her argumentative thinking (Billig, 1996).

The notion of polyvocality (multivoicedness) in dialogue refers to text and utterances that are not the speakers own but typically contain explicit or implicit elements from others utterances, other voices. Expressions, ideas and messages often travel between texts and contexts and are typically recirculated in discussions on socio-scientific controversies. In study II where students in a school context invoke a message encountered online, they cannot simply insert the message in a new context. Rather, the message comes in to different use depending on the situated activity. In this analysis, the concept of

communicative activity type (CATs) becomes relevant for understanding how the 'same' message gets new meanings and purposes as it is moved between CATs.

## 3.4 Reasoning as embedded in institutional activities

In study II, I argue for the significance of considering the local embeddedness of 'appeals to science' (Goodwin & Honeycutt, 2009; Nowotny, 1981; Sykes, 2016) when studying SSC reasoning and of paying attention to the challenges students encounter when faced with such complex issues when multiple contextualizations must be handled in face-to-face interaction. The analytic concept communicative activity type (CAT) (Linell, 2010; Marková, Linell, Grossen, & Salazar Orvig, 2007) is used for understanding student reasoning. CATs provide a link between situated micro-processes and the societal macro structure of discourses, between focusing on the detailed specifics in a dialogic exchange and focusing on the communication as a particular type of social situation (Linell, 2010). For the purposes of understanding the analytical procedure and findings in study II, the concept of CAT is briefly discussed in the following.

Communicative activities are carried out for particular purposes and accomplished by people together in situated encounters where the activity type defines the situation for the actors engaging in it, telling them what is 'going on' in the situation (Linell, 1998a). At school, students participate in different types of activities such as science labs, lectures, presentation of group work, and debates. In science education in schools these situations are linked to discourses such as scientific argumentation and arguing controversial issues in a debate. The activities are also framed by specific expectations and purposes that the participants are oriented to such as whether or not the activity is formally assessed etc. (Linell, 1998b). Students are accountable for what they say and do in interaction with each other and need to contribute with comprehensible and recognizable contributions to a conversation or a discussion. An utterance must be designed to fit certain particular conditions of where it is to be performed (Buttny, 1993; Mäkitalo, 2006). When SSCs are introduced in the classroom, students must unpack what is considered relevant for the various activities they engage in. The ways the tasks are initiated, the resources available and how the school work will be assessed

influences how the students engage with the tasks (Åberg et al., 2010). A CAT analysis can be performed on various empirically overlapping and interdependent dimensions (Linell, 2010), such as those associated with classroom activities. In study II, I attend to a limited number of empirical dimensions particularly relevant for the analysis of student 'appeals to science' in school as external framing dimensions such as the purpose of the activity and how participants adopt activity roles.

When I study the students' dialogues and how a particular message (eg. that GMO cause cancer in rats) is recirculated, I do not presuppose any set of fixed and readymade ideas that just move around. Rather, the ideas are understood to be "continuously or at least potentially negotiated, modified and transformed as they circulate in dialogue" (Marková et al., 2007, p. 133). The communicative situations studied here are institutionally framed as part of school projects and do not occur in isolation. Instead, they are connected in various ways, across space and time through artefacts such as written texts and photos online. This means that discursive content will travel across situations, a phenomenon that involves recontextualization, 'the dynamic transfer and transformation of something from one discourse/text in context to another' (Linell, 1998b; Sharma & Anderson, 2009). In this way, there is no pure transfer of a fixed meaning or message, rather, recontextualization involves transformations of meanings. In the settings studied here recontextualization can for instance involve that a part of a text such as a piece of evidence or conclusion from a scientific article in a journal is fitted into another context such as an activist group webpage.

## 3.5 Reasoning as becoming part of a biotechnologist community

The analytical approach to participants' discourse in study I is based in a discursive psychology tradition through which biotechnology course participants' reasoning is studied. The focus is not primarily on participants communicative competences revealed through their interactions, but rather on the content, what students talk about and what is made possible to learn within the community that the classroom is part of (Gee & Green, 1998). The fundamental idea of this approach is to take discourse as the unit of analysis rather than the individual who then is thought to realize possibilities that exist at the collective level. However, in addressing other person(s), the form and

content of the discourse is adjusted to the social situation. Any segment of discourse is therefore understood to be characteristic not of individual participants, but of the participants in the communicative effort and the type of social situations in which they take part. Biotechnology education is seen as contributing to a process in which novices are initiated into the biotechnological community (Lave & Wenger, 1989). This implies that I understand the development of student reasoning in an introductory biotechnology courseas a way to become a biotechnologist, involving coming to see the world in particular ways: "coming to understand how to articulate an appropriate argument given certain contexts; and coming to know how to present oneself and one's data in socially and scientifically appropriate ways" (Kelly et al., 1998, p 24). From this perspective, learning disciplinary knowledge entails more than simply acquiring basic skills and received knowledge. It also involves developing identity and affiliation as well as critical epistemic stances and dispositions as learners participate in the discourse and actions of a collective social field. From this perspective, knowledge is not solely held in texts and books, but is a product of ways of speaking, writing, and acting. Knowledge claims, evaluation of knowledge claims, and the criteria for the evaluation of knowledge claims change over time (Kelly, Luke, & Green, 2008). Such change occurs through actions taken by individuals and by groups through their common activities. So what counts as knowledge and whose knowledge counts is interactionally determined and potentially subject to change, revision, and critique, depending on the rules of the institutional, political, and economic fields in which such knowledge is produced. Knowledge is not held in the curriculum, although curricula support and constrain the possibilities for access to particular types of knowledge for students. According to the ethnographic approach to discourse analysis (Gee & Green, 1998), what defines learning is changed patterns of participation in specific social practices. Socialization is not only a question of appropriating the culture at the individual level, but also a collective process of interpretative reproduction. Bakhtin would call this appropriation of social languages or monologization into the authoritative genres of a particular community or group (Ball & Freedman, 2004). In relation to this, one particular argument by Bakhtin provides important ways of understanding how a biotechnological community can be conceptualized and how to uncover what it affords members. In each period of time, in each social circle, in each small world of family and friends in which a human beings grows and lives, there are always

authoritative utterances that set the tone – artistic, scientific, and journalistic works on which one relies, to which one refers which are cited, imitated and followed (Bakhtin, 1986).

The discourse analytical approach to participants discourse in study I focus mainly on discourse models or theories of what can be seen to play out within conversation or in students' written reports. I argue that this approach can be considered appropriate for understanding how new students in biotechnology come to be able to articulate appropriate arguments on a controversy involving the biotechnological community. The study particularly focuses on how participants characterize opposition and evaluate arguments opposing GM food. The idea in the discoursal approach used is to shift focus from the referents of discourse, for instance, a mental state such as cognition, to the discursive practices through which such referents are invoked. In the study, the discourse analytical approach is used to identify shared discursive resources and shared patterns of talking with the aim of finding categories, themes, ideas, views, roles, etc., within the discourse. I tried to determine, for example, how the discourse helps the participants understand the issue under study, how they construct their own version of a controversial issue, and how they use discourses to maintain or construct their own identities.

The terminology and approach used is that of Gee's discourse analysis (Gee, 2005), in addition to making use of Gee and Green's (1998) approach to understanding learning and social practice through discourse analysis to reveal what is made available to learn and what is learnt. The concept of discourse models (Gee, 2005) is useful as a tool of inquiry because the models mediate between the personal level of student and teacher interactions and the meta-level of the biotechnology community. Discourse models have been described as simplified, often unconscious, and taken-for-granted theories about how the world works that people use to get on efficiently with their daily lives. They are described as the theories we uphold that help us make sense of the world. Discourse models exist in the media, the knowledge we gain from others, and what we infer from the social practices around us. We learn discourse models from experiences shaped by the social and cultural groups to which we belong, such as science students or biotechnologists. Like all theories, they are simplifications useful for some purposes but not others. However, oversimplifications in discourse models can do harm by implanting dismissive or derogatory assumptions about other people. Assumptions may marginalize people, as part of their function is to establish what can be

considered to be central, typical cases, and what are considered marginal, non-typical ones (Gee, 2008). Discourse models embed assumptions about what is appropriate, typical, and normal. These assumptions are meant to express a perspective on things that foreground certain elements we consider important or salient and backgrounds other elements we consider less important.

## 3.6 Reasoning as mediated by tools

To understand how the students in the studies of this dissertation make use of digital tools to manage complexity encountered online when working with SSCs, I adopt a sociocultural approach (study IV). In the sociocultural tradition, the analogy of 'tools' was introduced to argue that cultural artifacts are fundamental for human activities and are recognized as the means through which we as humans make meaning and accomplish significant cultural change (Wertsch, 1998). Tools in this sense may include both material artefacts such as a pen and paper, or equally, Internet search algorithms or forms of language. They provide ways of perceiving and acting on things in situated practices. This implies that tools, when incorporated into our activities, mediate the world for us (Säljö, 1999). The students studied in this dissertation engaged in reasoning mediated by the available cultural tools, both physical (artefacts) and intellectual/psychological (signs). Following this line, mediation refers to a fundamentally social process of development and transformation by which human beings come into contact with the world through operating with symbolic means such as language and maps (Vygotsky, 1978). Tools such as the controversy maps created by students studied in this dissertation can in one sense can be understood as developed means for participation in epistemic practices where they simultaneously influence the coordination and modify the course for how, in this case, controversial issues can be presented. This is how they recreate and thereby shape people's participation.

Mediated action implies that there is a connection between action and "the cultural, institutional and historical contexts in which such action occurs" (Wertsch, 1998, p.24). Vygotsky emphasizes action with tools in activity rather than emphasizing tools themselves, suggesting that tools are constitutive of object-oriented meaning-making processes as part of people's situated use (Vygotsky, 1986). Our encounters with tools as we put them into use for some purpose or action shape our insights and understandings. Important to

acknowledge in this context is that we can be both positively and negatively impacted by such encounters. The question of how sociocultural perspectives view the processes by which people come to know is in other words closely related to interaction and participation in epistemic practices. In summary, this theoretical perspective views learning as a situated and fundamentally social activity characterized in terms of participants' joint coordination and meaning making.

From a sociocultural perspective, learning in the context of educational arrangements is a matter of being able to make use of cultural tools in situated practices in relevant and productive manners. Säljö (2010) has argued that it is not relevant to understand human competences solely in minds or bodies, but instead that knowledge becomes visible in peoples abilities to collaborate with external tools and to integrate them into what they are doing. Drawing on this argument, my perspective considers the interactional and contextual features of human discourse and interaction with tools, and understands students' ideas and perspectives on topics as being generated and sustained through interaction among students, teachers and tools. From this theoretical perspective, joint construction of a more legible representation of a controversy in a map, is made possible by the mutual coordinated interactions of the different participants.

## 3.7 Summing up

The different theoretical approaches chosen for this dissertation give rise to four distinctive but still conceptually related studies. Study I approached SSC reasoning through discourse analysis (Gee, 2005; Gee & Green, 1998) and stands out somewhat to studies II-IV. It is first and foremost the concept of discourse models that deviates from the concepts used in the other studies as it is sometimes conceptualized as mental models and existing in the world (Gee, 2005). However the approach as used in this dissertation is well aligned with a foundational aspect of a sociocultural approach to understanding students' actions and activities as embedded in historical and institutional settings, where norms and values become central aspects in argumentation and reasoning (Mercer, 2004). Teachers and students interact in settings that reflect the values and social practices of educational, cultural institutions. From this perspective, the students and professor's talk and activity in Study I can be characterized in terms of discourse models or equally in terms of

double dialogicality (Linell 1998; 2009). First, talk and activities relate to the existing interactional context, and in addition are also related to sociocultural practices established within long standing traditions:

> "[L]inguistic structures, cultural routines, norms etc. do exist prior to interactions (but only in and through the interactants' being acquainted with them). At the same time, however, these structures, routines and norms are interactionally generated, traded down and reconstructed. That is, they exist prior to individual interactions, yet would not exist without a living historical continuity of interactions. Social structures are (re)created, tried out, tested, negotiated and modified every time they are instantiated or drawn upon" (Linell, 1998, pp. 59- 60)

Students orient their activities and talk towards the more or less explicit expectations in the particular educational setting. For the science education settings studied here this implies that students' meaning making processes involve making sense of how to respond to implicit and explicit sets of institutional practices, values, and expectations. This can be in terms of making sense of the tasks and solving them satisfactorily, the resources in use, the teacher's instructions and feedback, or the curriculum and assessment criteria. In this way while Study I stands out, a shared assumption for all four studies in the dissertation is that students' reasoning is not determined by institutional practices and norms, but rather that institutional aspects are invoked and oriented to as structuring resources within their meaning making processes.

The introduction of SSCs in education, which makes problems of heteroglossia and conflicting arguments a part of schooling, implies that the complexity of considering what is considered relevant to learn and pay attention to increases dramatically for students. Meaning is always embedded in a particular form of discourse or genre and we always talk about issues in specific manners that are situationally appropriate.

# 4 Research design

The overarching aim of this dissertation is to investigate students' SSC reasoning in interaction and within the institutional contexts in which they learn and act. This implies investigating students reasoning as it unfolds, is embedded in activity, and shaped by framings and demands constituted through practice. The overarching research questions that were introduced in the first chapter are concerned with the contextual features and tools that mediate students meaning making of SSCs and the communicative competences that are displayed when students investigate SSCs digitally. To be able to follow and observe student activities, the empirical material collected for this dissertation includes video observations, field notes, documents, and student generated material such as written reports and controversy maps generated with digital tools.

In the following, I will describe the empirical material in more detail. I will begin by introducing the empirical settings, contextualizing the assignments that students and teachers were working with, and describing how the school and university research projects were organized. A presentation of the digital network visualization tool used by students to generate controversy maps is also included here. Then, I describe the empirical data collected and discuss the practical arrangements for making video recordings. Following this, the analytical procedures undertaken are discussed including transcription work and the analytical investigation of the interactional materials. Finally, I discuss the procedures used for selecting empirical examples to report the results of the analyses presented in the four empirical studies.

## 4.1 Introduction to the empirical settings

The four studies that make up the dissertation originate from empirical fieldwork in two different educational settings. The first site at a technical university was organized around group project work on genetically modified organisms (GMO) in an introductory course on biotechnology (study I). At the second site, an upper secondary school science program, group project work involved students to working on a variety of SSCs including HPV

vaccine, GMO, electronic waste, hydraulic fracturing, prenatal diagnosis, and animal testing in research. These students examined the SSCs through the use of digital controversy mapping tools (study II, III, IV). Study I, with empirical material from a technical university setting, was conducted within the frame of a doctoral research school focused on didactics in the molecular sciences. It was included in this dissertation due to its clear relevance to the other included studies and the overarching theme, examination of SSC reasoning in relation to ICT in science education settings.

**The technical university setting**

Data was collected in the first semester of a five-year program in biotechnology at a Swedish technical university (September-December 2009). This university has a general goal of promoting sustainable development throughout its courses and research. The course in introductory technical biology was particularly relevant for this study due to the issues it examines, which concern personal, professional and political decision making on a socio-scientific controversy. The students participating had recently graduated after 12 years of schooling from upper secondary school ('gymnasiet') programs focused on science and mathematics to gain a position in the competitive biotechnology program. The course aimed to give students insight into various areas of biotechnology and required that students learn how to gather information from various biotechnological sources and write a report. Apart from providing students with lectures and seminars intended to scaffold their work on various biotechnological issues, the course involved work with an extensive group writing assignment on which the students spent six weeks exploring a biotechnological issue. The empirical material for the first study consists of lectures on GMO and four supervision sessions organized as support for this writing assignment that eventually took the textual form of a report.

The first part of the course consisted of lectures on diverse aspects of biotechnology such as ethics and sustainability in addition to research areas such as tissue engineering, pharmaceutical applications, and producing GMOs. When the term 'GMO' (Genetically Modified Organisms) was used in the course, it refered to genetically modified crops and foods, not to, for example, genetically modified bacteria for the production of pharmaceuticals. In the second part, the students chose a biotechnology topic and worked in small groups to produce a written report and oral presentation to supervisors

and peers. Two groups (ten students in total) chose to examine GMOs and were supervised by the professor who gave the lecture on the subject. Themes for the report were suggested by the supervisor, but students were free to follow their own interests. One group chose to work on GMO use in the third world while the other group started off working on GMO products with proclaimed health benefits such as increased vitamin or mineral content, but ended up writing about the controversy in society more generally.

**The upper secondary school setting**

The major part of the fieldwork undertaken for this dissertation was conducted as part of the research project LETCOM[13] that arose from the transdisciplinary arrangement in the University of Gothenburg Learning and Media Technology Studio (LETStudio - http://letstudio.gu.se). The research was conducted in a Swedish public upper secondary school located in a suburban community. The school provided 14 programs and was the choice of approximately 50% of students in the community with the rest commuting to schools in nearby communities, putting the school in a competitive situation. All students at the school were provided with a personal computer and the students in the project were enrolled in the science program.

Discussions of SSCs are conducted at both lower and at upper secondary school levels in Sweden and studies could potentially be conducted at both levels. The background for choosing an upper secondary science program in particular, was that at the time of planning the pilot study for the project in 2013, I was working at a science center and was involved in a project where upper secondary school science students came to the center to conduct a project on science communication. In that context, I contacted a teacher with whom I was familiar from working at the science center and who I knew was interested in working with science-in-society projects. This teacher was also supported by a principal (contacted by the project leader) who showed an interest in supporting their teachers at the school in working in

[13] This collaboration has brought together educational researchers concerned with learning in digital environments and STS researchers interested in new forms of public engagement and involvement in science, technology and medicine. These researchers identified controversy mapping as a fruitful focus for collaboration and contacts were made with the Médialab in Paris to discuss how teaching methods might be successfully adapted to a school context. Subsequently, a funding application was made to the Swedish Research Council for a project aiming to develop an integrated approach to controversy mapping and socio-scientific issues teaching in an upper secondary school context (Project leader is Åsa Mäkitalo).

interdisciplinary projects. The teacher and principal were willing to collaborate with us, and the teacher was willing to both participate in the project and be responsible for introducing the project to colleagues at the school. The actual pilot and project ended up taking place at the school and did not involve the science center.

The science teacher collaborating with me and the other researchers was allocated worktime for engaging in projects such as this. During a period of six months, this teacher, her colleagues and the research team had monthly meetings to plan the instructional unit to be used and to coordinate in terms of our different goals. One example of such coordination of goals involved finding appropriate controversies to work with since certain controversies were deemed inappropriate for digital mapping. One member of the research team interviewed students to inform us on the kinds of controversies students had an interest in. Some controversies were judged not to be active enough online to produce usable maps while others, such as marijuana use, were deemed by teachers to be unsuitable for the particular school setting. Following this selection process, it was decided that the students would work in groups of four to six on either genetically modified organisms (GMO) or hydraulic fracturing (fracking). Among other reasons, the debate on GMO and fracking on the web were selected for their wide range of actors, their global reach, their perceived high level of scientific uncertainty, and the relatively distinct interests informing the debates.

Student project work was initiated by the research team which included researchers in education and science education concerned with engaging with SSCs in digital environments, and Science and Technology Studies (STS) researchers interested in new forms of public engagement and involvement in science, technology and medicine. The project was collaboratively developed by teachers from the upper secondary school along with a pedagogical developer focused on the integration of information communication technologies (ICT). The research team invited one of the developers of the digitial controversy mapping tools used in the project, Mathieu Jacomy who at the time was affiliated with Sciences Po in Paris, to present the aims of the school project and consult the pedagogical ICT developer. Based on these consultations, it was decided to use two tools for students to work with in order to map controversies. The students used these tools to collect data on websites that were visited while surfing for a particular topic and subsequently to visualize the websites as nodes in a network graph with the edges

representing the hyperlinks between them. This kind of information visualization is widely used as a tool for understanding data – discovering patterns, connections, and structure, and in this case, the mapping tools were used by students to generate copra of linked websites and visualization of these (Figure 1) that are described in more detail in section 4.2.

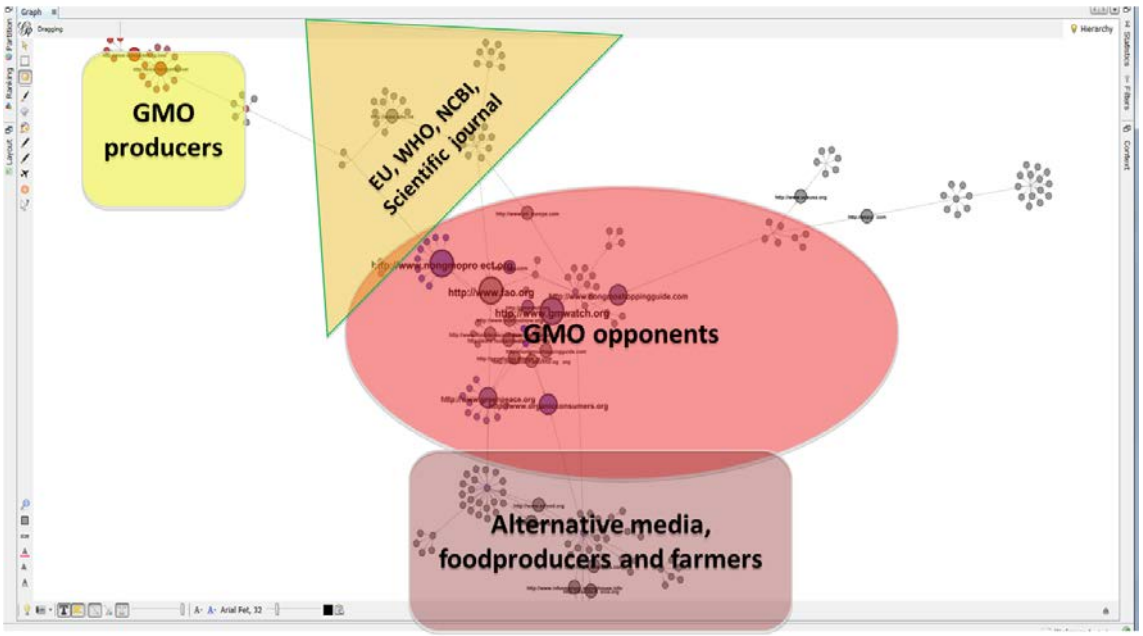


Figure 1 An example of a map of the controversy around consuming and producing GMOs

Working with SSCs calls for cross-disciplinary school projects since the relevant science regarding these issues is complex, multidisciplinary, emerging, and contested (Levinson, 2001; Levinson & Turner, 2001). In addition, SSCs encompass multiple ethical, social, economic, legal, and political dimensions. Coming from the subject areas of English, Physics, Swedish, and Biology, the four teachers involved in the pilot project (2013) were used to working together in cross-disciplinary projects on sustainable development that matched the interests of our research. They used a unit of lessons normally allocated for a sustainable development project in grade 11 for the unit investigated in this dissertation. Each teacher had between 15 and 30 years of teaching experience with one teacher (the same as was initially contacted) maintaining the necessary link between the school and the research team. The unit that was planned included the following steps:

1. Introduction: The project was introduced by the teachers and included aims related to the curriculum.

2. The notion of controversies was introduced by a research team member from science and technology studies.
3. The digital mapping tools were introduced by the pedagogical ICT developer.

Following the introduction, students started working according to the following procedure:

4. Surfing and scraping the Internet on a socio-scientific controversy. The web browser extension Navicrawler logged the URLs for all the webpages visited and those linked to on the visited pages
5. Selecting relevant data produced with Navicrawler and importing them to into the network graph visualisation tool Gephi
6. Presenting the data in visual form using Gephi, generating a digital map of 'actors' involved in the controversy
7. Sharing and discussing the map with peers in grade 12 that had done a quick Google search to familiarize themselves with the controversy
8. Participating in a debate, enacting an actor the students had identified through their controversy mapping
9. Taking part in a reflection seminar led by a teacher

Following the pilot, when the main school project was conducted in 2015 using a similar approach, a few changes were made due to constraints in the school setting (the second round of the project also involved changes in the data collection that I will address in the chapter on data production in the school setting, 4.5):

- All the students were in grade 12, student groups shared their maps with peers having worked with different controversies.
- The teacher team included the same teachers except the English teacher who was substituted with a chemistry teacher.
- The controversies worked on in 2015 were electronic waste, HPV vaccine, prenatal diagnosis, and animal testing in research.
- I introduced the controversies and digital tools rather than the pedagogical developer.

## 4.2 Using network visualization tools to explore SSCs

The particular combination of digital visualization tools and accompanying mapping process studied here have been suggested as a way of imparting new

creative directions for research on controversies, as well as being educationally relevant and a new means of assisting public participation in science and technology (Venturini, Ricci, Mauri, Kimbell, & Meunier, 2015). In studying controversies through the use of digital mapping tools in this tradition, researchers are cautioned to resist introducing their own theories concerning the forces at play in a controversy and to suspend judgement on who is right or wrong, in order to be better able to capture the unfolding dynamics of conflict and disagreement (Venturini, 2010a, 2010b).

In order for the upper secondary students to handle the increasingly complex and interconnected nature of SSCs, this new method was introduced. In a complex and multidimensional data environment using network visualization tools has previously been suggested to be a useful and valuable as a tool for communicating relevant information about complex issues to others (Venturini et al., 2015). It draws on computational as well as traditional statistical techniques help students locate useful points in dataset, which are then visualized. The overall idea of mapping controversies in the way used by participants in this dissertation was introduced by Bruno Latour as a didactic exercise in Actor-Network Theory (ANT), but it gradually evolved into a research method (Venturini, 2010b). Through this development, ANT was methodologically and technologically transformed into an experimental form of digital cartography known as controversy mapping (Venturini, 2010; 2012a). By drawing on resources from the social sciences and digital engineering and design, the Latour's Médialab group developed open source software packages that have been distributed and deployed by different user groups to explore and visualize web controversies. For example, in a transdisciplinary EU project named MACOSPOL (Mapping Controversies on Science for Politics)[14] it was proposed that citizens in general could be involved in complex matters of concern by engaging with controversy mapping. However, it has recently been realized that this goal is particularly challenging, and new ways forward for engaging specific publics are being developed (Venturini et al, 2015). In the following, I will describe the tools that were introduced to students in the school project so that they could engage with controversy mapping, the web crawler Navicrawler and the network visualization tool Gephi.

[14] (www.mappingcontroversies.net)

**Web exploration and corpus building**

In the first step of the controversy mapping process, students collected a data corpus consisting of a list of websites and the hyperlinks between them through Navicrawler, an add-on program to the web browser Firefox (Figure 2).

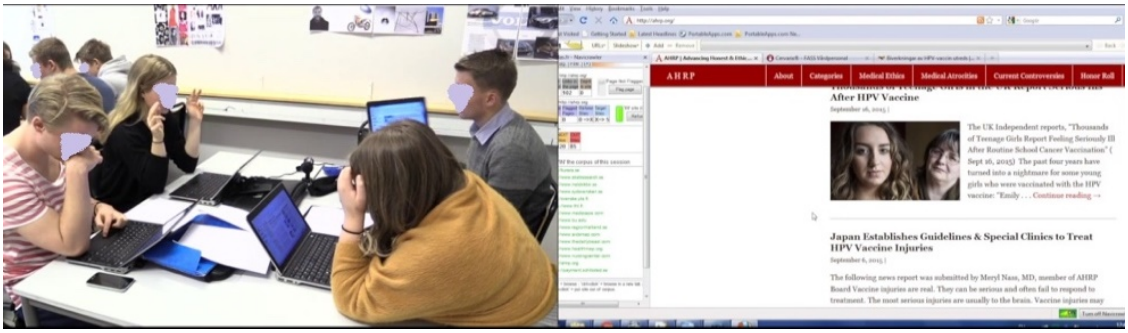


Figure 2

Students are doing web-search by using Explorer with added Navicrawler (left). Screen on one student's computer (captured by the software Screen-O-Matic) showing how Navicrawler is always present when students are visiting websites to the left of the screen (right).

Navicrawler was primarily developed for social sciences researchers as a way to make it easier to gather data for study of the Internet (Jacomy, Girard, Ooghe, & Venturini, 2016). The interface is located on the left of the currently browsed page in the student's webbrowser (figure 3). Students searched and browsed websites while Navicrawler collected the addresses of their visited sites and the sites that were linked to on those visited sites. Students sorted the resulting lists of collected sites by tagging those that they did not consider to be relevant as 'OUT sites' that would be ignored during the remainder of the mapping process. Because of its simplicity while providing the functionalities needed for the controversy mapping process, the software Navicrawler[15] was chosen for collecting corpuses of websites for this project.

[15] At the time of the running of the school project Navicrawler was a free open-source and publicly available. This tool is no longer provided for downloading due to lack of resources to maintaining the program. Developers focus on a new crawler and harvesting tool, Hyphe (personal communication, Mathieu Jacomy).

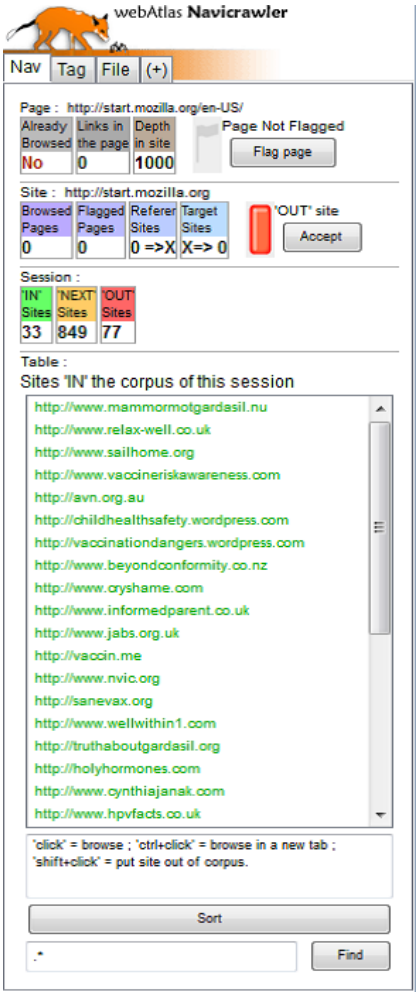


Figure 3 Navicrawler web interface

In green, the 'IN' sites visited are shown, the orange 'NEXT' box shows the sites that the visited sites link to, and the red 'OUT' box shows sites that the user has chosen to exclude from the data corpus. Sites that the students excluded were typically links on pages that were obviously not relevant such as advertisements and links designed to encourage sharing to social networks.

Since Navicrawler automatically and indiscriminately collects the addresses or Uniform Resource Locators (URLs) for all sites linked to from the pages visited pages, the subsequent manual sorting process is of particular importance. Many of the sites linked to from webpages are not in-fact websites, but are instead background elements of the infrastructure of the web such as advertising display systems and content management systems that deliver media like images and videos. For the students' purposes, these infrastructure elements were not relevant and needed to be filtered out to reduce the noise and complexity of their corpus of connected websites. Web sites placed by the students in 'OUT sites' were classified as irrelevant for the mapping process and were thus excluded from their controversy maps.

**Network visualization - manipulation and map interpretation**

Gephi is a network graphing tool that can be used when mapping how different websites relate to each other. The websites appear in the form of networks made up of circular nodes with arrows (edges) between them. The nodes represent the websites that information has been collected from and the arrows show how those websites are connected through the links between them (illustrative example, Figure 4).

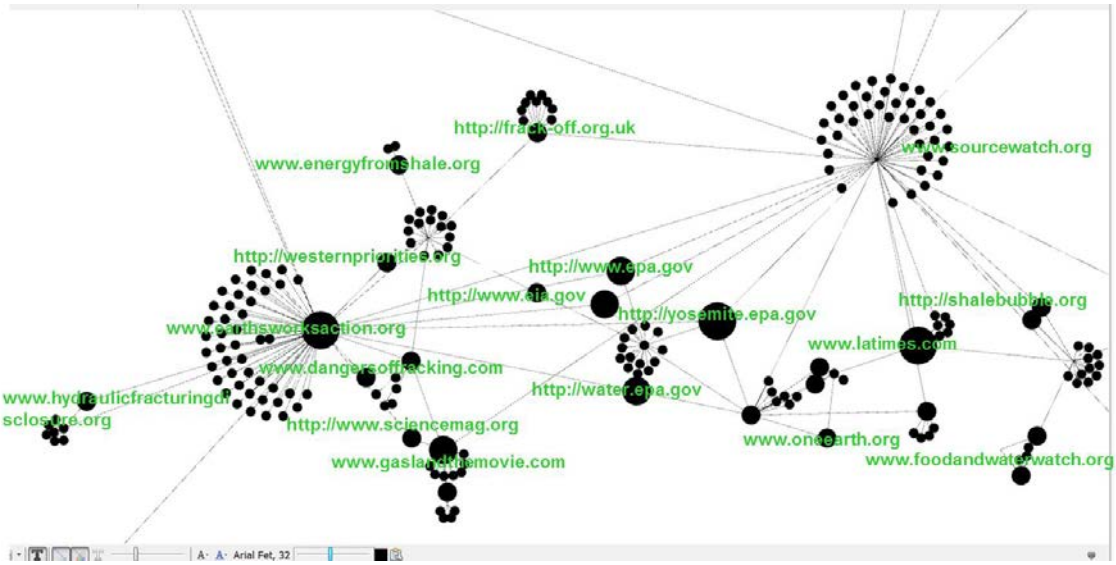


Figure 4 An example of a map showing how websites connected to the issue of fracking are connected when visualized through Gephi

Although the program offered the possibility to intervene in the network by changing the relative ranking of the nodes visualized in a number of different ways such as size and color, for the purpose of this project it was decided by the ICT developer that the most appropriate way to visualize the status of webpages in the network was to emphasize nodes that have many inbound links. Thereby websites that many others linked to, were made more prominent by making them larger in the network. In addition, the program was configured to place websites that connected to each other through many individual links closer to each other on the map, while those that did not, farther apart. This combination of properties provided controversy maps where it is possible to discern which websites are linked to often by others, as well as placing actors with many interconnections in clusters. Clusters of dots on a map are thus an indication of densely interlinked network neighborhoods. For example, websites that share many common neighbors will be

close together on the map, even if they are not directly linked to one another (Jacomy et al., 2011).

The second step in the visualization process consists of labelling websites according to thematic categories that are either pre-defined or identified during the data-collecting process. In the project described in this dissertation, the student's categories were not pre-defined, they were decided upon by the students as they worked to make their maps legible through a process of excluding irrelevant nodes and categorizing relevant ones.

## 4.3 Ethical considerations

The work included in this dissertation complies with the code of conduct for social science research established by the Swedish Research Council in 2017[16]. This means that although my work is regulated by local, national and international rules and regulations, it is my own ethical responsibility that forms the basis for the ethical decision making made. This means that ethical considerations were important not only during data generation but during all stages of research, including the analysis and reporting of findings. The research was an opportunity to be invited to share in participants' interactions and record them with the kind of detail video cameras allow. I have attempted to do justice to the material in relation to my research interest, attending to what the participants were oriented towards and contributing with new knowledge to the research field. In addition, in order to contribute to the field of practice implicated in my work, I had, for example, a meeting with the biotechnology course leader towards the end of that research project where I informed her about the results of my study and we discussed possible choices for developing the course.

All participants recorded as part of the projects in this dissertation gave their written approval to be video recorded. They were all informed about the right to withdraw from participation in the study at any point during the data collection. In the technical university setting, the course leader provided me permission to observe the lectures in the course. Prior to data collection, the professor was informed in writing and in a meeting prior to the video recording that the focus of the research was on how students learn to discuss GMO. The students engaged in the GMO projects were informed about the

[16] https://www.vr.se/analys-och-uppdrag/vi-analyserar-och-utvarderar/alla-publikationer/publikationer/2017-08-29-god-forskningssed.html

research project and that participation in the study was voluntary. They accepted to be video recorded and signed a letter of consent. I was uncertain regarding what kind of material and what part of the course would be most interesting to analyze and so presented the overall aim of project to participants, which was to investigate how students learn to argue on a societal issue in the university science education setting. In the upper secondary school setting, students were informed by the project through a visit to the school and the majority of the students gave their informed consent for participation in the project. The participants agreed to the video recording of lessons as well as to being interviewed by the research team. The students that did not want to be recorded were arranged within the classroom so that they did not appear on camera, but still took part in the instructional unit. These students formed one group, which we were careful not to catch on camera, even in the background. The teachers arranged for alternatives to the press conference so we could collect data from that activity without concern for including non-participating students on video.

To protect the participants' identities, the names of the students and teachers as well as the school and university were not used in the reporting of results or publishing of materials. During transcription of the video recordings, all names were replaced by pseudonyms. Photos of the student groups are published in studies II-IV in order to provide readers with an idea of the setting. For those in the local research community that are familiar with the setting it might be possible to recognize the students, especially in study III where the photo was not blurred in the publication process. Upon sharing this article with the participating teachers, the photo was not considered sensitive for the participants. The students had, for example, not been opposed to being presented in photos on the school website when engaging in school projects and the material presented in the article was not considered to be of a sensitive nature. In addition, collected documents were kept in locked cabinets and video recordings were kept on a encrypted and password protected servers and external hard drives only accessible to project members.

For the LETCOM project, an application for ethical review was prepared by the project leader and sent to the regional board for vetting the ethics of research involving humans. The application included the description of the aims of the project and the design for the collection of classroom data. The response was that the design of the project was of low ethical risk and did not demand further ethical vetting.

## 4.4 The empirical material

Video data offer unique opportunities to document details of ordinary situations as they can provide rich texture of people's situated activity and interaction. Capturing interaction in this manner not only offers documentation of the physical place where students and teachers work, but also makes it possible to revisit the activities and observe them in detail. Working from video data provided opportunities for close observation of how the digital tools and their specific features were brought in as mediational means in student's ongoing activities. Moreover, video data made it possible to revisit the material many times, thereby gradually creating a more detailed description of activities in which the participants were engaged. Approaching dialogue also requires the possibility to follow interaction in detail through participants' talk as well as through their physical actions such as pointing, gazing and gesturing (Heath, Hindmarsh, & Luff, 2010). Overall, analyzing how the participants' concerns and their reasoning develop through communicative projects was facilitated by rich data from the site of the kind that can be provided by video material.

One important consideration for research of the kind conducted in this dissertation is whether or not observations are based on reliable data. Recording educational situations in situ raises the issue of how cameras and researchers might affect participant conduct and interaction and it has been suggested that this is an empirical question (Heath, Hindmarsh, & Luff, 2010). In my material, there are a few occasions where the participants clearly noticed the camera and the recording procedure. For example, in the group work sessions in the upper secondary school setting, the students looked into the camera and made grimaces. One general observation was that the tasks at hand generally took participants attention away from the recording process. While other video-based studies (Eriksson, 2014; Lindwall, 2008) have noticed similar behavior, I would also like to raise the issue of how introducing researchers and cameras to an empirical site can affect the participants and the situation and thereby research results. It can be assumed, for example, that the teacher and students wanted to contribute to the research project and made great efforts during the observed lessons. My observation in this project was that students spent very little time off task, which the presence of researchers and cameras probably contributed to. If this was the case, it worked as a sort of monitor of their progress.

## 4.5 Data production: recording and collecting artefacts

Video enables capturing versions of the action, activity and interaction that arise within education so they can be subjected to analytic scrutiny (Heath et al., 2010). In many ways, this makes video the obvious choice for pursuing my research interest. This includes aspects of real-time social activities such as people's talk, their bodily conduct, their use of tools and technologies, and the simultaneous capture of onscreen activity. These types of data are largely unavailable through written field observations and audio data, and unlike these other forms of qualitative data, video also allowed me to show and share the material on which descriptions and analyses of activities are based. For example, parts of the empirical material have been shown and discussed at different seminars and meetings, during which colleagues have contributed with analytical input to my work and also judged the persuasiveness of the analysis[17].

While the methodological literature points to the merits of using video in the research process, it also suggests that the visual mode is often underused and that many analyses could be performed using audio only (Silverman, 2005). In my studies, I used video data in different ways. The audio component provided me with what people say while the visual component with what people do, and together these components provided me with the timings for when people say and do things. Study IV is the study that draws most extensively on the possibilities offered by video data. Analytic attention was drawn to the students' orientation to the computer screens displaying the visualization networks they created and the amount of detail presented in the resulting analysis would not be possible with any other method. In order to see how students synchronized verbal utterances, gestures, gaze and orientation to the screen required replaying the video repeatedly. By contrast, the question I ask in study II regarding the discursive function of 'appeals to science' could possibly have been answered through audio recordings and detailed field notes of the material conditions for how participants were

[17]Parts of the video recordings have been shown and discussed at the Hasselblad research school for molecular didactics, Sociocultural and Dialogical Studies seminar, the University of Gothenburg LETStudio group, LETCOM research group and FORCCAST summer school on mapping controversy, Sciences Po.

seated, but even here it was through repeated viewings that previously hidden phenomena became apparent (Jordan & Henderson, 1995).

Throughout the project I have come back to the video recordings for investigating the seen but unnoticed details of the practices investigated. The possibilities for investigating details of interaction and gradually finding analytically interesting aspects of the students' SSC discourse have thus been enabling conditions for the analyses made themselves, rather than something that increases the trustworthiness of them (Lindwall, 2008).

**University setting**

In order to capture participants' interaction and taking into account the practical constraints of the situation in technical university setting, one camera was mounted on a tripod and positioned to capture the participants physical orientation to each other and the tools they were using and material oriented to. In the lectures on GMO, I had mounted an extra microphone on the camera to improve audio quality and the camera was directed towards the professor and the Power Point presentation he used for his lecture. In the supervision sessions that took place in small seminar rooms the participants usually sat around a table. Working in small rooms meant that the camera was more physically present in those sessions than it might be in lectures or group discussions. For each session, I started recording before the session formally began and sat in the room observing the meeting. I decided not to manipulate the camera during recording and maintained the same angle and focus throughout the supervision, largely due to the decision that if I decided to zoom in on something, I would potentially lose out on something else. Given this, I decided to try to capture as much as possible from one static view, but since the participants were seated around tables I didn't have full access to all their facial expressions. Following the recorded sessions, I roughly transcribed all the collected video material. The university students' final reports were collected at the end of the projects.

**School setting**

In the first data collection in the upper secondary school setting, we followed two student groups. When the groups worked to seek information online using the digital mapping tools, we had one camera set up to capture the group interaction and one camera to capture the activity on one of the student's computer screens (Figure 5).

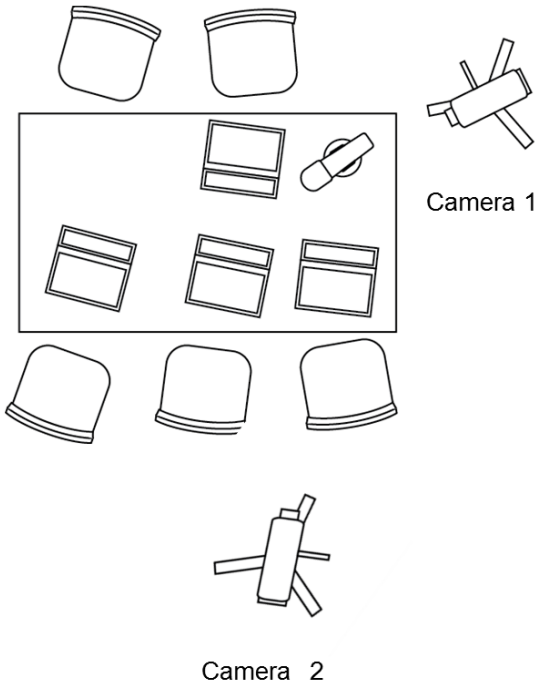


Figure 5 Four students working on their computers, one camera is filming the interaction (camera 1), one camera capturing the activity on one screen (camera 2)

We were two to three members in the data collecting team and it was possible to occasionally adjust the camera position, especially the camera following the screen needed adjustment since it was taken from behind the student working on that computer. Nevertheless, it was not possible to ensure a clear view of the screen at all times. The adjusting of the cameras to ensure a clear view had to be balanced with the intrusiveness of having a moving camera behind the participants. To overcome the issue of video recording the screen, for the second round of data collection we decided to install screen capture software in order to directly capture the activity on one screen.

All recordings were digitally processes and recompressed to reduce file sizes a few days after recording. This work required particular software expertise and was carried out by colleagues in a video research lab that is part of our research group. After the processing, each original recording media was labelled and stored in a fireproof room. The processed digital files were transferred to separate hardware encrypted external disks. From those disks, the two student group activities were documented in data logs by a research assistant in the project in order to produce a first thematic overview of the sequential activities undertaken within each school project session. I then

roughly transcribed material of particular interest producing rough separate digital files and paper copies. The students' reports, called PMs in the school project, including the final version of their controversy map were also collected.

## 4.6 Transcription

When transcribing and presenting video recordings there are various alternatives and many choices that have to be made. It is not possible or desirable to represent everything that happens in an activity, consequently there is always a selection of what to include and what to omit in the transcriptions. Interactions are full of details and nuances which implies that transcriptions differ depending on their theoretical basis and the transcripts created for this dissertation reflect the specific analytical interests I had in the different studies (eg. Linell 1998). In addition to my transcription work, data logs of the activities recorded by video where provided to the project in the upper secondary school setting pilot by a colleague who took ethnographic notes while recordings were made. Added to this, in the second phase of the upper secondary scholl setting project a master's student who wrote her thesis within the project went through the material and made notes on what happened in the material.

My transcription work can be described as an iterative process where more details were gradually transcribed from the video recordings as episodes of interest were identified. In the technical university setting study, I conducted verbatim transcription of classroom activities of interest which meant the lecture on GMO, all the subsequent supervision sessions with the professor, and the presentation of the project to peers. In the upper secondary school setting project, I conducted verbatim transcription of the classroom activities of particularly relevance including the presentation to peers, the debates, and the seminars. In addition, for the specific interest in study IV, I transcribed the activity where students worked with the network visualization tools. For this, I transcribed the data on my own, but discussed the transcripts and videos within several seminars and workshops that were designed for such analytical purposes. Throughout the work with this dissertation, these kinds of working research seminars have functioned to scrutinize my interpretations.

## 4.7 Selecting and representing episodes

The selection of episodes of interactional activity responds to the particular aims and questions of each study. Silverman (2005) underlines the importance of not trying to provide the 'full picture', but beginning from a theoretical perspective and choosing methods in light of the research interests underpinning a particular study. Following this, I have selected episodes in order to describe a process clarifying and relevant to the interest formulated in terms of what the participants do. An overview of the empirical material and activities studied in this dissertation is presented in section 4.8.

In study I, episodes presented and analyzed were selected for their relevance for the topic of interest, namely the characterization of the opposition to GMO food. Claims made throughout the course (in students reports, in the professors lectures, and in supervision) were included along with excerpts when opponents of GMOs where talked about, as well as referrals to reports and rebuttals of opponents arguments and discussion of sources.

In study II, the interest was students' use of the discursive resource 'appeal to science' when reasoning. Here, I was intrigued by how often students referred to cancerous rats (20 episodes) during the material and therefore focused on empirical instances where students referred to this subject. I selected four excerpts from three different instances in order to provide examples of how students' made uses of roughly the same message encountered online, that GMO causes cancer in rats, were designed to fit the particular circumstances of different activities commonly arranged for educational purposes in school. In this case, deliberative peer discussion, press conference/debate, and seminar.

In study III, the aim was to contribute with the implementation of an analytical approach that provides means for understanding how students engage in dialogue where multiple perspectives and modalities are salient and how they handle the discursive complexities this entails. The step in the student project process named 'Sharing and discussing the map with peers' was selected for the study. Then, empirical instances where students discursively handled multiple perspectives on a controversy were selected.

Finally in Study IV, students' collaborative exploration was investigated together with how the ordering of the complexity of a controversy is co-constitutive of the digital mapping tools in use. Given this interest which

involved the students' use of a network visualization tool for exploring and analyzing a controversy, the, 'Re-presenting the data in visual form using Gephi' session of the students' project work was selected as the analytical focus. During this session, the students worked to make a legible controversy map through categorization of their corpus of websites and the data recorded consisted of synced video recordings of a computer screen and student activity. In order to provide a sense of continuity and to follow the developments of a controversy map, episodes were chosen from a single student group. The particular group selected worked with the HPV vaccine controversy and were selected because their map was significantly more elaborated than the maps of other groups. Since the interest was in how the students made the complexity of the map legible, a simpler map would have implied less collaborative activity and thus less interaction of interest among students and the tools.

## 4.8 Data overview

An overview of the collection of video data used for the studies is provided below (Table 1).

Table 1 Overview of the empirical material

| | **Study 1** | **Study II** | **Study III** | **Study IV** |
|---|---|---|---|---|
| Empirical material | **Video:** Professor's lectures and supervision sessions.<br><br>**Students reports** | **Video:** Students Invoking of recirculated science claims in various project activities such as peer discussion, debate, seminar | **Video:** Students discussion with peers when sharing a controversy map they had collaboratively constructed | **Video:** Students interaction and screen-captures (synced) when producing a map using a digital tool to visualize networks<br>**Students reports** (PM) including the **controversy map** |
| **SSC** | **GMO** | **GMO** | **Fracking** | **HPV Vaccine** |

## 4.9 Participating as observer, part of the intervention and researcher

In study I, I observed and did not participate in developing the examined course. I simply followed a course that had already been running in a similar way previously. By contrast, in Study II, III and IV, I was involved in planning, introducing, and even supporting students. This was especially the case in the second upper secondary school setting data collection in 2015 when I introduced the digital tools as well as provided support as required during the school project work. The fact that I was involved to a great extent in these studies did not influence the kind of research questions asked, but I avoided including episodes in analysis if I was part of the interactions. Such interactions were not prevalent since I tried to avoid walking around and aimed at staying in the background unless I was called upon. In terms of my personal stance, I believe that introducing tools that aim to explore SSCs by finding actors, their claims and interests without privileging certain actors hold promises for school. However, I am aware that introducing certain methods does not necessarily result in positive results and that rather it is important to hold oneself as a researcher to describing and analyzing the actual practices one observes. When studying how tools are put to use in a school context, we need to take into account that students pay attention to, describe and act in response to what the school context allows and encourages (Säljö, 2010). When students engage with tools, it becomes relevant to analyze how they orient towards the task they have been given, and what they need to accomplish in the specific setting.

## 4.10 Focus on the everyday practices of science education

The purpose of this dissertation is to provide insights into how students' discursive work with socio-scientific controversies (SSCs) unfolds in science educational settings, by use of sociocultural and dialogical theories of learning and communication. This type of analysis provides me with ways of conceptualizing students work with SSCs in terms of interaction, discursive action and activity and to offer accounts of what is going on in the classroom. With this as point of departure, the aim is to contribute a qualified discussion about the role the introduction of socio-scientific issues in classrooms can

play in an online media society, the value of this type of education, and what students might learn within the kinds of educational institutions studied. The research object of most interest to me is students' communication and how they make meaning, formulate, discuss, and come to conclusions in conversation and in writing about the complex SSC topic of the project they are involved in. My approach provides accounts that focus attention on the actual practices of a social group, regardless of whether these accounts conform to established rules or norms of behavior, showing as many studies of this type do how norms in practice are more complex than a purported ideal (Kelly, 2008). In particular, the ideal of most relevance to discuss in relation to this dissertation is when socio-scientific controversies are understood to necessarily lead to rational, science informed decision making.

## 4.11 Reflections on research credibility

The terms reliability and validity are often closely associated with quantitative studies through such techniques as test-retest correlations or interrater-reliability (Kirk & Miller, 1986). Validity is often treated as being established by a congruence between different instruments, or perhaps a triangulation from different research methods. Because of the different theoretical assumptions in the discourse and interaction analysis work presented here, along with its largely non-quantitative nature, these approaches to reliability and validity are not applicable. Nevertheless, I would like to address questions regarding the reliability and validity of this work since the reliability of a qualitative study can be demonstrated thorough documentation of research procedures (Kirk & Miller, 1986). I have attended to this task in earlier in this chapter, but will discuss validity and reliability in relation to the different methods conducted more explicitly here.

Discourse analysis remains a matter of interpretation. The question of reliability in discourse analysis concerns whether different researchers would interpret the text in similar ways. There is no guarantee that such reliability is possible, given that researchers are likely to differ in their motivational factors, expectations, familiarity with the situation etc. Although the discourse analysis conducted in this dissertation has been discussed with a number of other researchers within the education research community, it has to be accepted that the interpretations of the data could still be interpreted differently by other researchers. Gee (2005) suggests that the base for the validity of

discourse analysis on four elements: convergence, agreement, coverage and linguistic details. The more the analysis offers compatible and convincing answers to the questions about building tasks such as significance, activities, identities, politics, connections, and sign systems, the greater the validity. Agreement with other researchers is what some researchers call reliability and is addressed above. An important and distinctive feature in the validation of discourse work is the presentation of materials in a way that allows readers of discourse studies to evaluate their adequacy. This allows the readers to assess the particular interpretation that is made side by side with the original materials. This is not the case in much ethnographic work where the interpretations have to be taken largely on trust; nor is it the case with much traditional experimental and content analytic work where 'raw' data is rarely included.

Of particular relevance to the goals of this dissertation, qualitative methods have distinct advantages for identifying the influence of contextual factors that can't be statistically or experimentally controlled, for understanding the unique processes at work in specific situations, and for elucidating the role of participants' beliefs and values in shaping outcomes (Maxwell, 2004). It has the potential to highlight the importance of the context of the phenomena studied, and to do so in a way that does not simply reduce this context to a set of 'extraneous variables'. It relies fundamentally on an understanding of the processes by which an event or situation occurs, rather than simply a comparison of situations involving the presence and absence of the presumed cause. Finally, it legitimates a concern with understanding particular situations and events, rather than addressing only general patterns. Insight into how students reasoning is contingent on contextual features and is realized in practice is only available through empirical analyses of the situated practice. However, this raises the question considering that studies taking a sociocultural and dialogic approach to understanding students reasoning processes are locally situated, is it then possible to make general claims based on analyses of interactions taking place within a particular setting? My findings are context specific and not generalizable as such, but the findings are also contextualized to such a degree that they are recognizable and thus transferable to other contexts with similar contextual features. Over time, empirical studies from similar educational settings generate robustness and nuances in analytic generalizations that cannot be made from one study

alone. This means that over time, we become more and more sensitive to students' SSC reasoning in various settings and topics.

# 5 Summary of the studies

This chapter summarizes each study focusing on the main findings and arguments. The four articles reporting the empirical studies can be found in Part 2 of this dissertation. The analyses in the four studies have been carried out with the overarching aim to explore how students in interaction and within the institutional contexts in which they learn and act, handle SSCs. This implies investigating students reasoning as it is embedded in activity, mediated by the cultural tools available, and shaped by the framings, demands, and traditions constituted through practice. The studies are reported in accordance with the particular aims and questions posed in each and the overarching research questions of the dissertation structure a discussion of the combined contributions of each study in the discussion chapter that follows.

## Study I: Learning to argue as a biotechnologist: disprivileging opposition to genetically modified food

This study examined how the opposition to Genetically Modified (GM) food was characterized when the controversy over GM food was addressed in a university introductory biotechnology course. Through discourse analysis guided by an ethnographic perspective (Gee & Green, 1998), what a group of biotechnology students needed to interpret and produce to participate appropriately and, through that participation learn was identified. The purpose was to examine how students and a professor justify and evaluate knowledge claims about GM food as manifested in discourse in a biotechnology course. Specifically, the study focused on two questions: (1) How do the participants characterize the opposition to GM food? and (2) How do the participants evaluate arguments opposing using and producing GM food?

Two lectures and the supervision meetings of two groups of students that worked with the issue of GM food were video-recorded. The video recordings made it possible to examine the participants discourse in detail and to analyze how opposition to genetically modified organisms (GMO) was characterized and opposing arguments were evaluated. The results show how students came

to understand how to articulate an appropriate argument in a technoscientific community exhibiting features of biotechnological discourse, a community specific use of language that legitimates the epistemic and moral authority of science and marginalizes opponents. The claims the students made at the end of the course are understood as active responsive understandings of what happened before the report in the lectures and supervision meetings. The claims regarding opposition to GMO in the students' final reports are understood as expressions of an expanded repertoire for responding and participating appropriately within this particular social setting. Both student groups claimed that negativity towards GMO reflects a lack of knowledge. In this way, how students begin to acquire 'the right way' of approaching the controversial issue of producing and consuming GMO is demonstrated. In this particular educational practice, 'the right way' entailed the dis-privileging of opposing arguments including:

- Framing opponents as ignorant and laughable. Opponents, referred to as 'the man on the street' and 'these folks' are suggested to be ignorant of GMO issues. Also, the ways opponents' enacted opposition are treated as laughable.
- Ignoring opposition from scholars in other fields of research. Possibly well-grounded opposition to GMO from fields of research such as nutrition, ecology, and economics are not referred to.
- Casting suspicion on the motives behind the actions of opponents. During supervision, for example, opponents are positioned as being 'very skillful' at 'propaganda'. Also, in the introductory lecture, the professor indicates the possibility that the opposition has ulterior motives by suggesting that 'one might wonder whether there are other motives behind it'.
- Emphasizing biotechnological research and researchers as truth-seeking and objective. Scientific literature is described as carefully reviewed by the scientific community and thereby established as trustworthy in contrast to the 'propaganda' produced by opponents.

These findings illustrate how an asymmetry between claims is created in this biotechnology setting, putting belief (irrationality) against scientific knowledge (rationality). The arguments made relevant underpin an explanatory theory distributed among people in a social group, in this case biotechnologists. In the article that reports the study, this theory was termed a discourse model, that opposition to GMO is irrational and the students are offered an identity

as rational decision makers. The biotechnology students learned to take sides in societal conflicts that extend beyond the university. It may be questioned whether students expressed what they really thought or whether they only expressed what they thought the teacher expected. However, for the approach taken here this is not an issue since understanding talk is always understood as situated action, employed to get things done. The investigation revealed ways of stating and supporting claims accepted in this classroom community rather than reporting on beliefs held by individuals.

In the reported study, the professor engaged in convincing students to be critical of opposition to GM food, characterized as being represented by an 'unknowledgeable public' informed by 'committed' environmentalists. Being a researcher in plant molecular biology, the professor was seen to be striving to make his claims more credible than those that are opposed to GMO, and can be seen to be part of doing science. This is not surprising given that part of the work of science is defining, negotiating, selling, and spreading the results to the outside world (Latour, 1987). From this perspective, it is necessary to enroll interested groups and students can be conceived as future members of the technoscientific community by actually doing plant biotechnology research may be more likely to help 'sell' the particular techno-science to a wider audience. This is different than a discussion in a school setting where the teacher is not part of the techno-scientific community and is not part of the conflict in the same way since their work is not directly challenged by opposition. However, given that science teachers at least partly have been trained by scientists, more research is required to understand whether or not and if so how privileging of science in SSC discussions begins earlier than the university level.

## Study II: Appeals to science: recirculation of online claims in socio-scientific reasoning

With this paper, I aim to contribute to our understanding of socio-scientific reasoning as sociocultural activity and suggest ways of developing opportunities to critically engage with knowledge claims online. This study examines how, having acquainted themselves with Genetically Modified Organisms (GMO) online, upper secondary school students recirculate the widespread online message that GMO causes cancer in rats in various project activities. The data in this study was collected in a grade 11 class of upper

secondary school science students working with controversy mapping. The project was divided into steps commencing with the work of producing a controversy map. In the next step, the groups presented and discussed their maps with older peers. Then, the students were asked to assume the position of actors in the controversy at a classroom 'press conference'. Finally, the students joined a seminar to reflect on the process and qualify their positions.

For the purpose of this study, a dataset consisting of verbatim transcripts of video recordings of three classroom activities was used: a deliberative discussion, a press conference/debate and a seminar. As part of the research project, the teachers and researchers had created an environment that encouraged students, through digital inquiry and digital mapping tools, to seek and select information, handle the complexities of controversial issues, generate questions, persuade others of their understanding, and engage extensively in collaborative discourse. When SSCs are introduced in the classroom students must figure out what is considered relevant to pay attention to in the various activities they engage. The ways the tasks are initiated, the resources available and how the school work will be assessed influence how the students engage with the tasks (Åberg et al, 2010). The interest in this study was the students' appeals to science when reasoning. In early analysis, how often students referred to cancerous rats was noted (20 episodes). This was therefore focused upon in the selection of empirical instances. The questions that guided the investigation were:

1. How do students invoke recirculated online claims from a scientific paper in conversations regarding GMOs?
2. How are such invocations effective for students when engaging accountably in various project activities?

The key analytic concept used for understanding student reasoning in this study was communicative activity types (CATs) (Linell, 2010; Marková et al., 2007). CATs provide a link between the situated micro-processes and the societal macro structure of discourses, between focusing on the detailed specifics in a dialogic exchange and focusing on the communication as a particular type of social situation (Linell, 2010). By using the notion of CATs, the meaning and function of appeals to science were analyzed in different learning arrangements of the school project on SSC such as 1) a staged debate where students enacted various actors, 2) a reflective seminar, and 3) a deliberative conversation with peers. In the analysis, I foreground instances of how student use of roughly the same message, that GMO causes cancer in

rats, is designed to fit the particular circumstances of different activities commonly arranged for educational purposes in school. The scientific claim is treated differently depending on the discursive function it is supposed to play when used for different purposes. It gains it's meaning and rhetorical power as a discursive resource as intrinsic to different CATs.

The sociocultural approach taken to studying students' reasoning in different types of conversations attends to how empirical dimensions such as the purposes, tasks and discourse types that are particular to a type of activity are relevant for understanding student claims. That the same message has different discursive functions in the three activities examined shows how the meaning and activity co-constitute the claim and therefore the argument students are able to make in the particular context. Hence, disciplinary norms of valid argumentation are made manifest in communication in the science classroom and what students say cannot be seen as what they believe irrespective of contexts, but rather as a way of participating and contributing accountably. This study reveals how the different framings of the three CATs, debate, seminar, and deliberative discussion, invoked different students uses of appeals to science for different purposes and show how the kinds of communicative skills trained are dependent on the kinds of activities engaged with:

When the students were arguing for a position in a debate, they were seen to use quantification (eg. 50% of the rats died prematurely), and also made use of what can be termed an externalizing device that is as a characteristic feature of the empiricist repertoire where agency is attributed to experimental data. Students were also seen to use other general features of making convincing fact descriptions including specificity. Taking on the position of a representative of an interest group, the students balanced the need to create public concern with the need to retain scientific credibility by being well informed.

When the students where qualifying a position in the seminar they invoked what seemed to be an indisputable fact, 'those rats have cancer', as a cautionary tale. They referred to consequences in the distant future, thereby maximizing uncertainty and their strengthening their assertion that more science and research is called for.

In the deliberations, students had opportunities to report others' claims and they critically reported how actors that are opposed to GMOs use appeals to science rhetorically to scare people from consuming such foods.

These results point to the importance of providing students with possibilities to engage in various types of conversations since they cultivate different kinds of communicative competences that can be considered relevant for citizenship.

In the science classroom, the authority of science is also an important legitimizing factor (Sykes, 2016). Depending on how students decided to talk about issues such as GMO, the points they want to make can be used differently when drawing on a scientifically-derived message, or what can be referred to as 'appeals to science' (Goodwin & Honeycutt, 2009; Nowotny, 1981; Sykes, 2016). The examples of 'appeals to science' analyzed in this study reveal how appealing to science can be effective for students when engaging accountably in the various activities studied. The examples illustrate the persuasive power of the 'appeal to science', enlisting scientific objectivity to underpin the credibility of socio-scientific arguments. In this sense, discussions of socio-scientific controversies (SSCs) provide rich opportunities to privilege scientific sources, since there are so many other arguments from other disciplines that are not attended to in the science curriculum and thus not made relevant in the classroom. From this perspective, to what extent the introduction of socio-scientific issues into science classrooms necessarily develops competences such as *addressing* and *weighing knowledge claims from different fields* and discourses can be questioned. In this regard, the present study brings to the fore that scientific evidence provided may not really be questioned, but may more often be established as indisputable fact. However, when working with online material, particularly when handling scientific claims presented as part of an ahistorical flow, it shows that there is an opportunity to develop not only digital but also scientific literacy.

## Study III: Navigating the complexity of socio-scientific controversies—how students make multiple voices present in discourse

This article shows how students' classroom discourse on SSCs can be fruitfully analyzed by using dialogical theories of language and communication (Bakhtin, 1986; Linell, 2009). It argues for the relevance of analyzing how an individual is in dialogue with present as well as remote interlocutors and contexts on the Internet. The analytical approach is suggested to be particularly sensitive to illuminating how students' handle multiple perspectives given that a dialogical perspective takes as its premise that SSCs are part of society, where politicians, interest groups, and scientists engage in debates and offer perspectives that are often in conflict. In this way, a dialogical approach dictates an analysis that incorporates several perspectives and voices, recognizing the multivocality that also resides with the individual.

In the upper secondary school setting, the students were introduced to digital mapping tools that were developed in order to tackle problems associated with the increasingly complex and interconnected nature of SSCs online (Venturini, 2010b, 2010a; Venturini & Latour, 2010). The maps provide the meditational means for the students to discover and display the many actors and perspectives involved in an SSC in a condensed and readable form. Having followed and video documented all the steps in the student project which involved searching and collecting data online, creating maps, engaging in debates, and conducting seminars, we selected the process involving sharing and discussing of the map with peers from the 12th grade for this study. As part of these discussions, students were asked to provide accounts of their respective controversies using the maps they had recently generated for the 12th grade students who had browsed the web using only search engines to orientate themselves and prepare questions. Relevant empirical instances where students discursively handled multiple perspectives on a controversy were subsequently selected. This activity was seen to form a dialogic space (Wegerif, 2007), a situation where two or more perspectives are held together in tension. The interactions were thus identified as opening up dialogical spaces for the students where the complexity of the controversies was discursively managed.

For this study, student groups discussing hydraulic fracturing were focused upon. The discussion of these groups included the bringing in of stakeholders

or voices, with what was stated or claimed, and how these voices within utterances were handled (the speaker's stance) was analysed in relation to what the in situ response was. This detailed analysis was guided by orienting to the notion of voice as single- or multi-voiced, generalized voice, or reported speech (double-voiced) (Linell, 1998a; Myers, 1999; Vološinov, 1973). In particular, the analytical notion of reformulation (Grossen, 2010) was used to analyze how students made use of reported speech. This approach was employed in order to understand how students navigate the discursive complexity of fracking as a socio-scientific controversy through dialogue and how they make multiple voices present in their discourse. In this way, the analysis reveals how the students orient to, account for, and handle multiple perspectives in interaction with each other.

This approach helped to identify the communicative and discursive competences required when examining issues from multiple perspectives. The activity reported on was seen as an established space of reflection that made it possible for students to submit themselves to the tension of conflicting viewpoints. Together the students were engaged in four emerging communicative projects (Linell 1998) that identified important stakeholders, brought out tensions between perspectives, justified claims with evidence, and challenged claims. Reported speech may be seen as conversational resources that speakers can make relevant for invoking voices in controversial issues, and the analysis here shows how reported speech enabled students to engage with SSCs in the classroom. In doing so, the analysis focuses on how reported speech worked as a way of (1) referring to relevant sources and making evaluations, (2) distancing oneself from the stakes involved, and (3) providing evidence. Examples were shown of how students co-authored utterances and made use of ideas, opinions, and perspectives attributed to other people to bring in multiple perspectives and the complexity of the issue. Reported speech also makes relevant assessment from the reporting speaker and the connection between reported speech and its assessment was accomplished in various ways. It supported the students' own views or functioned as counter-positions that the speakers wished to resist or argue against. In the course of these actions, competences that require training in a dialogical context can be developed, competences that are considered important for scientific literacy and reflective judgment (Sadler, 2009; Zeidler et al., 2009)

The students' discussion reflected the relevance of questions about evidence, objectivity, and neutrality when knowledge is put to use in SSC

reasoning. The science of relevance to current SSCs and decision-making is often science-in-the-making, characterized by a lack of consensus on whether the evidence is conclusive. This study reports on how the controversy map offered an understanding of the conflict that was beyond questions of evidence and neutrality. For example, one of the students who made a map claimed that it is not possible to arrive at a correct decision by merely examining data and evidence provided by the different sides in a conflict, but that instead, one way to make sense of a conflict is to make a controversy map where multiple perspectives are represented.

The methodological argument presented in this study was that consideration of voices when students are engaged in communicative projects can offer a nuanced understanding of how students are in dialogue with and engage in managing multiple discourses on SSCs. Rather than analyzing individual retrospective accounts as student beliefs about these issues, the dialogical approach invites an analysis of students' discursive management of multiple perspectives, a multi-vocality which is not only recognizable in ongoing public debates, but also part of our internal dialogue when confronted by controversial issues in our everyday lives.

## Study IV: Rendering controversial socio-scientific issues legible through digital mapping tools

In this study, ways digital mapping tools, developed within Science and Technology Studies (STS) to analyze controversial issues through visualizing networks of websites, were used by upper secondary science students for the collaborative exploration and ordering of controversial socio-scientific issues were examined. Through detailed interactional analysis, the study explores how students orient to and formulat points they find relevant in relation to visual means provided by the map, i.e how the map mediates students' activity. Through the selected episodes of interaction, how students used and responded to the various mediating features of the tool were examined in detail to understand what it provided in terms of support, restriction and guidance for action. The following research question guided the analysis: How do digital mapping tools developed for exploring and visualizing controversial issues in the STS field together with the local context mediate students' selection, analysis and critical review of online material?

Student activity was studied by taking into account the interrelationships between students and mediational means such as mapping tools with a focus on both talk-in-interaction and engagement with objects and artefacts. With this approach, the unit of analysis becomes tool-mediated activity (Säljö, 1999). That is, the ways participants engage in activities with and in relation to the technologies and other artefacts present in a situation. This implies an analytical stance that provides a way of accounting for how students' action is socioculturally embedded and contingent on social, institutional and material conditions (Wertsch, 1998).

In the episodes examined in this study, the students accessed, explored, analyzed and evaluated different kinds of content in a variety of forms encountered on the Internet. This is in accordance with the curricula goals communicated to the students such as development of an ability to assess different types of information sources while being able to distinguish between scientific and non-scientific claims. The students worked in five groups (4-6 persons) on a targeted controversy – electronic waste, HPV vaccine, prenatal diagnosis or animal testing in research. The project was divided into steps commencing with the work of producing a controversy map. This activity also encompassed the writing of a group memo describing the mapmaking process and the actors identified for inclusion. In the next step, the groups compared and discussed their maps together with peer groups. Then, the students were asked to assume the position of actors at a classroom 'press conference'. Finally, the students joined a seminar to reflect on the process and qualify their position on the controversy.

The project activities of two student groups were documented using video to record all the students in each group. In addition, recordings of students' laptop screens (one for each recorded group) through screen-capture software were collected. The various recordings were then synchronized enabling us to analyze interactional features. Given the interest in student use of the network visualization tool for exploring and analyzing a controversy, for this study a session of the students' work to 'Re-present the data in visual form using Gephi' was selected as the analytical focus. The process in which the students worked to make the map legible through categorization of the websites and coloring of the corresponding nodes accordingly was analyzed (90 minutes of synced video recordings). In order to provide a sense of continuity and to follow the developments of one controversy map, it was decided to use excerpts from one group. The group working with the vaccine controversy

was selected since the map was significantly more elaborated than the map of the other potential group.

An account was presented of how a group of students described the Human Papilloma virus (HPV) vaccine controversy in terms of three emergent category schemes that summarized actors as institutions, as being positioned as opposing the vaccine, and as trustworthy or not. The analysis showed how the production of a legible controversy map was a complex interplay between students, digital tools, other artefacts, and school setting. Students used and responded to the various mediating features of the mapping tool, in interplay with other mediational means in the local context. In particular, the analysis shows how one particular affordance with the tool slows down the process of examining, analyzing and categorizing online material providing time for engagement and discussion. Furthermore, alignments and misalignments between the tool and the students' logics were found to prompt students to engage in negotiation of how to make sense of the controversy as well as of the maps themselves. Finally, the analysis showed how the tool challenged and is challenged by the science curriculum.

An interesting contribution from the use of these digital mapping tools and an illustrative example of how the tools can challenge schooling, or the goals of the school subject science, was exemplified in this study. The Swedish curriculum states that students are to separate scientific from non-scientific claims. However, the data in this study shows how students struggle to understand claims made by actors that are opposed to the vaccine, and not to simply dismiss them as 'made up' when evaluating them in terms of trustworthiness. By contrast, the mapping method allowed for the presence of what can be termed 'disagreeing minorities'. A student, not engaging with the tool on their computer, can be seen to work according to what can be described as a demarcationist approach, using the mapping to adjudicate between sources. This reflects how making credibility judgments and coming to a shared understanding of what constitutes credibility has become an important aspect of engaging with social media and the Internet more generally in classrooms (Forte, 2015). However, the STS scholars that developed the tools used in this study primarily aim to facilitate the exploration of a controversy. They work according to the principle that cartographers would respect the actors they observe and thus not neglect actors' ideas just because they are not based on scientific theory or methodology (Venturini, 2010c). Controversy analysis does not seek to

establish the legitimacy of knowledge disputes, but instead uses tools for exploratory purposes; namely to detect relations between substantive arguments and socially and politically located actors and to render such relations available for interpretation. Thus there is a tension between these two different approaches one can take to understanding controversies, with both sides seen in the studied classroom.

This study reported on an attempt to introduce digital mapping tools developed for university courses in STS to science in upper secondary school. There is little doubt that the upper secondary students did not make as rich maps as STS university students who are taught by scholars dedicated to this area might. However, the students whose activity was chosen for analysis in this study made a rather complex map that was thoroughly worked on. The students had to handle a very complex task when working with one map where they needed to determine 1) who the actors were 2) what their arguments were 3) how they were connected to other actors in the controversy, and 4) when things were written etc. This study offered an initial exploration of the possibilities for supporting educational activities with these tools, but continued examination of the different ways teachers might take up these digital mapping tools would be an important area for further investigation.

.

# 6 Discussion

Several themes have been addressed in this dissertation, in the following I will discuss the most interesting contributions of the research. I will recapitulate the findings in relation to the overarching aim of the thesis and discuss them in relation to the literature reviewed. The overarching aim has been to explore how students, in interaction and within the institutional contexts in which they learn and act, mediated by cultural tools, handle complex issues. I have drawn on both a dialogic and a sociocultural framework in order to be provided with ways of understanding and formulating students work with SSCs that are involved in science education settings. In discussing the findings of the four empirical studies, three overarching research questions in part govern the disposition of this chapter:

1. How is student reasoning contingent on institutional, social and material contexts when investigating SSCs?
2. How is student reasoning mediated by mapping tools developed within Science and Technology Studies?
3. What communicative competences are displayed when students investigate SSCs digitally?

In the remaining part of the discussion, I zoom out from the studies and problematise the seemingly uncontentious claims made in both policy and research that I referred to in the introduction and the literature review. These claims imply links between the presence of an individuals' knowledge of science and their abilities to reason and come to decisions as a responsible citizen without consideration for context nor how they, as an individual, are part of larger collectives. The chapter is rounded off with a discussion of implications for education raised by this research and concluding remarks.

## 6.1 Privileging scientific perspectives

In this dissertation, I have reported on ways of stating and supporting claims regarding GMO that can be considered appropriate in a techno-scientific university community. The students who participated came to understand how to articulate an argument in a techno-scientific community exhibiting the

features of biotechnological discourse, a community-specific use of language that legitimates the epistemic and moral authority of science and marginalizes opponents. The students were seen to appropriate a discourse model (Gee, 2005) held in the biotechnological community that public opposition towards GMO is due to 'insufficient knowledge', an idea that can also encountered in science education research (eg. Cinici, 2016). It has previously been shown that science knowledge plays a crucial role when resolving SSIs (Lewis & Leach, 2006; Sadler & Zeidler, 2005b; Zohar & Nemet, 2002). Nuancing this insight, what has become evident through this dissertation project is that understanding how a scientific community's proximity to an issue plays a role in the resolving of an issue is particularly relevant, not solely the understood adequacy of an individual's science content knowledge. The controversy over production and consumption of GMOs engaged in by the university students was framed in terms of the science involved. Risks were considered only in terms of scientific knowledge at the expense of their social, cultural and political framings. The participants' displayed accountable and appropriate, to this biotechnological community, ways to take a stand in a conflict. The findings reveal how participants' marginalized opponents and rendered other potentially relevant perspectives for the GMO controversy as unimportant in ways similar to those the biotechnology community has been shown to do previously (Gisler & Kurath, 2011).

The handling of SSIs in science education is often associated with achieving scientific literacy in terms of informed decisions involving rational thought and discourse (Sadler et al., 2007; Simonneaux & Simonneaux, 2009; Zeidler et al., 2005). In the university science context studied (study I), rather than fostering "open-mindedness and respecting others arguments" (Zeidler & Keefer, 2003, p24), the participants were shown to be primarily concerned with using scientific language to privilege professional understandings of GMOs and discredit public worries and concerns. With similar findings, Pouliot (2009) has reported on how pre-university students ascribed deficits of knowledge to citizens and authorized them limited participation in a project based on students consulting various sources. In the present project it was found that the professor's talk expected no argument; what was required was comprehension and acceptance. The science professor's discourse was monological in two respects. First, one single perspective (voice) was systematically privileged - the biotechnologists perspective on a controversial issue, invoking that opposition to GMO is due to ignorance of biotechnology.

Second, one type of response or interpretation was imposed on the students as recipients - that they take the 'right side' in the conflict. Here, the monologic function is particularly important for passing on cultural meanings, thus preserving the continuity and stability of beliefs and values within a culture, in this case the biotechnological community. However, talk treated in this way is authoritative and not open to question or alternative perspectives (Wells, 2007).

I reported how science students in upper secondary school after having explored GMOs online, used a widely circulating message in different project activities that came from a scientific article that reports GMO as causing cancer in rats. I also showed how the meaning of the message was intrinsic to the communicative activity type (CAT) and what needed to be addressed in the specific activity. Using this message, students enlisted scientific objectivity and rigour to underpin the credibility of socio-scientific arguments in a debate and when they qualified a reflective position in the controversy, that more research was needed, they did so in light of the perceived serious consequences of GMO on rats. However, when the same students engaged in deliberative peer discussion they critically discussed and reflected on how non-science actors in an online context appeal to science rhetorically. That science students are privileging scientific perspectives on complex issues has also been shown to occur in the education of electronics technicians where students attributed a central role to empirical scientific evidence when proposing how scientific controversies might be resolved (Albe, 2008a). Claims were based on students' written answers to questions asking them to justify a position on whether mobile phones were dangerous having been provided with a number of research articles (Albe, 2008a). Albe (2008b) documented ways in which students' 'naïve epistemological representations' limited argumentation and suggested that, "students' work on socio-scientific controversies should be accompanied by an examination of the way in which scientific knowledge is produced within a community and, in particular the role of controversy in the process" (p. 86). Unlike Albe (2008b) who presents students reasoning in terms of 'naïve representation', I have approached the students' reasoning as appropriate to the curricular framing of the educational setting. I rather consider the ways students make use of the persuasive powers of 'appeals to science' as a discursive resource they use to engage accountably.

Similar to Nielsen (2012), the present project reveals how students are able to selectively use science in attempts to frame specific aspects of a

controversial issue as the salient aspects and to make it appear as if these aspects call for certain positions to be taken towards them. The students used a science to frame issues as particularly risky and involving unforeseen consequences on health (Nielsen, 2012). These findings also align with Orlander Arvola and Lundegård (2012) who reported on how students were able to use science in specific ways that suit their argumentative goals. In addition, this study showed how the information most prominent online, highly controversial scientific results, can do the same work as more or less readymade science. The controversial nature of certain scientific findings was not made relevant by students since their purpose was to make accountable contributions such as a persuasive argument in a debate or a qualification of a reflective position in a seminar. In relation to this, however, I have provided a different take on assumptions for why particular resources are drawn on or not in communicative situations. When Walker and Zeidler (2007) interpret the absence of certain kinds of claims displaying knowledge of science as a lack of robust frameworks, I and others (cf. Rudsberg and Öhman, 2015) taking contextual features, such as the purpose of the activity, into consideration when analysing students reasoning understand these uses of resources as helping with the particular purpose at hand.

To conclude, both in the technical university setting and in the upper secondary school setting, scientific perspectives on complex issues were seen to be privileged (study I and II). As I mentioned in the literature review, I have encountered many studies in the SSI literature that associate the introduction of complex issues in the classroom and appraisal of multiple perspectives and that the development of knowledge of science has a positive influence on daily thinking and decision making outside of school. Almost 30 years ago Lemke (1990) reported on how students in school were often told very subtly that science is a special truth. Acknowledging the limiting number of settings studied in this dissertation, care must be taken when extrapolating these findings to other educational settings. However, based on my work and others findings (viz., Albe (2008a), Pouliot (2009), Nielsen (2012)), I find it reasonable to further investigate to what extent the introduction of SSCs such as GMO into science classrooms entails not only *examining* multiple persectives but also *acknowledging* other *perspectives* than the scientific ones and acknowledging that the knowledges at play are results of socially constructed investigation processes.

## 6.2 Understanding of SSC when mediated by digital mapping tools

In this dissertation, I have reported on students' locally embedded reasoning and how it was mediated by mapping tools designed to support the analysis of controversies in science and technology studies (viz., Venturini & Latour, 2010). The rational for introducing controversial issues can somewhat simplistically be compared between the two approaches, 'Controversy mapping (CM)' and 'SSI framework'. CM practices are concerned with exploring and visualizing the co-production of science, technology and society by mobilizing digital technology with little focus or consideration for the trustworthiness of actors' claims. By contrast, the SSI framework is more concerned with educating scientifically-literate citizens (Elam et al., 2019) and with developing and encouraging scientific habits of mind (Zeidler, Sadler, Applebaum, Callahan, 2009). As such, the SSI framework acknowledges the relevance of considering multiple perspectives (Sadler, Barab, Scott, 2007), but more research have been called for in order to focus on the analysis of these considerations (Zeidler & Kahn, 2016).

I have described ways in which socio-scientific reasoning was mediated by artifacts such as controversy maps (studies III & IV). In one examined instance, a group of students discussed hydraulic fracturing having worked with online data and constructed a controversy map through a network visualization tool. They used the map they had made to point out certain actors including interest groups, affected citizens and governmental agencies. They explained their arguments and assessed the reliability of the various web pages while using the map as a way of positioning the conflict as a matter of different actors having different interests. The student used the arguments available in the included sources instead of focusing on questions of proof and neutrality. In responding to another group of students who challenged the evidence for claims made by opponents to fracking, the map allowed one of the map-making students to distance himself from the controversy, invoking the map when multiple perspectives were represented. The map-making students then claimed that it is not possible to arrive at a correct decision merely by examining data and evidence provided by the different sides in a conflict. Instead, they invoked the map in order to show how various sides are in conflict with each other and that actors on all sides refer to data and evidence in their argumentation. Hence, the tool mediated an

understanding of controversies inline with how they are understood in science and technology studies (Venturini & Latour, 2010).

The idea that socio-scientific activities are valuable because they develop students' evidence-based reasoning is found throughout the canons of the socio-scientific framework (Nielsen, 2013a). It has been argued that it is misleading to think in terms of scientific evidence in socio-scientific decision making since this process involves deliberations in which people weigh multiple and incommensurate perspectives (Nielsen, 2013b). Following a similar line, controversies are understood in the theoretical root of controversy mapping, Actor Network Theory (ANT), as matters of concern that cannot be distilled down to matters of facts. The issues and questions at the centre of disagreement are understood to typically remain undecided and open to both political as well as scientific interpretation. Therefore, focusing on the established facts of a matter can be seen as representing an attempt to avoid or sidestep greater controversy and subtract from its reality (e.g. Latour, 2004, p. 232). In this sense, matters of fact are "very partial…very polemical, very political renderings of matters of concern only a subset of what could also be called states of affairs" (Latour, p. 232) and accordingly, controversies can be recognized as important empirical occasions for investigating the production and stabilization of social and political entities as much as scientific and technological ones (Latour, 1992).

In this dissertation, I have provided accounts of the production of knowledge of SSCs as part of collaborative processes with and through digital technology (study IV). I have reported on how digital mapping tools developed for exploring and visualizing controversial issues work together with the local context to mediate collaborative handling of online information. This focus aligns with a key concern within the field of Computer Supported Collaborative Learning (CSCL), that of helping people to effectively engage in handling multiple perspectives and uncertainties of information in the Internet age (Wise & Schwarz, 2017). The results expand on previous studies of the role of representations in learning processes (e.g. Kolloffel, Eysink, & de Jong, 2011) by focusing on students' communication and adding to existing research on how visualizations in become productive resources in the learning process during curricular interventions (e.g. Furberg, Kluge, & Ludvigsen, 2013). In particular, the results extends previous findings in the CSCL field by detailing ways network visualization tools may provide means for working out what is relevant and useful in extensive corpora of online data. The detailed analysis

of chronologically organized episodes from one group of students in study IV reveals ways students use and respond to the various mediating features of the tools; and how particular affordances and constraints interplay with other mediational means in the local context. Further, the analysis reveals how the examined activity enabled the process of judging and categorizing actors online in terms of criteria such as institutional status, trustworthiness, and position within a controversy.

The use of digital tools to explore and analyze SSCs implies challenges for students. Tools such as those examined in this dissertation challenge the institutional practices of schooling and the goals described in the science curriculum that emphasize the need for students to be able to distinguish scientific from nonscientific claims. This dissertation demonstrates how the mapping method allows for students to investigate the presence of what has been termed 'disagreeing minorities' (Venturini, 2010). Making judgments of credibility and coming to a shared understanding of what constitutes credibility has become an important aspect of engaging with social media and the Internet more generally in classrooms (Forte, 2015). However, the approach outlined in the curriculum is focused on the identification of trustworthy and reliable sources, a focus that the tools examined in this dissertation do not necessarily facilitate. Instead, the STS scholars that developed the tools used emphasize the need to scrutinize as many viewpoints as possible and to listen to the various actors more than one's own presumptions, no matter their disciplinary or institutional affiliation (Venturini, 2010). These scholars suggest not excluding actors' ideas because they are not based on scientific theory or methodology. In this way, controversy analysis in the STS tradition does not seek to establish the legitimacy of knowledge claims (Venturini, 2010c). Instead it uses tools for exploratory purposes; namely to detect relations between relevant and influential arguments and socially and politically located actors, and to render such relations available for interpretation. This stands in contrast to the SSI framework and there is a tension between these two different approaches one can take to understanding controversies. However, the approaches coexist with both sides seen in the classrooms studied. One approach was made relevant by the curriculum and the traditional science education approach and the other by the STS approach to using the mapping tools introduced as part of the reseach project.

Highlighting the issue of alignment between tools and students' own logics, the students in this study collaboratively interacted with the tools and used them for the purposes of the project at hand with varying results. This is similar to many earlier CSCL studies (cf. Furberg 2016; Kolloffel et al. 2011), however, the case examined in this study follows in the tradition of a smaller group of CSCL projects that have investigated the collaborative use of non-school specific technologies in school settings (cf. Cekaite 2009; Forte 2015). The mapping tools studied here were developed for research in science and technology studies and were not always well aligned with the school project. While students were faced with the challenge of categorizing the content of the nodes appearing in their maps as nodes, the software only operated on the relationships between nodes agnostic to their content relationships. It has been argued that it isn't necessarily the best possible alignment by tools to students' logic that produces the best pedagogical result and that in fact some mismatches between a tool's logic and the process students engage in might be beneficial (Hillman, 2014). In this sense, the findings of this dissertation reveal how aspects of the tools became what Davis and Sumara (2014) have refered to as 'enabling constraints'. That is, structural conditions that help to create a balance between coherence and randomness, or in this case between a certain way of describing controversies and the freedom to freely explore. In conclusion, the results of this dissertation foreground the importance of mediational means afforded through the use of the features of digital mapping tools and how learning about the technical side of the visualalisations made was integral to students' meaning making processes.

## 6.3 Communicative competences as students investigate SSC digitally

In this dissertation, I have described how students in interaction were given the opportunity to develop communicative competences for activities such as generating questions, persuading others and engaging in collaborative discourse when justifying choices regarding categorizing actors in order to rendering the complexity of a controversy map more legible (studies II, III, IV). In the following I will focus on an analytical approach particularly sensitized to analyzing students reasoning on SSI (study III). The study, in my view, highlights the significance of employing a dialogical approach to understand how students engage with SSI online in a classroom context. More

specifically, it helped to identify the communicative and discursive competences required when examining complex issues from multiple perspectives.

This analytical approach is related to one recently taken by Byhring and Knain (2016) to study students' handling of complexity. By investigating students' SSI discourse using tools from Systemic Functional Linguistics (SFL), they showed how students engaging in high complexity discourses used *grammatical resources* such as modality and projection to opening up, for different positions, multiple voices and various contextual resources. They also reported in accordance with findings in this dissertation, how potentially complex challenges were treated as simple ones. Whereas both Byhring and Knain (2016) and the study included in this thesis (III) make use of the concept of voices, I reported on how students made use of reported speech, conversational resources used by speakers for invoking voices in controversial issues. The analytical notion of reported speech (Vološinov, 1973) became useful to understand how the students studied in this dissertation draw on others' words while shaping them for their own purposes. This double-voiced quality makes reported speech interesting for analysis of discussions of SSCs. Speakers used quoted utterances from other people for their own purposes while simultaneously attributing them to somebody else. It was also reported on ways in which students commented on the utterances they reported, for instance by adopting a slightly ironic tone while simultaneously appearing to simply reproduce them. Students were using this resource as a way make assessments of other's claims either in order to support their own views or to argue against or resist counter-positions.

Reported speech also worked as a way of providing evidence when a space of reflection was established as students presented and discussed their controversy maps. In such spaces of reflection they engaged in four emerging communicative projects: identifying stakeholders, bringing out tensions between perspectives, justifying claims, and challenging of claims. These competences partly overlap with a previous study (Sadler et al., 2007) which identified four aspects socios-scientific reasoning: recognizing complexity within SSI; incorporating multiple perspectives; appreciating the ongoing, open-ended nature of scientific inquiry; and demonstrating skepticism. Although the authors (Salder et al., 2007) claim that they believe that all aspects of socioscientific reasoning will be shaped by context, they also claim that fundamental to their view of SSI and science education is the idea that

learners can come to recognise invariant features of socioscientific inquiries in ways that transfer to other contexts. Their study provide guidance for teachers who need to assess individual students' socio-scientific reasoning. The argument in the present dissertation project is that consideration of voices and reported speech can offer a nuanced understanding of students SSC reasoning. Rather than analyzing individual retrospective accounts reflecting students' abilities to reason about these issues, the dialogical approach entails an analysis of students' discursive management of multiple perspectives, a multivocality which is both recognizable in ongoing public debates and also part of our internal dialogue when confronted by controversial issues in our lives. The speakers' direct and indirect relations to others, individuals, and groups play a decisive role and are not compatible with more product-centered, individual models of communication.

## 6.4 Limitations and future research

The accounts that are presented in this dissertation describe one possibility among several other ways of responding to the purpose of how students in interaction and within their educational contexts in which they learn and act, handle SSCs. Thus, what is studied here is pedagogical practice, in the context of the two empirical settings, on its own premises. It could of course be argued that in-depth studies of the kind I have conducted here are limiting in terms of generalizability. I would argue that what I have empirically studied contributes to problematizing general claims regarding individuals' reasoning on complex issues made without consideration of contexts. Thus, the results of my work challenge the seemingly uncontentious claims that occur in both policy and research that imply links between scientific knowledge and responsible citizens taking informed decisions[18]. This dissertation illustrates how such claims can be made a matter of empirical study and debate rather than being taken for granted.

The findings reported here are justified empirically in relation to the theoretical frameworks chosen and the analytical tools that have directed the analysis towards students' actions and interactions. They have contributed to

[18] mentioned in policy documents like 21st century science project (cited in page 14 in this dissertation), one of the core criteria in Project 2061's Science for All Americans asks: does the content help students to participate intelligently in making political decisions involving science and technology?' (2061:AAAS, 1990, pp. xix–xx) and (Zeidler & Keefer 2003; Zeidler, Sadler, Simmons & Howes 2005; Pedretti, 2003) are examples of researchers making connections between responsible citizenship and science knowledge.

filling the gap identified previously that there is a lack of in-depth studies of students reasoning on SSC while working with the Internet, and that investigate the relationship between the institutional setting, the technologies involved, and the interacting participants. In this way, this dissertation contributes to the comprehension of the multitude of various science classroom practices and the complexities involved when SSCs and the Internet are brought into educational settings.

From a pedagogical perspective, it is important to gain an in-depth understanding of the processes that occur in technology-mediated activities that involve working with complex information online. This study has offered an exploration of the possibilities for supporting educational activities with such tools, suggesting that using instructional approaches committed to dialogical interaction which incorporate the use of digital tools to produce controversy maps shows promise for critical multi-perspectival appraisal of socio-scientific controversies. However, additional empirical studies are required to be able to answer questions regarding the affordances and constraints of such instructional approaches and a continued examination of the different ways teachers might take up these digital mapping tools would be an important area for further investigation. Expanding understanding of how students handle information online is highly relevant since teachers can often no longer solely direct students to curated sources such as books, and while they may be able to direct them to what could considered appropriate websites, it is not likely or perhaps even desirable that students would restrict themselves in this way. Understanding the ways that students work together to navigate online information, the role of teachers and the ways they can help students is important for improving students' competences for engaging in dialogue on such issues. Further investigation is needed to determine how advanced tasks can be scaffolded when SSCs are used to progress student's digital and scientific literacy. Along these lines, a potential object of study of particularly relevance for the local Swedish context, is how recent additions on digital competency in the national curriculum[19] are transformed and accomplished by teachers and students when working with complex issues online.

[19] The Swedish curriculum has been changed (July 1st 2018) in order to strengthen students' ability to be critical of sources, working with digital texts, media and tools, and use and understand digital systems (https://www.regeringen.se/pressmeddelanden/2017/03/starkt-digital-kompetens-i-laroplaner-och-kursplaner/).

## 6.5 Implications

The findings of this dissertation suggest the need for continued efforts to understand if and how activities that handle controversies in science education foster the capacity to engage with others thus providing students with support in handling diversity and complexity when 'exposed to the world' (Biesta 2007, 2014; Biesta & Lawy, 2006). They illuminate educational issues using examples from actual educational practices, but do not present solutions concerning how teachers or educators should act. Ultimately, it is up to teachers in their everyday practices to create new ways of arranging classroom activities in accordance with the demands and framings of the practices their students are to engage in. However, acknowledging the limitations of this exploratory study and the number of classrooms studied, this dissertation offers insights into the challenges met in the practices examined and, in the following, I will suggest ways of facilitating teaching and learning with SSCs.

Resolving questions regarding issues of concern, such as SSCs handled by the students studied in this dissertation, cannot be simply outsourced to science. Engaging with complex issues online such as food biotechnology is demanding and involves encountering knowledge claims from a variety of areas including science, economics, global perspectives, governance issues, and multiple stakeholder perspectives. When science students are taught to privilege science in complex SSCs and not to consider social or political views they may be less able to see relevant ethical and political dimensions and less prepared for the political realities of a pluralist, democratic society. Such students, having learned to make what appears to be well-founded knowledge claims by appealing to science, may also be less prepared for the need to balance the needs of multiple groups and for integrating science with other sources of knowledge to develop appropriate, contextualized responses to complex issues. The solutions to problems for such students would naturally be grounded in what is known and understandable to them, and they would be likely to favor technological change over social and political change. Like many scientists, these students might be too quick to equate resistance to new policies on a scientific or technical innovation to scientific ignorance, rejecting or marginalizing accounts that originate from other disciplines and other cultural perspectives. For example, teaching and learning about agricultural biotechnology for such students would likely focus on questions of health and

environmental risk, missing that much resistance to agricultural biotechnology is based on ethical and economic objections.

This dissertation also foregrounds a problematic aspect of the SSC discourse namely when students engaged in SSC practices in science education such as privileging the scientific perspectives on a complex issue, invoke controversial scientific findings that circulate online as objective 'truths' in activity types that make such appeals to science relevant. The findings highlight the importance of addressing the disjunctures among the claims made in a scientific journal, how such claims are interpreted in a scientific setting, and the way the claims are recontextualized by interest groups online once stripped of their scientific context. Similarly to the argument previously made by scholars in the field of nature of science (NOS) (Bell & Lederman, 2003), the findings of this dissertation indicate that students' work on SSCs should be accompanied by examination of the ways in which scientific knowledge has been produced within a community. They show that when students search for information and encounter links to scientific articles online, they don't necessarily have full access to them and can be left to deal work with only the information made available freely online. Providing access to databases of scientific journals in schools would be a good step towards handling critical engagement with science in-the-making.

Many different distinctions need to be made to relate critically to knowledge claims found on the Internet including the 'non-science versus science' distinction emphasised in the curriculum. Teachers need to attend to this distinction, but also to others such as the distinction between a single scientific article versus a scientific field, a relevant distinction in terms of controversies like those surrounding vaccines, GMO, and global warming. The relevance of focusing on this distinction is highlighted by how claims made by students studied in this dissertation who refer to single scientific articles in a scientific field that have long since been refuted are circulating online.

Introducing a variety of distinctions has the potential to develop students' competences so that they become more comfortable with contradiction and ambiguity and avoid simply using scientific knowledge to 'resolve' the issue at hand. One approach to expanding students' understanding of SSCs is to ask them to engage closely with controversies, to explore and visualize their complexity by embracing difference, seeking to interpret this complexity and communicate it to others. Explicitly acknowledging the complexity of

controversies and asking students to describe and interpret the shifting entanglements of knowledge and is one plausible way forward. The results of this dissertation suggest that instructional approaches committed to dialogical interaction that incorporate the use of digital visualization tools, show promise for analyzing online material and handling the complexity of SSC discourses. However, developing controversy mapping into a commonplace tool in schools would require significant development work on the tools and require support for teachers faced with the challenge of choosing whether and how to use them. In order for these tools to work in upper secondary education settings where teachers are not focused on controversy mapping per se, a key question is how these they can be designed and instructionally integrated. When the aim for the use of these tools is not focused on research and advanced science studies courses in higher education, but instead on usefulness, reliability, and sustainability for educational settings, further development is needed before these methods and software are made widely available.

In a time of massive flows of information and multifaceted sources, concepts like 'scientific' and 'evidence based' are challenged in relation to SSCs in society, in curricula, and in the research literature on SSI. Clearly, several types of knowledge are useful for reasoning in an informed way about complex SSCs that include scientific knowledge, but the connection between (scientific) knowledge and responsible citizens that is often pointed to is not as clear. By focusing on individual knowledge and reason as the basis for decisions made with reference to technological solutions and individual choices, conflicts are hidden and highly politicized issues are de-politized. One might get the impression that complex questions have simple answers when it might be more productive to 'stay with the trouble'[20].

## Final remarks

As mentioned at the beginning of this dissertation, providing students with opportunities for handling complex information online is important for developing democratic citizenship. It is pertinent that schools including science education play a role in giving students the opportunity to examine

[20] Donna Haraway stresses that in the face of great challenges in the Anthropocene, it is silly to believe in technofixes and suggests to rather focus upon situated technical projects and their people.

and reflect upon complex issues. Engaging in the discourses of socio-scientific controversies (SSCs) requires developing new repertoires for interaction with people, texts, and technologies and we are only beginning to understand how students could be learning and participating as citizens in the digital age. In this study, the particulars of the discursive activities when students handle SSCs online in a classroom context were revealed by studying how student reasoning was contingent on contextual features. The methodological and theoretical approach to analyzing students reasoning undertaken in this dissertation enabled me to reveal:

- How making claims and taking a stand regarding SSCs can be seen as being shaped by the framings and demands characteristic of the activity in which students are engaged.
- How tool-mediated activity provides means for students to work out what is relevant when handling multiple perspectives encountered in online data, and how students respond to mediating features of a visualization tool for handling multiple perspectives online.
- What it can mean that science education is part of larger communities and their cultures, including the sense in which the members of such communities take sides in controversial issues.
- The kinds of communicative competences that could be cultivated through engaging in SSC reasoning and public debates in science education. In the classrooms handling SSCs online, voices representing different perspectives will typically be implicated, enabling students to reflect on other voices across time. Such practices are characteristic of handling SSCs today. and therefore essential to the processes of exercising citizenship.

Overall, this dissertation points to the importance of learning to not only make what appears to be well-founded knowledge claims informed by science. It also shows the need for being helped to understand how science is used rhetorically in order to develop appropriate contextualized responses to complex issues in a pluralist society in the digital age. Since democratic citizenship invariably relates to individuals-in-context and cannot solely be understood as an attribute of the individual, society's challenges regarding the handling of SSCs should not be couched in individualistic terms. Instead, attention must be paid to the contexts in which individuals act and interact as they negotiate the multiplicity of information and views available in the digital age.

# 7 Swedish summary

In this chapter a summary of the dissertation is provided in Swedish.

## Introduktion

Den övergripande ambitionen med denna avhandling är att utveckla kunskap om elevers och studenters samtal om, och digitala undersökningar av, socio-vetenskapliga kontroverser (SSC) inom naturvetenskaplig utbildning. Som medborgare står vi inför problemet att kunna hantera en komplex kunskapsintensiv värld där utvecklingen inom vetenskap och teknik är en framträdande del av det socio-politiska landskapet. Genom nätverksbaserade digitala medier blir kunskapsanspråk från olika fält och aktörer lättillgängliga för oss. Att kunna navigera och kritisera innehåll som görs tillgängligt via tekniskt sofistikerade medier blir allt viktigare och kräver nya och komplexa kompetenser (Mason, Scrimin, Tornatora, Suitner, & Moè, 2018). Skolan och dess pedagoger kan spela en viktig roll genom att behandla frågor om SSC och arrangera aktiviteter där eleverna uppmanas att utforska och diskutera deras komplexitet och mångfald (Biesta, 2007), inklusive meningsskiljaktigheter, och de perspektiv på frågorna som olika discipliner och kunskapsområden tillhandahåller. I dessa aktiviteter behöver studenterna inte bara reproducera kunskap, utan även konstruera, skapa, välja, analysera och kritiskt granska den (Säljö, 2010).

Det finns ett etablerat forskningsområde inom naturvetenskaplig utbildning som undersöker undervisning och lärande i komplexa samhällsfrågor; så kallade socio-vetenskapliga frågor (socio-scientific issues, SSI). Frågor som då behandlas i klassrummen kan handla om massvaccinationer av ungdomar, effekter och orsaker till klimatförändringar och produktion och konsumtion av genetiskt modifierade växter. För att göra det möjligt för unga att reflektera över frågorna, icke minst med tanke på framtidiga ställningstaganden och beslut, har undervisningsaktiviteter skapats för att låta studenter bekanta sig med frågorna, diskutera dem och reflektera över de berörda aktörerna, deras argument, påståenden och intressen (Ekborg, 2016; Sadler, 2011; Zeidler, 2014).

Jag studerar hur elever och studenter arbetar med frågor om SSC inom naturvetenskaplig utbildning genom att analysera deras kommunikation och interaktion som del av det pedagogiska och institutionella sammanhanget, och hur de kulturella verktyg eller redskap som finns tillgängliga medierar deras aktiviteter (Säljö, 2010). Ett sådant kulturellt verktyg utgörs av de sökmotorer elever och studenter använder sig av för att bekanta sig med ett obekant ämne på Internet. Dessa rutinmässiga sätt att få tillgång till information (Walraven, Brand-Gruwel, & Boshuizen, 2009) är redan en integrerad del av skolans arbete (Johnson, Bulfin, Nemorin, & Selwyn, 2018, Livingstone, Mascheroni, Staksberg, 2018). Elever söker regelbundet information på webben för att lösa sina skoluppgifter i stället för i böcker och bibliotek, när de till exempel behöver förbereda essäer eller presentationer (Mason et al., 2018; Walraven et al., 2009). Nyckeln för att lyckas med sådana aktiviteter är förmågan att navigera och kritiskt bedöma innehåll i det flöde av information som finns tillgängligt med hjälp av stödjande strategier för att hantera informationsmängden (Chung & Neuman, 2007). Inom naturvetenskaplig utbildning används sökmotorer bland annat för att få tillgång till information om en mängd olika ämnen som vaccinationer, klimatförändringar, kärnkraft eller genetiskt modifierade organismer (GMO) (Tsai, Hsu, Tsai, 2012, Tsai, 2018).

Utmaningarna inom utbildningssektorn att hantera information på Internet tydliggörs också genom att läroplaner uttryckligen kräver att skolor ska ta itu med frågor kring digital kompetens och hjälpa studenter att utveckla de kompetenser som krävs för att konstruktivt hantera komplexa frågor som SSC. För att kunna kartlägga och analysera kontroversiella frågor på nätet har digitala metoder och verktyg föreslagits, som har sitt ursprung inom teknik och vetenskapsstudier (STS) (Venturini, 2010c, 2010b, Venturini & Latour, 2010). Sådana kartläggningsverktyg används av de elever på gymnasiet som studeras i denna avhandling. De tillhandahåller redskap för att utforska, manipulera och visualisera nätverk av Internetdata (Jacomy, Venturini, Heymann & Bastian, 2014).

Avhandlingen tar sin utgångspunkt i sociokulturella och dialogiska perspektiv på kommunikation och lärande i relation till kontroversiella frågor. Empiriskt material samlades i två olika utbildningssammanhang. Ett material genererades vid ett tekniskt universitet, på en introduktionskurs i bioteknologi, där jag följde projektgrupparbeten om GMO (Studie I). Ett annat material genererades vid ett naturvetarprogram på en gymnasieskola där jag följde ett

projektgruppsarbete inriktat på att behandla frågor om SSC med hjälp av digitala kartläggningsverktyg (Studie II, III, IV). Etnografiska data omfattade videoinspelningar och observationer vid föreläsningar och redovisningar, inklusive kursmaterial samt de texter och visualiseringar som producerades av studenter och elever,

Avhandlingen inkluderar fyra studier som fokuserar på hur studenters och elevers resonerade om SSC är inbäddade i sociala, institutionella och materiella kontexter (Linell, 2009; Säljö, 1999, 2010; Vygotsky, 1978; Wertsch, 1998). I studie I undersöks hur studenter och en professor inom ramen för en bioteknologisk diskurs, karaktäriserar motstånd mot GMO och utvärderar motståndarnas argument. Studie II undersöker hur elever åberopar vetenskapliga forskningresultat som frekvent förekommer på webbsidor, i skolprojektens samtalaktiviteter om GMO. Studie III antar ett dialogiskt perspektiv för att förstå hur elever diskursivt hanterar de motstridiga perspektiv som visar sig i deras kartläggningar av SSC på Internet. I studien undersöks hur individen går i dialog med andra – både de som är närvarande i klassrummet och med de som yttrar sig på institutions- och samhällsnivå. Slutligen undersöks i studie IV hur studenters kollaborativa utforskande och ordnande av kontroversens komplexitet konstitueras med de digitala nätverksvisualiseringar som används.

## Syfte och frågeställningar

Det övergripande syftet med denna avhandling är att utforska hur elever och studenter i interaktion och inom de institutionella sammanhang där de lär sig och agerar, hanterar SSC. Detta innebär att undersöka hur studenter och elever resonerar när aktiviteten pågår och hur resonemangen formas av de inramningar, krav och traditioner som gör sig gällande i praktiken. De övergripande forskningsfrågor som ligger till grund för avhandlingen är:

1. Hur formas studenters och elevers resonerande av de konkreta institutionella, sociala och materiella sammanhangen när de undersöker SSC?
2. Hur medierar de digitala kartläggningsverktyg som används elevernas resonerande?
3. Vilka kommunikativa kompetenser blir relevanta när elever undersöker SSC digitalt?

# Tidigare forskning

Eftersom jag försöker utveckla kunskap om *hur eleverna (och studenterna) resonerar om SSC* och hur det medieras av sina institutionella och materiella kontexter när elever *söker information på Internet*, placerar jag avhandlingen i relation till tidigare forskning inom två huvudområden. Jag har med studier av studenters resonerande om komplexa sociala problem i naturvetenskaplig utbildning (Albe, 2008; Almqvist & Östman, 2006; Byhring & Knain, 2016 Furberg & Ludvigsen, 2008; Nielsen, 2012; Rudsberg & Öhman, 2015; Sadler, 2011; Zeidler, 2014) och studier av informationssökande på Internet (Almqvist & Östman, 2006; Linn, Davis, & Bell, 2004; Stadtler & Bromme, 2007; Walraven, Brand-Gruwel, & Boshuizen, 2009; Wiblom, Rundgren, & Andrée, 2017). Litteraturöversikten i kappan ska ses som bakgrund och motivering till de avväganden och val som görs i denna avhandling genom att presentera och diskutera resultat från relevanta studier.

Studier av individuella studenters resonemang har starkt bidragit till SSI-fältet och bidragit till vår förståelse av hur studenter hanterar argumentation och vetenskapligt innehåll. För att kunna förstå komplexiteten hos elevernas resonemang i en viss lärmiljö betonar jag i detta projekt vikten av att ta mer hänsyn till sammanhangen för samtalen. Denna avhandling syftar till att bidra till SSI fältet enligt följande:

Jag observerar elevernas (och studenternas) handlingar *in situ* och tar sammanhangen där resonemangen äger rum i beaktande i analysen genom ett sociokulturellt och dialogiskt perspektiv på kommunikation och lärande (Linell, 1998a, Säljö, 1999; Wertsch, 1998). Genom att ta sammanhangen och de medierande verktygen i beaktande vid analys av elevernas SSC-resonemang strävar jag efter att komplettera tidigare forskning där individens uttalanden förstås som en återspegling av vad de förstår, och där deras sätt att resonera bedöms oavsett sammanhang. Jag önskar att bidra till studier som förstår samtal om SSC som socialt och kulturellt betingade, vilket innebär att kunskapsanspråk och argument alltid måste analyseras och värderas med hänvisning till de sammanhang där de uppkommit (Almqvist & Östman, 2006; Furberg & Ludvigsen, 2008; Orlander Arvola & Lundegård 2012; Rudsberg, Öhman & Östman 2013; Åberg, Mäkitalo & Säljö, 2010). Jag analyserar därför studenters och elevers resonerande och användning av verktyg utifrån sociokulturella och dialogiska perspektiv på samtal och interaktion.

Det finns för närvarande få empiriska klassrumsstudier av elever som arbetar med material från Internet som inte valts ut av deras lärare (Klosterman et al, 2012). Det finns också få studier som är baserade på direkt observation av hur elever hanterar och bearbetar information söker på Internet (Knight & Mercer, 2014). Att adressera denna brist är av relevans både för forskning inom naturvetenskaplig utbildning om komplexa frågor såväl som för forskningsområdet kring hur digitala verktyg kan premiera lärande och samarbete (CSCL)[21]. En ny artikel som föreslår framtida riktningar för CSCL-fältet hävdar att behovet av att hantera den mångfald perspektiv och osäkerheter som är förbundna med information i Internetåldern är av särskild betydelse (Wise & Schwarz, 2017). Det föreslås att i förhållande till dessa frågor är ett framväxande mål att hjälpa människor att effektivt engagera sig i processen. Den genomgripande användningen av Internet i samhället och dess konkreta tillämpning i formella utbildningssammanhang är relativt ny och särskilt sällsynta är detaljerade studier av hur frågor och aktiviteter som behandlar SSC medieras av digitala verktyg i skolan.

# Teoretiskt och metodologiska angreppssätt

I denna avhandling använder jag dialogiska och sociokulturella teorier för att förstå och formulera hur elevernas arbete med SSC ser ut i olika utbildningssammanhang, när de interagerar med medierande verktyg och är i dialog med andra. Dessa teoretiska ingångar ger möjligheter att närma sig det empiriska materialet som situerat, institutionellt och kulturellt, och gör det också möjligt att ta elevernas dynamiska meningsskapande i beaktande. De teoretiska resonemangen bidrar också med analytiska begrepp för att få insikt i hur studenterna resonerar om SSC när komplexiteten är framträdande, frågorna är omtvistade och de vetenskapliga resultaten är instabila ("in-the-making"). En premiss för ett dialogiskt ramverk är att dialogen inte bara sker i en dialog mellan personer som samtalar här och nu, utan även institutionellt och sociokulturellt (Linell, 1998a, Wertsch, 1998). En förutsättning för ett sociokulturellt synsätt innebär att man studerar social interaktion med artefakter, man tar hänsyn till ömsesidiga beroenden mellan studenter och digitala teknologier (Säljö, 1999, 2010). Genom att använda begrepp från

[21] Ett vetenskapligt fält som ägnar sig åt att förstå hur digitala verktyg kan stödja lärande och samarbete är Computer Supported Collaborative Learning (CSCL)

sociokulturella och dialogiska traditioner för att undersöka social interaktion visar denna avhandling hur elevernas användning, utvärdering, förhandling och reflektion över uttalanden om SSC medieras av de konkreta verktyg som de har tillgång till och använder i sina projekt. De används i analyser för att beskriva och analysera särskilda diskursiva aktiviteter där elever och studenter hanterar SSC med hänsyn till de förhållanden som finns i klassrummen.

De teoretiska ingångarna har givit upphov till fyra olika, men relaterade studier i avhandlingen. Studie I analyseras SSC-resonemang genom diskursanalys (Gee, 2005; Gee & Green, 1998) vilket skiljer den något från de andra studierna. Det är först och främst begreppet diskursmodell (Discourse model) som avviker från andra begrepp, då det innebär att man analyserar samtal i termer av sådana modeller, och därmed som mindre dynamiska.

Emellertid är en grundläggande premiss inom ett sociokulturellt förhållningssätt att förstå elevernas handlingar som inbäddade i institutionella miljöer, där normer och värderingar blir centrala aspekter i argumentation och resonemang (Mercer, 2004). Lärare och studenter interagerar i utbildningsmiljöer som upprätthåller de värderingar och praktiker som de har ansvar för. Ur detta perspektiv kan studenternas och professorns samtal och aktivitet karakteriseras i form av en dubbel dialogicitet (Linell 1998, 2009). Dels relateras samtal och aktiviteter till ett här och nu, dessutom är det relaterat till sociokulturella praktiker som grundar sig på långa traditioner.

Eleverna orienterar sina aktiviteter mot de mer eller mindre uttryckta förväntningar, värderingar och praktiker de är inbäddade i som en del av det specifika utbildningssammanhanget. Detta kan handla om hur studetner tolkar och förstår uppgifterna och hur de löser dem på ett tillfredsställande sätt, genom de resurser som används, lärarens instruktioner och kommentarer, läroplan och bedömningskriterier. Ett gemensamt antagande för de fyra studierna är att elevernas resonemang inte bestäms av institutionella praktiker och normer, utan snarare att institutionella praktiker och normer verkar som strukturerande resurser i deras meningsskapande processer.

Introduktionen av SSC i skolan där motstridiga argument, skillnader och spänningar mellan olika röster blir en del av naturvetenskaplig utbildning, innebär att komplexiteten i att överväga vad som anses relevant att lära ökar dramatiskt för elever. Betydelsen av det man ägnar sig åt är på detta sätt alltid inbäddad i särskilda diskurser. Lärare och studenter tenderar att prata om frågor på sätt som är relevanta och lämpliga i den kontext de befinner sig. För att studera hur studenter lär sig resonera kring SSC ansågs de analytiska

begreppen vara användbara, dels för att belysa vad det innebär att behärska olika genrer i allmänhet, och för att genomlysa vad det innebär att göra det i en viss institutionell (pedagogisk) aktivitet.

### Videofilmat klassrumsmaterial

Vid sidan av de dialogiska och sociokulturella teorierna för kommunikation baserades studien på analyser av videoinspelat klassrumsmaterial. Två olika utbildningssammanhang undersöktes. Vid ett tekniskt universitet fokuserade jag på en introduktionskurs i bioteknologi, närmare bestämt ett projektgrupparbete om GMO. I naturvetarprogrammet på en gymnasieskola fokuserades projektgruppsarbete inriktat på hur frågor om SSC behandlas med hjälp av digitala kartläggningsverktyg (Studie II, III, IV). Etnografiska data omfattade videoinspelningar av studenternas projektaktiviteter i klassrummet för att kunna analysera interaktionen på detaljnivå, i tillägg omfattades materialet av de texter och visualiseringar som producerades av studenterna, dokument och kursmaterial samt fältobservationer vid föreläsningar och redovisningar.

## Sammanfattning av delstudierna

I denna del sammanfattas varje studie med fokus på de viktigaste resultaten och argumenten som presenteras i respektive artikel. De fyra artiklarna återfinns i del 2. Studierna redovisas i enlighet med de syften och frågor som ställs i respektive artikel. De övergripande forskningsfrågorna kommer istället att strukturera slutsatserna och resonemangen i diskussionskapitlet.

### Delstudie 1

I den allmänna diskussionen om genetiskt modifierad (GM) mat har vetenskapens sätt att representera frågan blivit utsatt för intensiv granskning och ifrågasättande. Forskare som arbetar inom dessa områden har kämpat för vetenskapens position i samhället. Men få studier av hur debatten om vetenskap förs inom ramen för utbildningen på universitetsnivå har genomförts. I den här studien observerades en introduktionskurs i bioteknik under en termin. Föreläsningar och grupparbeten om GMO spelades in på video och studentrapporterna om GMO samlades in. Den etnografiskt baserade diskursanalys som valdes (Gee, 2005; Gee & Green, 1998) genomfördes med hjälp av en uppsättning noggrant utvalda och representativa

observationer av hur en grupp studenter lär sig att argumentera och appropriera de ställningstaganden som är vanliga i den bioteknologiska diskursen de socialiseras in i. Medan socio-vetenskapliga frågor (SSI) ofta är förknippade med att uppnå teknisk-vetenskaplig literacy[22] och i vad man menar är välgrundade beslut som involverar rationella överväganden, visar denna studie att SSI i praktiken, i det sammanhang som studeras här, främst handlar om att använda vetenskapligt språk för att privilegiera bioteknologers förståelser av GMOs och diskreditera allmänhetens invändningar och farhågor. Vetenskapliga kunskapsanspråk privilegierades över etiska, ekonomiska och politiska kunskapsanspråk som antingen gjordes irrelevanta eller motades med vetenskapliga argument. Studenterna approprierade, i Gee & Greens (1998) mening, en diskursmodell etablerad bland bioteknologer, som istället beskrev allmänhetens motstånd till GMOs som ett resultat av otillräckliga kunskaper.

## Delstudie 2

Motstridiga argument om komplexa problem och frågor har blivit tillgängliga genom nätverksbaserade digitala medier i vardagen och tillgången till Internet i skolan har gett möjligheter att ta del av ett stort antal källor. Naturvetenskaplig utbildning spelar dessutom en viktig roll för att ge studenter möjligheter att utvärdera information och engagera sig i att diskutera komplexa sociovetenskapliga frågor. Syftet med denna artikel var att analysera hur elever i skolans projektarbete kring GMO åberopar resultat från en vetenskaplig artikel som cirkulerar på nätet. Syftet är att se hur sådana åberopanden till forskningsresultat kommer in i situerade samtal kring GMO i skolan, närmare bestämt på vilka sätt de blir användbara inom ramen för olika slags klassrumsaktiviteter. Genom att använda begreppet kommunikativa aktivitetstyper (CATs) analyserades betydelsen och funktionen av de recirkulerade uttalandena i 1) en diskussion kring kontroversen med äldre elever 2) en iscensatt debatt 3) ett reflekterande seminarium. Artikelns resultat åberopas som diskursiv resurs för att göra anspråk på vetenskaplig objektivitet och noggrannhet när man levererar en ståndpunkt, både då ett arguments trovärdighet prövas som en del av en debatt och för att berättiga sitt eget ställningstagande i ett seminarium. När eleverna deltar i en diskussion med

[22] Oftast används anglicismen literacy eftersom svårt översätta till svenska. I bland används ”teknisk-vetenskaplig läskunnighet” (Säljö, Jacobsson, Lilja, Åberg, & Mäkitalo, 2011) eller naturvetenskaplig allmänbildning (Sjøberg, 2010)

äldre elever reflekterar de även över hur aktörer i en webbkontext använder vetenskapliga argument och resultat retoriskt. Studien ger insikt de kommunikativa kompetenser som är inblandade i konversationer och hur "vetenskapliga fakta" kan motivera, i detta fall, motstånd mot GMO.

## Delstudie 3

I denna artikel hävdas att det kan vara produktivt att analysera elevers samtal om SSC med hjälp av dialogiska teorier om språk och kommunikation (Bakhtin, 1986; Linell, 2009). Medan forskning inom naturvetenskaplig utbildning ofta har analyserat individers resonemang och hur dessa utvecklats efter att SSIs har behandlats i klassrummet, argumenterar vi för relevansen av att analysera hur individen är ”i dialog” med fysiskt närvarande såväl som med mer avlägsna samtalspartners och sammanhang (via internet). I artikeln föreslås att det analytiska tillvägagångssättet är särskilt väl anpassat för att belysa hur eleverna hanterar flera perspektiv. Ett dialogiskt perspektiv tar som utgångspunkt att SSI är en del av samhället, där politiker, intressegrupper och forskare deltar i debatter och erbjuder perspektiv som ofta är i konflikt. Snarare än att anta att den enskilda studenten är den primära enheten för analys, är ett dialogiskt tillvägagångssätt baserat på en analys som innehåller flera perspektiv och röster - en multivokalitet som också bor hos individen. Vi argumenterar i artikeln för relevansen av denna tillnärmning genom att empiriskt analysera en grupp elever på naturvetenskapsprogrammet i gymnasiet när de diskuterar hydraulisk frakturering efter att ha arbetat med den information de har hittat på Internet. Resultaten belyser hur eleverna diskursivt hanterar den flerstämmighet och multimodalitet som SSIs på nätet uppvisar. Vi beskriver en uppsättning diskursiva resurser som eleverna använder för att hantera de många perspektiv som är involverade när de kommunicerar om det kontroversiella ämnet. Dessutom beskriver och formuleras vilken typ av kommunikativa kompetenser som är inblandade när man deltar i debatter och därmed kan utvecklas genom utbildning.

## Delstudie 4

Att tillhandahålla och strukturera elevers kollaborativa arbete med den komplexa information som finns på Internet är en pedagogisk utmaning. I denna artikel undersöktes hur de digitala kartläggningsverktyg som utvecklats inom teknik och vetenskapsstudier (STS) användes av gymnasieelever i det naturvetenskapliga programmet för att tillsammans utforska, ordna och

hantera komplexiteten i SSC på Internet. En detaljerad sociokulturell interaktionsanalys av videodata visar hur eleverna tillsammans konstruerar och delar interaktiva visualiseringar och samtidigt responderar på verktygets medierande funktioner i processen. Analysen visar hur verktygen som tillhandhålls medierar relevant och användbar information för eleverna i den stora mängden insamlade Internetdata. Vi beskriver på detaljnivå den komplexa dynamik som uppstår i studenternas arbetsprocess, när de utvärderar och kategoriserar webbplatser, och visar hur deras interaktion förändras med den framväxande visualiseringen. Verktyget som kunskapsartefakt samkonstituerar deltagandet i det lokala sammanhanget. I synnerhet visar denna analys hur den verktygsmedierande aktiviteten saktar ner processen med att bedöma och kategorisera online material i enlighet med kriterier som institutionell status, trovärdighet och ställningstagande i en kontrovers. Dessutom visar analysen hur eleverna anpassar sig till det digitala verktyget i vissa skeden av arbetet och hur diskrepanser mellan elevernas egen logik och verktyget engagerar dem i produktiva förhandlingar om hur man kan förstå en kontrovers

# Diskussion

I diskussionen behandlas inledningsvis de tre övergripande forskningsfrågorna om hur elevernas och studenternas resonerande är del av de institutionella, sociala och materiella förutsättningarna, hur studenternas resonemang medieras av de kartläggningsverktyg de använder och som är utvecklade inom teknik och vetenskapsstudier (STS), och slutligen vilka kommunikativa kompetenser som blir observerbara när studenterna utforskar SSC digitalt.

I diskussionen zoomar jag slutligen ut från studierna och problematiserar de till synes obestridliga påståenden som präglar både styrdokument och forskning. Dessa påståenden innebär kopplingar mellan individernas vetenskapliga kunskaper och deras förmåga att motivera och fatta beslut som ansvariga medborgare utan hänsyn till sammanhang eller hur individer ingår i större kollektiv. Diskussionskapitlet avrundas med en diskussion om implikationer för utbildning.

## Implikationer

Resultaten av denna avhandling visar på behovet av fortsatta forskningsinsatser för att förstå om och hur aktiviteter som hanterar kontroverser i naturvetenskaplig utbildning främjar förmågan att hantera mångfald och komplexitet när de "utsätts för världen" (Biesta 2007, 2014; Biesta & Lawy, 2006). Resultaten belyser utbildningsfrågor med hjälp av exempel från klassrumspraktiker, men presenterar inte lösningar om hur lärare ska agera. Med förbehåll om studiens begränsningar, erbjuder denna avhandling insikter i de utmaningar som finns då man arbetar med dessa komplexa frågor inom naturvetenskaplig utbildning.

I en tid av massiva informationsflöden och mångfacetterade informationskällor blir ord som vetenskaplig eller evidensbaserad hållpunkter för att skapa mening i frågor om SSC, både i samhällsdiskursen, läroplaner och i den vetenskapliga litteraturen, även om dessa frågor inte kan artikuleras och ”lösas” genom enbart naturvetenskaplig kunskap. Det behövs många olika typer av kunskap för att på ett initierat sätt resonera kring sådana komplexa frågor, icke minst av naturvetenskaplig art, men relationen mellan (naturvetenskaplig) kunskap och ansvarstagande medborgare som ofta görs är inte självklar. Genom att fokusera på kunskap och förnuft döljs konflikter, och politiska frågor avpolitiseras med hjälp av referenser till tekniska lösningar och individuella val. Inte minst kan man ges intryck av att komplexa frågor har enkla svar. Mina studier pekar på vikten av att beakta ämnesövergripande arbeten för att kunna hantera dessa komplexa frågor. Lärare som arbetar med Internet som resurs i klassrummet behöver adressera hur enskilda studier som inte är i överenskommande med det vetenskapliga fältet i övrigt används framgångsrikt av aktörer på nätet. Utöver att beakta den viktiga distinktion mellan vetenskapliga och ovetenskapliga uttalanden som görs relevanta i läroplanen måste man även se till skillnaden mellan vad en enskild vetenskaplig artikel och ett helt vetenskapligt fält säger. I de fall man önskar stödja utvecklingen av digital och naturvetenskaplig ”literacy” och förståelse av skillnaden på enskilda artiklar och vetenskapliga fält skulle det underlättas om lärare och skolan fick tillgång till vetenskapliga artiklar genom tex universitetsbiblioteken. I ett projektarbete får studenterna möjlighet att utveckla fler kommunikativa kompetenser om de får engagera sig i olika typer av diskussionsaktiviteter, inte enbart debatt, eftersom viktiga kritiska reflektioner möjliggörs genom andra kommunikativa aktiviteter. En sådan aktivitetstyp är mer deliberativa samtal med andra studenter.

## Avslutande kommentar

Som nämnts i början av avhandlingen är det nödvändigt att ge studenterna möjligheter att hantera komplex information på Internet. Det handlar om både om ökade möjligheter att välja internetbaserade resurser för utbildningsändamål och utmaningen att stödja elevernas utveckling av kompetenser som behövs för att delta som medborgare. Att engagera sig i diskurser kring SSC kräver att man utvecklar sin kompetens i interaktion med människor, texter och teknik. Det metodologiska och teoretiska förhållningssättet till elevernas och studenternas samtal och resonemang gjorde det möjligt för mig att uppmärksamma:

- Hur studenter och elevers resonemang och ställningstaganden till SSC, utvecklas som svar på de sammanhang och krav som är karakteristiska för de aktiviteter de engageras i.
- Hur de verktyg som tillhandahålls medierar elevernas arbete i termer av vad som är potentiellt relevant när de undersöker och hanterar alla de perspektiv som finns representerade på Internets webbsidor.
- Att naturvetenskaplig utbildning är en mänsklig, social aktivitet som ingår i kulturella och institutionella sammanhang inklusive det sätt på vilket man tar ställning i kontroversiella frågor.
- Ett antal kommunikativa kompetenser som kan utvecklas inom naturvetenskaplig utbildning när elever ges möjlighet att diskutera SSC som de utspelar sig på nätet.

Avhandlingen pekar på vikten av att lära sig mer om vad kontroverserna består i, inte bara att ta utgångspunkt i vad som verkar vara välgrundade kunskapsanspråk baserade på vetenskap, utan också att hjälpa till att förstå hur vetenskap används retoriskt. På så sätt kan människor tillsammans utveckla lämpliga, kontextualiserade svar på komplexa frågor i ett pluralistiskt, demokratiskt samhälle. Eftersom det demokratiska medborgarskapet alltid har att göra med individen-i-kontext och inte enbart som individens attribut, bör samhällets utmaningar beträffande hantering av kontroversiella frågor inte uttryckas i individualistiska och psykologiska termer. Snarare bör man uppmärksamma sammanhangens betydelse för hur individerer agerar och interagerar när de förhandlar den mångfald av information och synpunkter som de måste hantera i den digitala tidsåldern.

# References


Aikenhead, G. S. (1985). Collective Decision Making in the Social Context of Science. *Science Education*, *69*(4), 453–475.

Aikenhead, G. S. (2007). Humanistic Perspectives in the Science Curriculum. In S. Abell & Lederman (Eds.), *Handbook of Research on Science Education* (p. 881–910). London: Lawrence Erlbaum Associates.

Albe, V. (2008a). Students' positions and considerations of scientific evidence about a controversial socioscientific issue. *Science & Education*, *17*, 805–827.

Albe, V. (2008b). When Scientific Knowledge, Daily Life Experience, Epistomological and Social Considerations Intersect: Students' Argumentation in Group Discussion on a Socio-scientific Issue. *Research in Science Education*, *38*(1), 67–90.

Almqvist, J., & Östman, L. (2006). Privileging and Artifacts: On the Use of Information Technology in Science Education. *Interchange*, *37*(3), 225–250.

Bakhtin, M. (1981). *The dialogic imagination*. Austin: University of Texas Press.

Bakhtin, M. (1986). *Speech genres and other late essays*. Austin: University of Texas Press.

Ball, A. F., & Freedman, S. W. (2004). *Bakhtinian perspectives on language, literacy, and learning*. Cambridge: Cambridge University Press.

Banaji, S., & Buckingham, D. (2013). *The Civic Web*. Cambridge, MA: MIT press.

Bell, P. (2004). The Educational Opportunities for the Contemporary Controversies in Science. In *Internet environments for science education* (p. 233–260). Mahwah: Lawrence Erlbaum Associates.

Bell, R. L., & Lederman, N. G. (2003). Understandings of the Nature of Science and Decision Making on Science and Technology Based Issues. *Science Education*, *87*, 352–377.

Belova, N., & Eilks, I. (2016). German Teachers' Views on Promoting Scientific Media Literacy Using Advertising in the Science Classroom. *International Journal of Science and Mathematics Education*, *14*(7), 1233–1254.

Bencze, L., & Alsop, S. (2014). Activism! Toward a More Radical Science and Technology Education. In *Activist Science and Technology education* (s. 1–20). Dordrecht: Springer.

Berkowitz, M., & Simmons, P. (2003). Integrating Science Education and Character Education. In D. Zeidler (Ed.), *The Role of Moral Reasoning om Socioscientific Issues and Discourse in Science Education* (pp. 117–138). Kluwer Academic Publishers.

Biesta, G. (2007). Education and the democratic person: Towards a political conception of democratic education. *Teachers College Record*, *109*(3), 740–769.

Biesta, G. (2011). The Ignorant Citizen: Mouffe, Rancière, and the Subject of Democratic Education. *Studies in Philosophy and Education*, *30*(2), 141–153.

Biesta, G. (2014). Cultivating humanity or educating the human? Two options for education in the knowledge age. *Asia Pacific Education Review*, *15*, 13–19.

Biesta, G., & Lawy, R. (2006). From teaching citizenship to learning democracy: overcoming individualism in research, policy and practice. *Cambridge Journal of Education*, *36*(1), 63–79.

Billig, M. (1996). *Arguing and thinking: A Rhetorical Approach to Social Pshychology*. Cambridge University Press.

Buttny, R. (1993). *Social Accountability in Communication*. London: SAGE Publications.

Byhring, A. K., & Knain, E. (2015). Intertextuality for Handling Complex Environmental Issues. *Research in Science Education*, 46(1), 1–19.

Cekaite, A. (2009). Collaborative corrections with spelling control: Digital resources and peer assistance. *International Journal of Computer-Supported Collaborative Learning*, 4(3), 319–341.

Choi, M. (2016). A concept analysis of digital citizenship for democratic citizenship education in the internet age. *Theory & research in social education*, *44*(4), 565–607.

Choi, M., Glassman, M., & Cristol, D. (2017). What it means to be a citizen in the internet age: Development of a reliable and valid digital citizenship scale. *Computers & Education*, *107* 100–112.

Christensen, C., & Fensham, P. J. (2012). Risk, uncertainty and complexity in science education. In *Second international handbook of science education* (p. 751–769). Dordrecht: Springer.

Christenson, N., Chang Rundgren, S.-N., & Höglund, H.-O. (2012). Using the SEE-SEP Model to Analyze Upper Secondary Students' Use of Supporting Reasons in Arguing Socioscientific Issues. *Journal of Science Education and Technology*, *21*(3), 342–352.

# REFERENCES


Chung, J. S., & Neuman, D. (2007). High school students' Information seeking and use for class projects. *Journal of the American Society for Information Science and Technology*, *58*(10), 1503–1517.

Cinici, A. (2016). Balancing the pros and cons of GMOs: socioscientific argumentation in pre-service teacher education. *International Journal of Science Education*, *38*(11), 1841–1866.

Dawson, V., & Venville, G. (2010). Teaching Strategies for Developing Students' Argumentation Skills About Socioscientific Issues in High School Genetics. *Research in Science Education*, *40*(2), 133–148.

Elam, M., Solli, A. and Mäkitalo, Å. (2019). Socioscientific Issues via Controversy Mapping: Bringing Actor-Network Theory into the Science Classroom with Digital Technology. *Discourse: Studies in the Cultural Politics of Education* 40(1), 61-77.

Ekborg, M., Ideland, M., Lindahl, B., Malmberg, C., Ottander, C., & Rosberg, M. (2016). *Samhällsfrågor i det naturvetenskapliga klassrummet*. Malmö: Gleerup.

Erduran, S., & Jiménez-Aleixandre, M. P. (2008). *Argumentation in Science Education: Perspectives from classroom-based research*. Dordrecht: Springer Science.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into Argumentation: Developments in the Application of Toulmin's Argument Pattern for Studying Science Discourse. *Science Education*, *88*, 915–933.

Eriksson, A.-M. (2014). *Formulating knowledge engaging with issues of sustainable development through academic writing in engineering education*. Doctoral Dissertation. Göteborgs universitet

Feinstein, N. (2011). Salvaging Science Literacy. *Science Education*, *95*, 168–185.

Feinstein, N., & Kirchgasler, K. (2015). Sustainability in Science Education? How the Next Generation Science Standards Approach Sustainability, and Why It Matters. *Science Education*, *99*(1), 121–144.

Fidel, R., Davies, R. K., Douglass, M. H., Holder, J. K., Hopkins, C. J., Kushner, E. J., … Toney, C. D. (1999). A visit to the information mall: Web searching behavior of high school students. *Journal of the American society for Information Science*, *50*(1), 24–37.

Fleming, R. (1986). Adolescent reasoning in socio-scientific issues, part I: Social cognition. *Journal of Research in Science Teaching*, (23), 677–687.

Forte, A. (2015). The new information literate: Open collaboration and information production in schools. *International Journal of Computer-Supported Collaborative Learning*, *10*(1), 35–51.

Fraser, B., Tobin, K. & McRobbie.C. (2012). *Second International Handbook of Science Education* (Vol. 24). Dordrecht: Springer Netherlands.

Furberg, A. (2016). Teacher support in computer-supported lab work: bridging the gap between lab experiments and students' conceptual understanding. *International Journal of Computer-Supported Collaborative Learning*, 11(1), 89–113.

Furberg, A, & Ludvigsen, S. (2008). Students' meaning making of socioscientific issues in computer mediated settings: Exploring leaning through interaction trajectories. *International Journal of Science Education*, *30*(13), 1775–1799.

Furberg, A., Kluge, A., & Ludvigsen, S. (2013). Student sensemaking with science diagrams in a computer-based setting. *International Journal of Computer-Supported Collaborative Learning*, *8*(1), 41–64.

Gee, J. P. (2005). *An introduction to discourse analysis theory and method* (Second edition). London & New York: Routledge Taylor & Francis Group.

Gee, J. P. (2008). *Social Linguistics and literacies. Ideology in discourses.* (Third Edition). London & New York: Routledge Taylor & Francis Group.

Gee, J. P., & Green, J. (1998). Discourse Analysis, Learning, and Social Practice: A Methodological Study. *Review of Research in Education*, *23*, 119–169.

Gisler, P., & Kurath, M. (2011). Paradise Lost? "Science" and "the Public" after Asilomar. *Science, Technology & Human Values*, *36*(2), 213–243.

Goodwin, J. (2002). Designing issues. In F. H. van Eemeren & P. Houtlosser (Eds.), *Dialectic and rhetoric: The warp and woof of argumentation analysis* (s. 81–96). Amsterdam: Kluwer.

Goodwin, J., & Honeycutt, L. (2009). When science goes public: From technical arguments to appeals to authority. *Studies in Communication Sciences*, *9*(2), 19–30.

Grace, M. M., & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education*, *24*(11), 1157–1169.

Grossen, M. (2010). Interaction Analysis and Psychology: A Dialogical Perspective. *Integrative Psychological and Behavioral Science*, *44*(1), 1–22.

Halverson, K. L., Siegel, M. A., & Freyermuth, S. K. (2010). Non-Science Majors' Critical Evaluation of Websites in a Biotechnology Course. *Journal of Science Education and Technology*, *19*(6), 612–620.

Haraway, D. J. (2016). *Staying with the trouble: Making kin in the Chthulucene*. Durham, NC: Duke University Press.

Heath, C., Jon Hindmarsh, & Luff, P. (2010). *Video in qualitative research. Analysing Social Interaction in Everyday Life*. London: Sage.

Hillman, T. (2014). Tracing the construction of mathematical activity with an advanced graphing calculator to understand the roles of technology developers, teachers and students. *The International Journal for Technology in Mathematics Education*, 21(2), 37–47.

Hodson, D. (2014). Becoming Part of the Solution: Learning about Activism, Learning through Activism, Learning from Activism. In *Activist Science and Technology education* (pp. 67–98). Dordrecht: Springer.

Hogan, K. (2002). Small groups' ecological reasoning while making an environmental management decision. *Journal of Research in Science Teaching*, *39*(4), 341–368.

Hsu, C.-Y., Tsai, M.-J., Hou, H.-T., & Tsai, C.-C. (2014). Epistemic Beliefs, Online Search Strategies, and Behavioral Patterns While Exploring Socioscientific Issues. *Journal of Science Education and Technology*, *23*(3), 471–480.

Ideland, M. (2016). *Den KRAV-märkta människan*. Lund: Celander.

Irwin, A., & Michael, M. (2003). *Science, social theory and public knowledge*. Buckingham: Open University Press.

Irwin, A., & Wynne, B. (1996). *Misunderstanding Science? The public reconstruction of science and technology*. Cambridge, MA: Cambridge University Press.

Jacomy, M., Girard, P., Ooghe, B., & Venturini, T. (2016). Hyphe, a Curation-Oriented Approach to Web Crawling for the Social Sciences. Presented at International AAAI Conference on Web and Social Media, Association for the Advancement of Artificial Intelligence.

Jacomy, M., Venturini, T., Heymann, S., & Bastian, M. (2014). ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PloS one*, *9*(6), e98679.

Johnson, N., Bulfin, S., Nemorin, S., & Selwyn, N. (2018). *Everyday schooling in the digital age : high school, high tech?* Abingdon : Routledge.

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *The Journal of the Learning Sciences*, *4*(1), 39–103.

Kahn, S., & Zeidler, D. L. (2016). Using our Heads and HARTSS*: Developing Perspective-Taking Skills for Socioscientific Reasoning (*Humanities, ARTs, and Social Sciences). *Journal of Science Teacher Education*, *27*(3), 261–281.

Kelly, G. J. (2008). Discourse, Description, and Science Education. In W.-M. Roth & R. K. Yerrick (Eds.), *Establishing Scientific Classroom Discourse Communities Multiple Voices of Teaching and Learning Research* (p. 79–104). New Jersey: Lawrence Erlbaum Associates, Inc.

Kelly, G. J., Chen, C., & Crawford, T. (1998). Methodological Considerations for Studying Science-in-the-making In Educational Settings. *Research in Science Education.*, *28*(1), 23–49.

Kelly, G. J., Luke, A., & Green, J. (2008). What counts as Knowledge in Educational Settings: disciplinary Knowledge, assessment, and Curriculum. *Review of Research in Education*, *32*, vii–x.

Kelly, G. J., McDonald, S., & Wickman, P.-O. (2012). Science Learning and Epistemology. In *Second International Handbook in Science Education* K.B.J. Fraser, K.G. Tobin and C.J. McRobbie (Eds.), p. 281–291). Dordrecht: Springer.

Kirk, J., & Miller, M. (1986). *Reliability and validity in qualitative research*. London: Sage.

Klosterman, M. L., Sadler, T. D., & Brown, J. (2012). Science Teachers' Use of Mass Media to Address Socio-Scientific and Sustainability Issues. *Research in Science Education*, *42*(1), 51–74.

Knight, S., & Mercer, N. (2014). The role of exploratory talk in classroom search engine tasks. *Technology, Pedagogy and Education*, 1–17.

Kolloffel, B., Eysink, T., & de Jong, T. (2011). Comparing the effects of representational tools in collaborative and individual inquiry learning. *International Journal of Computer-Supported Collaborative Learning*, *6*(2), 223–251.

Kolstö, S. D. (2001). Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues. *Science Education*, *85*, 291–310.

Latour, B. (1987). *Science in action*. Cambridge, MA: Harvard University Press.

Latour, B. (1992). One more turn after the social turn: Easing science studies into the non-modernworld. In E. McMullin (Ed.), *The social dimensions of science* (pp. 272–292). Notre Dame: Notre Dame University Press.

Latour, B. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry*, 30(2), 225–248.

Lave, J., & Wenger, E. (1989). *Situated learning: Legitimate peripheral participation (report No. IRL 89-0013)*. Paolo Alto, CA: Institute for Research on Learning.

Lawy, R., & Biesta, G. (2006). Citizenship-as-practice: The educational implications of an inclusive and relational understanding of citizenship. *British Journal of Educational Studies*, *54*(1), 34–50.

Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). *Inarticulate science? Perspectives on the public understanding of science and some implications for science education*. Leeds, UK: University of Leeds.

Lemke, J. L. (1990). *Talking Science: Language, learning, and Values*. Norwood New Jersey: Ablex Publishing Corporation.

Lemke, J. L. (2001). Articulating Communities: Sociocultural Perspectives on Science Education. *Journal of Research in Science Teaching*, *38*(3), 296–316.

Lemke, J. L. (2006). Towards Critical Multimedia Literacy: Technology, Research and Politics. I M. McKenna, L. Labbo, R.D. Kieffer & D. Reinking (Eds.), *International Handbook of Literacy and Technology Vol. II* (p. 3–15). New York: Routledge.

Levinson, R. (2001). Should controversial issues in science be taught through the humanities? *School Science Review*, *82*(300), 97(6).

Levinson, R. (2006). Towards a Theoretical Framework for Teaching Controversial Socio-scientific Issues. *International Journal of Science Education*, *28*(10), 1201–1224.

Levinson, R. (2010). Science education and democratic participation: an uneasy congruence? *Studies in Science Education*, *46*(1), 69–119.

Levinson, R., & Turner, S. (2001). Valuable lessons: Engaging with the social context of science in schools. London: Wellcome Trust.

Lewis, J., & Leach, J. (2006). Discussion of Socio-scientific Issues: The role of science knowledge. *International Journal of Science Education*, 28(11), 1267–1287.

Lin, C.-C., & Tsai, C.-C. (2012). Participatory learning through behavioral and cognitive engagements in an online collective information searching activity. *Journal of Computer-Supported Collaborative Learning*, *7*(4), 543–566.

Lindwall, O. (2008). *Lab work in science education: Instruction, inscription, and the practical achievement of understanding*. (Doctoral Dissertation). Linköping University.

Linell, P. (1998a). *Approaching dialogue: Talk, interaction and contexts in dialogical perspectives*. Amsterdam: Johns Benjamins.

Linell, P. (1998b). Discourse across boundaries: On recontextualizations and the blending of voices in Professional discourse. *Text*, *18*, 143–157.

Linell, P. (2009). *Rethinking language, mind and world dialogically*. Charlotte, NC: Information Age Publ

Linell, P. (2010). Communicative activity types as organisations in discourses and discourses in organisations. *Discourses in interaction*, (203), 33.

Linell, Per. (2000). What is dialogism. *Aspects and elements of a dialogical approach to language, communication and cognition*. Retrieved 20190129 from http://cspeech.ucd.ie/Fred/docs/Linell.pdf

Linn, M. C. (2003). Technology and science education: Starting points, research programs, and trends. *International Journal of Science Education*, *25*(6), 727–758.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Liu, S.-Y., Lin, C.-S., & Tsai, C.-C. (2011). College Students' Scientific Epistemological Views and Thinking Patterns in Socioscientific Decision Making. *Science Education*, *95*, 497–517.

Livingstone, S., Mascheroni, G., & Staksrud, E. (2018). European research on children's internet use: Assessing the past and anticipating the future. *New Media & Society*, *20*(3), 1103–1122.

Lorenzen, M. (2001). The land of confusion?: High school students and their use of the World Wide Web for research. *Research Strategies*, *18*(2), 151–163.

Marková, I., Linell, P., Grossen, M., & Salazar Orvig, A. (2007). *Dialogue in focus groups: exploring in socially shared knowledge*. London: Equinox.

Marres, N., & Rogers, R. (2005). Recipe for tracing the fate of issues and their publics on the Web, in Latour, B. and Weibel, P. (Eds.). In *Making things public: Atmosphere of democracy*. Cambridge, MA: MIT Press.

Mason, L., Junyent, A. A., & Tornatora, M. C. (2014). Epistemic evaluation and comprehension of web-source information on controversial science-related topics: Effects of a short-term instructional intervention. *Computers & Education*, *76*, 143–157.

Mason, L., Scrimin, S., Tornatora, M. C., Suitner, C., & Moè, A. (2018). Internet source evaluation: The role of implicit associations and psychophysiological self-regulation. *Computers & Education*, *119*, 59–75.

Maxwell, J. A. (2004). Causal Explanation, Qualitative Research, and Scientific Inquiry in Education. *Educational Researcher*, *33*(2), 3–11.

McClune, B., & Jarman, R. (2012). Encouraging and equipping students to engage critically with science in the news: what can we learn from the literature? *Studies in Science Education*, *48*(1), 1–49.

McClune, B., & Jarman, R. (2014). Promoting Science Literacy via Science Journalism: Issues and Challenges. In L. Tan Wee Hin & R. Subramaniam (Red.), *Communicating Science to the Public: Opportunities and Challenges for the Asia-Pacific Region* (p. 3–20). Dordrecht: Springer Netherlands.

Mercer, N. (2004). Sociocultural discourse analysis: analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, *1*(2), 137–168.

Myers, G. (1999). Functions of reported speech in group discussions. *Applied Linguistics*, *20*(3), 376–401.

Mäkitalo, Å. (2006). Effort on Display: Unemployment and the Interactional Management of Moral Accountability. *Symbolic Interaction*, *29*(4), 531–555.

Mäkitalo, Å., Jakobsson, A., & Säljö, R. (2009). Learning to reason in the context of socioscientific problems. Exploring the demands on students in "new" classroom activites. In K. Kumpulainen, C. Hmelo-Silver, & M. Cesar (Eds.), *Investigating Classroom Interaction. Methodologies In Action* (s. 7–26). Rotterdam: Sense publishers

Nielsen, J. A. (2012). Science in discussions: An analysis of the use of science content in socioscientific discussions. *Science Education*, 96(3), 428–456.

Nielsen, J. A. (2013a). Dialectical Features of Students' Argumentation: A Critical Review of Argumentation Studies in Science Education. *Research in Science Education*, *43*(1), 371–393.

Nielsen, J. A. (2013b). Delusions About Evidence: On Why Scientific Evidence Should Not Be the Main Concern in Socioscientific Decision Making. *Canadian Journal of science, mathematics and technology education*, *13*(4), 373–385.

Nowotny, H. (1981). Experts and Their Expertise: On the Changing Relationship Between Experts and Their Public. *Bulletin of Science, Technology & Society*, *1*(3), 235–241.

Orlander Arvola, A., & Lundegård, I. (2012). 'It's Her Body'. When Students' Argumentation Shows Displacement of Content in a Science Classroom. *Research in Science Education*, *42*(6), 1121–1145.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. Nuffield Foundation.

Ottander, C., & Ekborg, M. (2012). Students' Experience of Working with Socioscientific Issues - a Quantitative Study in Secondary School. *Research in Science Education*, *42*(6), 1147–1163.

Pedretti, E. (2003) Teaching Science, Technology, Society and Environment (STSE)

Education. In *The role of moral reasoning on socioscientific issues and discourse in science education* (p. 219-240). Dordrecht: Springer.

Pouliot, C. (2009). Using the Deficit Model, Public Debate Model and Co-production of Knowledge Models to Interpret Points of View of Students Concerning Citizens' Participation in Socioscientific Issues. *International Journal of environmental & Science Education*, *4*(1), 49–73.

Regeringskansliet (2017). *Stärkt digital kompetens i skolans styrdokument. [Strengthened digital competence in school directives.]* (Promemoria 2017–03–09.).

Rommetveit, R. (2008). *Språk, individuell psyke, og kulturelt kollektiv*. Oslo: Gyldendal.

Roth, M. (2014). Science language Wanted Alive: Through the dialectical/dialogical lens of Vygotsky and the Bakhtin circle. *Journal of Research in Science Teaching*, *51*(8), 1049–1083.

Roth, W.-M., & Désautels, J. (2004). Educating for Citizenship: Reappraising the Role of Science Education. *Mathematics and Technology Education*.

Rudsberg, K. (2014). Elevers lärande i argumentativa diskussioner om hållbar utveckling. (Doctoral Dissertation). Uppsala University.

Rudsberg, K., & Öhman, J. (2015). The role of knowledge in participatory and pluralistic approaches to ESE. *Environmental Education Research*, *21*(7), 955–974.

Rudsberg, K., Öhman, J., & Östman, L. (2013). Analyzing Students' Learning in Classroom Discussions about Socioscientific Issues. *Science Education*, *97*(4), 594.

Sadler, T. D. (2004a). Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research. *Journal of Research in Science Teaching*, *41*(5), 513–536.

Sadler, T. D. (2004b). Moral and Ethical Dimensions of Socioscientific Decision-Making as Integral Components of Scientific Literacy. *Science Educator*, *13*(1), 39–48.

Sadler, T. D. (2006). Promoting discourse and argumentation in science teacher education. *Journal of Science Teacher Education*, 17(4), 323 – 346.

Sadler, T. D. (2009). Situated learning in science education: socio-scientific issues as contexts for practice. *Studies in Science Education*, *45*(1), 1–42.

Sadler, T. D. (2011). *Socio-scientific Issues in the Classroom. Teaching, Learning and Research*. Germany: Springer.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What Do Students Gain by Engaging in Socioscientific Inquiry. *Research in Science Education.*, *37*, 371–391.

Sadler, T. D., & Dawson, V. (2012). Socio-scientific Issues in Science Education: Contexts for the Promotion of Key Learning Outcomes. In *Second International Handbook in Science Education* (Vol. 1–1). Dordrecht: Springer.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific Argumentation: The effects of content knowledge and morality. *International Journal of Science Education*, *28*(12), 1463–1488.

Sadler, T. D., & Zeidler, D. L. (2004). The Morality of Socioscientific Issues: Construal and Resolution of Genetic Engineering Dilemmas. *Science Education*, *88*, 4–27.

Sadler, T. D., & Zeidler, D. L. (2005a). Patterns of Informal Reasoning. *Journal of Research in Science Teaching*, *42*(1), 112–138.

Sadler, T. D., & Zeidler, D. L. (2005b). The significance of content knowledge for informal reasoning regarding socio-scientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education, 89(1), 71–93.*, *89*(1), 71–93.

Selwyn, N. (2011). *Education and Technology: Key Issues and Debates*. New York: Bloomsbury Publishing.

Sharma, A., & Anderson, C. (2009). Recontextualization of Science from Lab to School: Implications for Science Literacy. *Contributions from History, Philosophy and Sociology of Science and Mathematics*, *18*(9), 1253–1275.

Silverman, D. (2005). *Doing Qualitative Research A Practical Handbook* (Second edition). London: Sage.

Simmons, M. L., & Zeidler, D. L. (2003). Beliefs in the Nature of Science and Responses to Socioscientific Issues. In *The role of moral reasoning on socioscientific issues and discourse in science education* (p. 81–96). Dordrecht: Kluwer Academic Publishers.

Simonneaux, L., & Simonneaux, J. (2009). Students' socioscientific reasoning on controversies from the viewpoint of education for sustainable development. *Cultural Studies of Science Education*, *4*, 657–687.

Sjøberg, S. (2010). *Naturvetenskap som allmänbildning: en kritisk ämnesdidaktik* Lund: Studentlitteratur.

Skolinspektionen. (2010). *Fysik utan dragningskraft. En kvalitetsgranskning om lusten att lära fysik i grundskolan* (No. 2010:8).

Solomon, J., & Aikenhead, G. S. (1994). *STS Education: International Perspectives on Reform. Ways of Knowing Science Series*. New York: Teachers College Press.

Stadtler, M., & Bromme, R. (2007). Dealing with multiple documents on the WWW: The role of metacognition in the formation of documents models. *Computer-Supported Collaborative Learning*, *2*(2), 191–210.

Sykes, K. (2016). The Appeal to Science and the Formation of Global Animal Law. *European Journal of International Law*, *27*(2), 497–518.

Säljö, R. (1999). *Learning as the use of tools*. London New York: Routledge.

Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: technologies, social memory and the performative nature of learning: The performative nature of learning. *Journal of Computer Assisted Learning*, *26*(1), 53–64.

Säljö, R., Jacobsson, A., Lilja, P., Åberg, M., & Mäkitalo, Å. (2011). *Att förädla information till kunskap: lärande och klassrumsarbete i mediesamhället*. Stockholm: Norstedt.

Toulmin, S. E. (2003). *The uses of argument*. Cambridge, MA: Cambridge university press.

Tsai, C.-Y. (2018). The effect of online argumentation of socio-scientific issues on students' scientific competencies and sustainability attitudes. *Computers & Education*, *116*, 14–27.

Tsai, M.-J., Hsu, C.-Y., & Tsai, C.-C. (2012). Investigation of High School Students' Online Science Information Searching Performance: The Role of Implicit and Explicit Strategies. *Journal of Science Education and Technology*, *21*(2), 246–254.

van Eijck, M. (2012). Capturing the dynamics of science in science education. In *Second International Handbook of Science Education* (p. 1029–1039). Dordrecht: Springer Netherlands.

Venturini, T. (2010a). Building on faults: How to represent controversies with digital methods. *Public Understanding of Science*, *21*(7), 796–812.

Venturini, T. (2010b). Diving in magma: How to explore controversies with actor-network theory. *Public Understanding of Science*, *19*(3), 258–273.

Venturini, T. (2010c). How to represent controversies with digital Methods. *Public Understanding of Science*, *21*(7), 796–812.

Venturini, T., & Latour, B. (2010). The social fabric: Digital traces and qual-quantatitive methods. Retrieved from (www.medialab.sciences-po.fr/publications/ Venturini_Latour The_Social_Fabric.pdf).

Venturini, T., Ricci, D., Mauri, M., Kimbell, L., & Meunier, A. (2015). Designing Controversies and Their Publics. *Design Issues*, *31*(3), 74–87.

Vološinov, V. N. (1973). *Marxism and the philosophy of language* (Vol. 1). New York: Seminar Press.

von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to Learn and Learning to Argue: Case Studies of How Students' Argumentation Relates to Their Scientific Knowledge. *Journal of Research in Science Teaching.*, *45*(1), 101–131.

Vygotsky, L. (1978). *Mind in society: The development of higher social processes.* Cambridge, MA: Harvard University Press.

Vygotsky, L. (1986). *Thought and language.* Cambridge, MA: MIT press

Walker, K. A., & Zeidler, D. L. (2007). Promoting Discourse about Socioscientific Issues through Scaffolding Inquiry. *International Journal of Science Education*, *29*(11), 1387–1410.

Walraven, A., Brand-Gruwel, S., & Boshuizen, H. P. A. (2009). How students evaluate information and sources when searching the World Wide Web for information. *Computers & Education*, *52*(1), 234–246.

Wegerif, R. (2007). *Dialogic Education and Technology Expanding the Space of Learning.* Dordrecht: Springer.

Wegerif, R. (2011). Towards a dialogic theory of how children learn to think. *Thinking Skills and Creativity*, (6), 179–190.

Wells, G. (2007). Semiotic Mediation, Dialogue and the Construction of Knowledge. *Human Development*, *50*, 244–274.

Wertsch, J. V. (1998). *Mind as action.* New York: Oxford University Press.

Wertsch, J. V. (2007). Mediation. In H. Daniels, M. Cole, & J. V. Wertsch (Eds.), *The Cambridge companion to Vygotsky* (p. 178–192). New York: Cambridge University Press.

Wiblom, J., Rundgren, C.-J., & Andrée, M. (2017). Developing Students' Critical Reasoning About Online Health InformationOnline Health Informationica. *Research in Science Education*.

Wickman, P.-O., Liberg, C., & Östman, L. (2012). Transcending science: scientific literacy and bildung for the 21st century. In *Science Education Research and Practice in Europe: Retrospective and Prospective* (p. 39–61). Rotterdam: Sense Publishers.

Wickman, P.-O., & Östman, L. (2002). Learning as Discourse Change: A Sociocultural Mechanism. *Science Education*, 86, 601–623.

Wise, A. F., & Schwarz, B. B. (2017). Visions of CSCL: eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning*, *12*(4), 423–467.

Wu, Y.-T., & Tsai, C.-C. (2011). The Effects of Different On-line Searching Activities on High School Students' Cognitive Structures and Informal Reasoning Regarding a Socio-scientific Issue. *Research in Science Education*, *41*(5), 771–785.

Zeidler, D. L. (2014). Socioscientific Issues as a Curriculum Emphasis. Theory, Research and Practice. I S. Abell & N. Lederman (Red.), *Handbook on research in science education* (Vol. 1–II, s. 697–726). New York: Routledge.

Zeidler, D. L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In *The role of moral reasoning on socioscientific issues and discourse in science education* (p. 7–38). Dordrecht: Springer.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: theory and practice. *Journal of Elementary Science Education*, *21*(2), 49.

Zeidler, D. L., Osborne, J., Erduran, S., Simon, S., & Monk, M. (2003). The role of argument during discourse about socioscientific issues. In D. L. Zeidler (Ed.), *The role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education* (p. 97–116). Netherlands: Kluwer Academic Publishers.

Zeidler, D. L., & Sadler, T. D. (2010). An inclusive view of scientific literacy. *Exploring the landscape of scientific literacy*.

Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing reflective judgment through Socioscientific Issues. *Journal of Research in Science Teaching*, *46*(1), 74–101.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A Research-Based Framework for Socioscientific Issues Education. *Science Education*, *89*(3), 357–377.

Zohar, A., & Nemet, F. (2002). Fostering Students' Knowledge and Argumentation Skills Through Dilemmas in Human Genetics. *Journal of Research in Science Teaching*, *39*(1), 35–62.

Åberg, M., Mäkitalo, Å., & Säljö, R. (2010). Knowing and arguing in a panel debate. Speaker roles and responsivity to others. In K. Littleton & C. Howe (Eds.). *Educational dialogues: understanding and promoting educational dialogues (*p. 13-31*)*. London: Routledge.

# Part II The studies

Study I[23]: Solli, A., Bach, F., & Åkerman, B. (2014). Learning to argue as a biotechnologist: disprivileging opposition to genetically modified food. *Cultural Studies of Science Education*, *9*(1), 1–23.

Study II: Solli A. (under review) Appeals to science: recirculation of online claims in socio-scientific reasoning. *Research in Science Education.*

Study III[24]: Solli, A., Hillman, T., & Mäkitalo, Å. (2017). Navigating the Complexity of Socio-scientific Controversies—How Students Make Multiple Voices Present in Discourse. *Research in Science Education.*

Study IV: Solli, A., Mäkitalo, Å, & Hillman, T. (2018). Rendering controversial socio-scientific issues legible through digital mapping tools. *International Journal of Computer Supported Learning,* 13(4), 391-418

[23] Reprinted with permission from Springer

[24] Study III and IV are open access articles distributed under the terms of the Creative Commons Attribution License; which petmis unrestricted use, distribution and repreoduction in any medium provided the original work is properly cited.