Socioscientific argumentation

Aspects of content and structure

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Biology

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Abstract

Socioscientific argumentation has shown to be a feasible educational framework for promoting citizenship and for cultivating scientific literacy. However, there are several aspects of this educational framework that have been shown to be problematic. Consequently, in this thesis I investigated various aspects of quality of socioscientific argumentation from both an upper secondary student and a teacher perspective. By using students' written argumentation on socioscientific issues (SSI) I studied how they justified their claims. The results showed that different SSI led students to use different subject areas in their justifications. I also compared science majors with social science majors and found that the number of justifications provided by the students is related to their discipline background. In these two studies, a new content focused analytical framework for analyzing content aspects of socioscientific argumentation, the SEE-SEP model, was used and shown to be suitable for this purpose. However, to ensure that students are able to produce high-quality arguments I suggest that both content and structural aspects need to be considered. As a result of this, I have presented a framework based on research literature and the Swedish curriculum, for analyzing and assessing both these aspects of socioscientific argumentation. Moreover, I investigated how science and language teachers assess students' socioscientific argumentation and found that the science teachers focused on students' ability to reproduce content knowledge, whereas language teachers focused on students' ability to use content knowledge from references, and the structural and linguistic aspects of argumentation.

The complexity of teaching socioscientific argumentation makes it difficult to teach and assess comprehensively. In order to promote quality and include both content and structural aspects, I suggest that a co-operation among teachers of different disciplines is beneficial.

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Kabul
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List of papers

Paper I

Using the SEE-SEP model to analyze upper secondary students' use of supporting reasons in arguing socioscientific issues

Nina Christenson, Shu-Nu Chang Rundgren, and Hans-Olof Höglund (2012).
Journal of Science Education and Technology 21, 342-352.

Paper II

The relationship of discipline background to upper secondary students' argumentation on socioscientific issues

Nina Christenson, Shu-Nu Chang Rundgren, and Dana L Zeidler (2014).
Research in Science Education 44, 581-601.

Paper III

A framework for teachers' assessment of socio-scientific argumentation: An example using the GMO issue

Nina Christenson and Shu-Nu Chang Rundgren (2014).
Journal of Biological Education (published online).

Paper IV

Science and language teachers' assessment of upper secondary students' socioscientific argumentation

Nina Christenson, Niklas Gericke, and Shu-Nu Chang Rundgren.
Submitted to *International Journal of Science Education.*

Authors’ contributions

Authors’ contributions to Paper I

The overall work on this paper was done in collaboration by the first author (Christenson) and the second author (Chang Rundgren). All three authors read and approved the paper before submission.

The first author’s contributions to Paper I

- The introductory and overall plan and idea of the project
- Constructing the design of the project
- Collecting data, transcribing data
- Analyzing the data, managing validation process
- Writing text for all parts of the paper

The second author’s contributions to Paper I

- Mentoring the idea, the design and the writing process (including revisions)
- Mentoring the data analysis process
- Mentoring result calculations and presentation
- Executing the submission process and the correspondence with the publishers

The third author’s (Höglund) contributions to Paper I

- Discussing the idea of the project
- Elaborating and mentoring the development of the instrument, the four SSI scenarios used in Paper I and Paper II

Authors’ contributions to Paper II

The overall work on this paper was done in collaboration by the first author (Christenson) and the second author (Chang Rundgren). A substantial contribution was made by the third author (Zeidler). All three authors read and approved the paper before submission.

The first author’s contributions to Paper II

- The introductory and overall plan and idea of the project
- Constructing the design of the project
- Collecting data, transcribing data
- Analyzing the data, managing validation process
- Writing text for all parts of the paper
- Executing the submission process and the correspondence with the publishers

The second author’s contributions to Paper II

- Mentoring the idea, the design and the writing process (including revisions)

- Taking part in the validation process
- Mentoring the data analysis process and being responsible for the calculations and presentation of the results

The third author's contributions to Paper II

- Mentoring the writing process
- Mentoring and participating in revisions of the paper
- Mentoring and English language audit

Authors' contributions to Paper III

The overall work on this paper was done by the first author (Christenson). A substantial contribution was made by the second author (Chang Rundgren). Both authors read and approved the paper before submission.

The first author's contributions to Paper III

- The introductory and overall plan and idea of the project
- Constructing the design of the project
- Writing text for all parts of the paper
- Executing the submission process and the correspondence with the publishers

The second author's contributions to Paper III

- Mentoring the idea, the design and the writing process (including revision)

Authors' contributions to Paper IV

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The first author's contributions to Paper IV

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- Constructing the design of the project
- Collecting data, transcribing data
- Analyzing the data, managing validation process
- Writing text for all parts of the paper
- Executing the submission process and the correspondence with the publishers

The second author's contributions to Paper IV

- Mentoring the idea, the design, data collection, analyses and the writing process

The third author's contributions to Paper IV

- Mentoring the research process and the writing process

List of contents

Introduction

In democratic societies power comes from their citizens. Democracy is about equality, human rights and ensuring everyone has the opportunity to participate actively in politics and civic life. In a democratic society people need to have the skills to express their opinions, think critically and debate. This is the foundation on which democracy relies.

Today's societies impose many challenges on individuals. In many areas of our lives we are confronted with complex socioscientific issues (SSI). Contradictory messages from media about health, complex political issues and environmental challenges need to be decided upon, on both personal and societal levels. Consequently, people need to be prepared for these challenges and individuals need a wide range of competences. For many of the issues confronting us, science plays a vital role in our understanding of them. Hence, science education has an important role in enabling students not only to convey scientific knowledge but also to use this knowledge in decision-making and become socially responsible citizens.

To achieve the goal of sustainable development, we need to make sure that everyone can make decisions based on the better outcomes for the world. According to Jiménez-Aleixandre and Erduran (2008), democratic participation requires debate on different views rather than blind acceptance of authorities. This demands extensive support from educational systems in order to let students experience scientific concepts in authentic settings, meaningful contexts and socioscientific decision-making. Decision-making is recognized as an important part of scientific literacy, and includes processing scientific knowledge, using scientific content knowledge in problem-solving and developing the ability to think critically (Norris & Phillips, 2003). Moreover, scientific literacy has been referred to as the ultimate goal of science education. SSI and socioscientific argumentation have been proven to be a feasible educational framework for connecting science to matters of social importance and cultivating scientific literacy (Zeidler, 2014).

SSI are issues that have a basis in science (often at the frontier of scientific endeavor) and have a potentially large impact on societies (Ratcliffe & Grace, 2003). They are ideal for use in argumentative discourse in classrooms, and inclusion of socioscientific argumentation in science education means that students, according to Zeidler (2014), engage in methods of inquiry, make decisions including moral judgments, and solve problems.

Engaging in discourse about SSI aims at developing the character of the students so they become more critically responsible citizens and this requires a shift from the more traditional instructional paradigm towards a more student-centered science education (Zeidler, 2014). This poses challenges for science education and consequently for science teachers who need to provide students with opportunities to practice and develop the skills of socioscientific argumentation.

But how do upper secondary students justify their claims when arguing about SSI? Are there any differences between science and social major students' justifications in their socioscientific argumentation? How do teachers assess students' socioscientific argumentation? Are there any differences between science teachers' and Swedish language teachers' assessments? And what constitutes high-quality socioscientific argumentation? These are the questions I try to answer in this thesis about upper secondary students' socioscientific argumentation.

The thesis includes four papers based on the Swedish context. The Swedish curriculum for the upper secondary school is partly SSI-driven, recognizes the importance of education for democracy, and aims to develop responsible and active citizens: "Students should develop their ability to think critically, examine facts and relationships, and appreciate the consequences of different alternatives" (Swedish National Agency for Education, 2011a, p. 9). The aims of science subjects are addressed to help students participate in public debates, discussing issues and views from a scientific perspective. Moreover, students should also be able to put forward well-grounded, balanced arguments about complex issues where science plays a role for the individual and society (Swedish National Agency for Education, 2011a).

The first two papers of the thesis focus on content aspects of socioscientific argumentation among upper secondary students and the use of a framework named the SEE-SEP model. In the third paper, a framework, based on a literature review, for teachers' assessment of socioscientific argumentation with the consideration of both content and structure as quality aspects of socioscientific argumentation is developed and introduced. The fourth paper focuses on how science and language teachers assess students' socioscientific argumentation. Swedish language teachers have a long tradition of teaching and assessing argumentation, in contrast to science teachers, to whom the skill of socioscientific argumentation is relatively new in the curriculum, making this comparison interesting.

Aims and research questions

The aims of this thesis are to explore aspects of quality in students' socioscientific argumentation, investigate what aspects teachers consider in their assessment of socioscientific argumentation and develop a framework which makes it possible to consider both structural and content aspects of socioscientific argumentation.

Overall research questions

- What aspects with regard to content do students include in their argumentation on socioscientific issues? Are there any differences between science and social science major students?
- How can both structural and content aspects be taken into consideration when analyzing students' socioscientific argumentation with a focus on quality?
- What aspects do upper secondary science teachers and Swedish language teachers consider when assessing students' socioscientific argumentation? Are there any differences in their assessment of socioscientific argumentation?

Background

Scientific literacy

Science education is important for all students, not only for those who intend to pursue a career in science. This is called scientific literacy. In the following section two tenets of scientific literacy are outlined and discussed, along with a presentation of the various components and aspects associated with the notion of scientific literacy.

Vision I and Vision II

In Roberts' (2007) seminal work, he describes two different views about scientific literacy, Vision I and Vision II. Vision I focuses on knowledge in science and views science as a process and a product. Advocates of Vision I believe that there are fundamental ideas in science that need to be taught. Focus is on the content of science as a means to scientific literacy and to educate future scientists.

In Vision II, the aim is to prepare students to meet the challenges of a changing world. It recognizes the need for argumentation skills, the social context of science and that scientific literacy is of importance to all (Roberts, 2007). Vision II addresses the skills and knowledge needed by responsible citizens of modern societies. Roberts and Bybee (2014) also emphasized that it is the "outside world" that should inform science curricula and advocate for "science for citizenship" (p. 546).

To enshrine Vision II in science education, teaching needs not only to focus on science content but also on a teaching strategy, which involves discourse and the societal use of science such as socioscientific argumentation. Traditional science education has focused on a more content-oriented science teaching and this view is still prevalent among science teachers today (Holbrook & Rannikmae, 2009). Vision II's approach to scientific literacy is well in line with this thesis in dealing with students' socioscientific argumentation. However, I believe that the aim of science education should be to educate all students to become responsible citizens capable of decision-making, socioscientific argumentation and critical thinking. We also need people to be all of this *and* specialists in science, and both tenets of scientific literacy are relevant.

Definition of scientific literacy

Scientific literacy is not an easy notion to define, giving rise to a great number of different interpretations of what aspects to include (e.g. Laugksch, 2000; Roberts, 2007). According to Norris and Phillips' (2003) review of the literature on how the concept of scientific literacy is perceived among researchers, scientific literacy includes a variety of components, inter alia knowledge about the nature, scientific concepts and theories (the products of science). The concept also includes the skills of thinking scientifically along with the ability to use scientific knowledge in problem-solving as well as the knowledge needed for discussing science-based issues. Moreover, understanding the nature of science (the values, assumptions and characteristics of scientific knowledge, e.g. Wu & Tsai, 2007) and thinking critically about science and its relation to culture are included (Norris & Phillips, 2003). Critical thinking is a complex concept; in this thesis it is perceived as a crucial quality that citizens in a democratic society need. It refers to the ability to make choices and to know why you made these choices as well as respecting the choices of others and being able to participate in discussions (ten Dam & Volman, 2004). Roberts and Bybee (2014) also include the significance of discourse and, in particular, argumentation about SSI.

Scientific literacy and socioscientific argumentation

Including socioscientific argumentation in science education can promote the achievement of various aspects of scientific literacy. Sadler and Zeidler (2009) relate and frame SSI and socioscientific argumentation within the scientific literacy framework and point out that scientific literacy should be a goal for all students. Moreover, science learning should feature real issues and experiences and science education should embrace the multidisciplinary nature of SSI. According to Zeidler (2007), Vision II emphasizes a functional approach that is broader than Vision I in the sense that it involves personal decision-making on SSI.

Being a complex and multi-faceted concept, scientific literacy is hard to measure in a composed manner (Laugksch, 2000). Concerns have been raised about that science education has been too willing to assert the notion of scientific literacy despite the lack of evidence of its usefulness (Feinstein, 2010). Individual aspects of scientific literacy have been investigated but it is hard, not to say impossible, to cover such a broad concept in its whole. However, aspects of scientific literacy related to socioscientific argumentation have been investigated (e.g. Zeidler, Sadler, Appelbaum, & Callahan, 2009; Sadler & Zeidler, 2004) and in the following sections SSI and socioscientific argumentation will be outlined and presented.

Socioscientific issues (SSI)

SSI are contemporary scientific topics with a potentially large impact on societies and people's lives (Sadler, 2004). They have a base in science (often relating to cutting edge research) and require decision-making on a personal or societal level. SSI are complex and do not have any obvious correct answer, making them ideal for discussions. Moreover, SSI can be controversial and up to debate in the media

(Ratcliffe & Grace, 2003). SSI are multidisciplinary and often related to several fields of science and social science, e.g. gene technology or environmental issues (Chang Rundgren & Rundgren, 2010). Dealing with SSI often involves making a risk assessment (Kolstø, 2006) and these issues always contain ethical aspects (Zeidler & Sadler, 2008).

SSI provide a context for scientific content but also acknowledge the significance of social and cultural aspects of science in science education. SSI can be used in science education to promote citizenship and practice decision-making skills both for promoting a democratic society and on a personal level. Including SSI has been shown to evoke interest in learning science involving contemporary issues and it can also provide a context for learning about the nature of science (e.g. Sadler, 2004). As complex issues with dimensions from both science and social science SSI are multidisciplinary and they also serve as contexts for practicing and developing argumentation skills.

SSI as citizenship education

Since SSI have the potential to bridge science education and students' personal life, they can help to promote citizenship education (Sadler, Barab, & Scott, 2007). Including SSI can help students to be prepared and able to undertake their roles as active citizens in democratic societies. To function as active citizens, members of society need critical thinking and decision-making skills (ten Dam & Volman, 2004). However, the skills of critical thinking are hard to measure, and according to ten Dam and Volman (2004) no appropriate instrument for doing this is yet available. Despite this, several researchers in science education agree upon the usefulness of including SSI in the curriculum promoting critical thinking and citizenship (e.g. Albe, 2008a; Kolstø & Ratcliffe, 2008; Lee, 2007; Simonneaux, 2008).

Decision-making is central to research about SSI. Ratcliffe and Grace (2003) state, "decision-making implies commitment to a choice made voluntarily and from which deliberate action follows" (p. 118). Yet when discussing SSI in science education students mostly develop an "informed opinion" rather that an "informed decision", as the scenario is constructed for educational purposes and not real-life (Ratcliffe & Grace, 2003). This means that a real commitment, and deliberate action, is not necessarily the case. Nevertheless, the term decision-making will be used throughout this thesis, as it is a concept extensively adopted in literature describing similar tasks and research.

SSI and interest in science

Many national and international studies point to a decline in young people's interest in science (e.g. Schreiner & Sjöberg, 2004) and that many pupils perceive science as something difficult and uninteresting. In Sweden there is concern because fewer young people enroll in higher education focused on science and technology and also the lack of interest might lead to a less scientifically literate population (SOU, 2010).

Research has shown that using SSI in science education can help to evoke interest in science (e.g. Albe, 2008b; Bulte, Westbroek, de Jong, & Pilot, 2006; Chang Rundgren & Rundgren, 2010; Harris & Ratcliffe, 2005). The common explanation for this is that students are more motivated when the learning context involves issues they may encounter in their lives and can relate to (Sadler, 2009). In addition, the open-ended features of SSI, with no obvious correct answers, can make students feel free to talk openly. However, it is important to keep in mind that teaching science through SSI includes more discussions than does traditional science education. Some students can feel uncomfortable with this and, for example, do not speak up in group discussions because of social demands (Albe, 2008b).

Moreover, Ottander and Ekborg (2012) found in a large-scale quantitative study in Sweden about upper secondary students' experience of working with SSI, that students perceived this kind of work as interesting. In particular, learning science through SSI attracted girls who saw themselves as less interested in science and did not consider regular science classes engaging. They also reported a higher level of perceived relevance of science in school. However, the researchers also raised some concerns. Their results were based on students' self-reporting and not actual learning outcomes. In addition, the students reported that the work forms they used when working with SSI in class were similar to their regular school practice, indicating that they did not work with the SSI cases in the way suggested by the researchers and possibly underestimated their tasks (Ottander & Ekborg, 2012). However, the fact that including SSI in instruction evoked interest and a feeling of relevance must still be perceived as an important finding.

SSI and nature of science

Research shows that including discussions of SSI promotes learning about the methods of science, how to process and value the information related to the issue, and how finally to adopt an informed position (Sadler & Zeidler, 2004). In addition, several researchers suggest that SSI have the potential to help students better understand the nature of science (e.g. Khishfe & Lederman, 2007; Liu, Lin, & Tsai, 2011) and develop students' ability to reflect about science on a metacognitive level (Zohar & Nemet, 2002). Although SSI can help students better understand the nature of science, the findings of Sadler and Zeidler (2004) highlight that much more practice on this is needed. In their study, only about half of the students were able to identify and describe data. Other results from this study were more positive; many of the students were able to recognize the impact of multiple societal factors on science. The authors concluded by suggesting that using SSI in science education has the potential to help students develop knowledge and understanding of the nature of science and that how to do this needs to be included in pre-service teacher education (Sadler & Zeidler, 2004).

Multidisciplinary features of SSI

As stated earlier, SSI are complex and multidisciplinary issues involving several aspects of science (e.g. chemistry, physics, biology, etc.) but also morality and ethics (Sadler & Zeidler, 2009) economy and ecology (Patronis, Potari & Spiliotopoulou, 1999) and other social aspects of science. In a review by Chang Rundgren and Rundgren (2010) it was revealed that students' reasoning about SSI involved many subject areas and aspects, and they developed the SEE-SEP model to show this. This model serves as an analytical tool in two of the papers presented in this thesis and will be elaborated on later. Depending on the particular SSI that is introduced and included in science instruction, the learners get the opportunity to relate the science content that is included in the curriculum to a great variety of areas relevant in society. Hence, SSI can help students understand the complexity of and the many dimensions embedded in these kinds of issues (Lee & Grace, 2012). However, the multidisciplinary nature of SSI not only requires students to bring together different domains; the teachers must also be able to participate in and moderate discussions and consequently the pressure on them becomes high.

Since SSIs involve many different subjects they are suitable as cross-disciplinary projects (Ratcliffe & Grace, 2003). In addition, the vast number of different SSI makes it possible for teachers to choose what to focus on in their teaching. For example, in a lesson on genes and gene function in biology, an SSI about the implication of modern gene technology, e.g. designer babies, could be included in biology instruction. Consequently, complex content knowledge about genes and gene function is put in a context. An SSI about deforestation in the Amazon, for example, could be about biodiversity, people's working conditions, economic versus environmental interests and so on.

In addition to involving a large number of disciplines, SSI could also be reasoned about using the aspects of knowledge, values or experiences (Chang Rundgren & Rundgren, 2010). A vast number of studies investigate the use of content knowledge with regard to SSI in science education and highlight the importance of students supporting their socioscientific argumentation by using content knowledge (e.g. Chang & Chiu, 2008; Lewis & Leach, 2006; Sadler & Zeidler, 2004).

Moreover, the use of values has been found to be a common factor in students' reasoning on SSI (e.g. Chang & Chiu, 2008) as well as their experiences (e.g. Albe, 2008a; Chang & Chiu, 2008).

Morality and ethics are central to working with SSI. By including SSI in science instruction teachers give students the ability to develop reflective judgment, including moral and ethical aspects (Zeidler, Sadler, Appelbaum, & Callahan, 2009). Morals and ethics are often used together as concepts. However, morality describes the activities or behavior of a person and her/his understanding of right and wrong. Ethics are the rules by which moral actions are guided. Ethics is the reflection on activities and the norms that direct actions (Bergem, 2010). If one of the goals of science education is to educate citizens capable of responsible decision-making, SSI are a useful tool to help students develop more advanced ethical reasoning including consequences for others on a long-term and broader scale (Reiss, 2010). Research has shown that students' decision-making on SSI is in fact largely determined by moral considerations, showing the importance of addressing these aspects in science education (Sadler & Zeidler, 2004). The inclusion of moral and ethical aspects also evokes interest and motivation for learning science.

Challenges of SSI

Researchers have emphasized the importance of personal experience in the process of decision-making (e.g. Chang Rundgren & Rundgren, 2010; Patronis et al. 1999). Sadler (2004) concludes that using local issues that had direct impact on their own lives made students engage more as stakeholders in debates and that if SSIs are to be used for making science more relevant to students then local issues should be selected. However, as many of the great challenges we face today are global in nature, e.g. climate change, strategies for helping students to envisage connections between global issues and their own lives need to be developed as well.

There is also a challenge relating to students' ability to evaluate information used in decision-making about SSI. Since SSI are issues which are often on the frontiers of scientific endeavors, there are many different sources of information from media, politics, friends and so on to take into account when a decision is taken. Researchers have reported that students have limited capacity to perceive and use scientific data (Sadler, Chambers, & Zeidler, 2004) and use inconsistent evaluation criteria and superficial information (e.g. Kolstö, 2001). Hence, students tend to evaluate information or its sources in their decision-making on SSI in a questionable manner.

One important aim of including SSI in science education is, apart from sparking interest, conveying knowledge about the nature of science and promoting citizenship, is that SSI can serve as contexts for learning science. Hence, using SSI makes students understand and learn content knowledge within the science disciplines. Several researchers have investigated this relationship and the results suggest a positive relationship between learning science and working with SSI in science education (e.g. Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007; Klosterman & Sadler, 2010; Yager, Lim, & Yager, 2006). However, teaching according to an SSI-focused curriculum requires more resources than traditional science instruction in terms of time, and it is important to investigate further the relationship between learning outcome and use of SSI.

SSI and student discourse

Several researchers emphasize the central role of language in learning (and teaching) science (e.g. Lemke, 1990; Thörne, 2012). It was shown in a review article by Chang Rundgren and Rundgren (2010) that when working with SSI students get the opportunity to participate in scientific discourse and their communication can be enhanced accordingly. Hence, transfer of scientific content knowledge to real-life contexts means that students' scientific communication is promoted. Involving students in working with SSI in science education also include argumentation about these issues. Researchers have reported on interventions showing that SSI can serve as effective contexts for developing argumentation skills (e.g. Tal & Kedmi, 2006; Zohar & Nemet, 2002) but there are also results showing that this relationship is strongly related to the nature and quality of these interventions and that students struggle with producing advanced argumentation in the context of SSI (Albe, 2008a; Harris & Ratcliffe, 2005). However, argumentation and SSI are closely interwoven and in the research presented in this thesis socioscientific argumentation is in focus.

Argumentation and quality of socioscientific argumentation

In formal logic, which goes back to Aristotle and the Greek concept of *Logos*, argument is seen as form of syllogism, i.e. that a conclusion necessarily follows from the premises in a strict way. Sampson and Clarke (2008) describe argumentation as a complex process in which people participate when they generate, justify and explain claims and define an argument as the "artifact" that is created by a person in order to articulate and justify a claim. However, in science education dealing with SSI, formal argumentation with its rigid structure and fixed premises is not feasible. Since SSI are characterized as complex, open-ended issues that are ill-structured, Chang and Chiu (2008) suggested the term "informal argumentation", whereas arguers could base their argumentation on personal values and experiences and draw on information from a great number of resources.

Informal argumentation can, according to Kolstø and Ratcliffe (2008), be divided into rhetorical and dialectal forms of argument. A dialectal form of argument involves dialogues among two or more discussants. Rhetorical argumentation, on the other hand, refers to arguments used in monologic situations where a person tries to persuade an opponent or an audience. Hence, rhetorical argumentation can be seen as individualistic, inter alia when a person writes an opinion piece in a newspaper, whereas dialectical is more social in its nature. However, rhetorical and individual argumentation is, at least potentially, also part of a social context. One example is when a researcher carefully builds an argument in a scientific article. This article is then meant as a contribution to a debate in the scientific community and consequently is part of a social context (Kolstø & Ratcliffe, 2008). The same principle applies to the debate element in a newspaper; it is meant to be read and evoke some kind of reaction in the reader.

In science education both rhetorical and dialogical argumentation processes take place. Dialogical argumentation can be found among all the discussions going on in a classroom between the students and the teacher: both scientific argumentation when, e.g. students try to reason and find plausible explanations for phenomena observed during laboratory practical, and socioscientific argumentation when they are discussing scientific issues with ethical and societal implications. Individual rhetorical argumentation is also commonly present in the science classroom and, in addition, several researchers stress the important role of written text in conveying knowledge in education (e.g. Kelly, Regev, & Prothero, 2008; Sandoval & Millwood, 2005; Takao & Kelly, 2003). It is also common practice for students to be assessed on the basis of their written discourse.

In the research presented in this thesis the terms informal argumentation, SSI argumentation and socioscientific argumentation are used and clearly relate to the terms argumentation, reasoning and informal reasoning that are used in the literature. In the first two papers the terms argumentation and informal argumentation is used to refer to students' argumentation on SSI. Informal argumentation is a concept presented in the article introducing the SEE-SEP model (Chang Rundgren & Rundgren, 2010) that was used as an analytical framework in Papers I and II. In the third paper, the term SSI argumentation is used and in the fourth paper it is stressed even more clearly by use of the term socioscientific argumentation, emphasizing that the argumentation takes place within the context of SSI (informal argumentation can also take place in contexts other than SSI). The term socioscientific argumentation is used by several science education researchers (e.g. Acar, Turkmen, & Roychoudhury, 2010; Sadler & Donnelly, 2006) and adopted in this thesis. The changes in terminology mirror the fact that the research underlying this thesis has taken almost seven years and the concepts tend to change in contemporary published research and consequently also in the papers included in this thesis.

Argumentation in science education

Argumentation is a core epistemic practice in science and by engaging students in argumentation they acquire access to "the scientific enterprise" (Bricker & Bell, 2008, p. 474; Kelly & Bazerman, 2003). Bricker and Bell (2008) mean that via argumentation students get to "live" science, in contrast to more traditional science education, where teaching conclusions is the main event. Argumentation helps students to engage more efficiently in scientific ideas as they interact socially. Hence, structuring science education to focus on argumentation makes students experience science as it is (e.g. Bricker & Bell, 2008; Driver, Newton, & Osborne, 2000; Sandoval & Millwood, 2008).

Argumentation can be conceived as context-dependent: in order for arguments to be considered as good or valid, they need to be consistent with the epistemological criteria used by the scientific community in the context of which the arguments are produced. To be able to engage in argumentation certain skills and knowledge are needed. Important epistemic criteria related to argumentation also include the need to provide backing and relevant justifications for claims (Sampson & Clark, 2008), establish the credibility for evidence (Driver et al., 2000) and base arguments on reasoning that is logical (Zeidler, 1997). Hence, including argumentation in science education promotes the development of students' personal epistemology.

The advantages of including argumentation in science education are many. Jiménez-Aleixandre and Erduran (2008) propose several dimensions relating to disciplinary, social and personal epistemological perspectives resulting from the inclusion of argumentation in the science classroom:

- supporting the development of communicative competences and particularly critical thinking;
- supporting the achievement of scientific literacy and empowering students to talk and write the languages of science;
- supporting the enculturation of students into the practices of scientific culture and the development of epistemic criteria for knowledge evaluation;
- supporting the development of reasoning, particularly the choice of theories or positions based on rational criteria.

Socioscientific argumentation

All the reasons outlined above supporting the inclusion of argumentation in science education are also valid for socioscientific argumentation. According to Tiberghien (2008) there are two main goals of scientific argumentation in science education: "developing students' knowledge and skills on the nature of science" and "favouring learning, more specially developing higher order thinking" and about socioscientific argumentation "developing students' citizenship in particular in the case of socio-scientific issues" (p. xi).

So what are the characteristics of socioscientific argumentation? The context provided by SSI for argumentation practice renders socioscientific argumentation different from scientific argumentation (Chang & Chiu, 2008). Socioscientific argumentation, like scientific argumentation, involves the evaluation of evidence. It also involves conceptualizations on the nature of science and how values play a role in decision-making. The term socioscientific argumentation means that the argumentation is about an SSI, an ill-structured, complex issue. As mentioned earlier, these issues are often positioned on the frontier of scientific research and, consequently, evidence on socioscientific argumentation may include many uncertainties (Kolstø, 2001). One example of this is the issue of whether extensive use of cell phones poses a risk to human health. Research reports contradictory results, making it hard to rely on authorities when making an argument on this issue and the evaluation of evidence is hard (Kolstø, 2001).

Values play a fundamental role in socioscientific argumentation. Accordingly, researchers have shown that students tend to use emotive reasoning more than other reasoning types (Sadler & Zeidler, 2005a). In addition, there can be more than one position on an issue, each with appropriate justification, because of the uncertainty of evidence and because values are part of socioscientific argumentation (Acar et al., 2010).

Inclusion of socioscientific argumentation in science education is intended to develop students' understanding of and ability to consider scientific evidence (Durschl & Osborne, 2002) and to develop higher-order thinking skills (Walker & Zeidler, 2007). However, as pointed out by Solli (2012), most studies of the learning outcomes of including socioscientific argumentation are focused on individuals and not social contexts. However, normally students have access to a plethora of resources, including other people, when confronted with SSI and consequently Solli (2012) argues it is of great interest to investigate how students use SSI in social contexts. Hence, there is a gap between reality and research about students' socioscientific argumentation that needs to be filled.

Challenges of teaching socioscientific argumentation

As shown earlier, there are many advantages of including socioscientific argumentation in science education such as developing students' knowledge and skills on the nature of science, developing higher-order thinking and developing students' citizenship. However, inclusion of socioscientific argumentation in science education can be a challenging task for teachers. As mentioned earlier, the multidisciplinary nature of SSI requires students to bring together several different domains. This poses a challenge to teachers, who need to have knowledge of both the content of various disciplines (Levison, 2006; Simonneaux, 2008) and recent scientific endeavors (Harris & Ratcliffe, 2005) making it hard to decide which scientific evidences to include in socioscientific argumentation.

The pedagogy of teaching science using socioscientific argumentation includes students actively discussing the dilemmas. Several researchers have found that managing this kind of discussion is difficult and complex for science teachers (e.g. Levison, 2004; Osborne, Duschl, & Fairbrother, 2002). More difficulties to be overcome are science teachers' lack of confidence about teaching argumentation (Levison & Turner, 2001) and their uncertainties around epistemological distinctions of what counts as data and theories (Grace & Ratcliffe, 2002). In addition, to value messages in the media and how to use media in science education can also be problematic (Simonneaux, 2008).

Newton, Driver, and Osborne (1999) found that the science classroom discourse in their investigation was mainly teacher-dominated and gave two explanations for this. The teachers relied on an "old", traditional pedagogy and it was hard to shift towards a more student-active classroom discourse. Also, even though the curriculum changed, the time pressure caused by more and more assessment activities and fulfilling the syllabus made teachers "unable to pay attention to broader issues… to discuss the social and ethical implications of scientific developments" (Newton et al., 1999, p. 571). In addition, learning argumentation skills is a time-consuming activity that requires a lot of practice with repeated sessions (Jiménez-Aleixandre, 2008). These findings are supported by Ekborg, Ottander, Silfer, and Simon (2013), who found that teachers reporting on their experiences of working with SSI, felt great pressure to cover the canonical content in the syllabus and prepare students for tests. The teachers raised the question of whether it was realistic to spend time on including SSI in science education. Consequently, the authors concluded that transforming pedagogy (from more traditional science teaching towards including socioscientific argumentation) is difficult and that teachers need support to do this.

Quality of socioscientific argumentation

Assessing and evaluating the quality of socioscientific argumentation is not easy for teachers (Simonneaux, 2008). According to Evagorou, Sadler, and Tal (2011) the tools available are limited. Assessing socioscientific practices is a very complex task since argumentation in terms of SSI concerns social, ethical and scientific perspectives and both context and content are important considerations. Therefore, development of strategies to evaluate and assess argumentation consistently is needed (Evagorou, 2011). Sampson and Clark (2008) emphasize the importance of including both content and structure in analysis and assessment of socioscientific argumentation. However, existing analytical frameworks tend to focus on either content or structural aspects (Sampson & Clark, 2008).

Toulmin Argumentation Pattern

The majority of research on analytical approaches and argumentation in science education has used the Toulmin structural framework for analyzing arguments. This framework, also known as the Toulmin Argumentation Pattern (TAP), is an analytical framework and a tool for analyzing the strengths and weaknesses of arguments (Bricker & Bell, 2008). In a review article by Sampson and Clark (2008), TAP is categorized as a domain-general analytical framework with focus on structural issues. It consists of *claims*, which are a conclusion, proposition, or assertion about the issue, *data* (grounds), which include any evidence provided by the arguer that supports the claim and *warrants*, which involve an explanation of the relationship between the claim and the data. The next component is *backings*, which are the basic assumptions that support the warrants, data and claims. *Qualifiers* provide conditions under which the arguer considers a claim to be true (e.g. usually, possibly, certainly, necessarily). The last component is *rebuttals*, which are the conditions under which the claim can be rejected (Toulmin, 2003). According to TAP the strength of an argument is based on the presence or absence of specific combinations of these structural components (Sampson & Clark, 2008). This framework has had great influence on later analytical frameworks, particularly those focused on the structure of arguments.

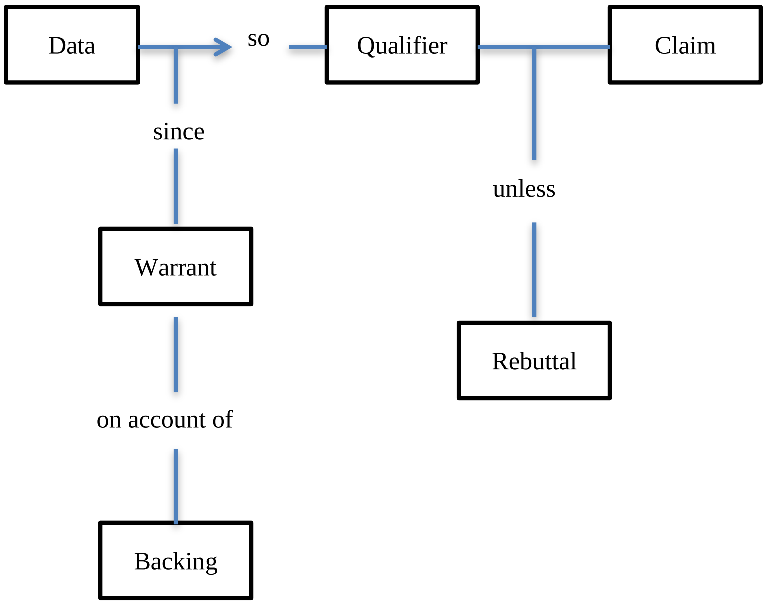

Figure 1. Toulmin Argumentation Pattern, TAP (Toulmin, 2003).

Toulmin argues that the context is critical to understanding an argument and criticizes the strict rules of argumentation set by formal logic (Bricker & Bell, 2008; Toulmin, 2003). Despite this, TAP is used and often perceived as if the context is of no significance (Bricker & Bell, 2008). Although Toulmin developed TAP to function in an everyday argumentation context (differently from formal logic), it has often been perceived as quite the opposite – not possible to apply in everyday contexts (e.g. Bricker & Bell, 2008; Chang & Chiu, 2008; Erduran, Simon, & Osborne, 2004; Jiménez-Aleixandre & Erduran, 2008; Sampson & Clark, 2008). Some of the components of the TAP framework are missing in everyday argumentation and a possible explanation of this, according to Simosi (2003), is that the missing elements seem so obvious or well-known to the arguer that she/he does not include them explicitly in her/his argumentation. Another complication in applying TAP is that segments of arguments made by students can be hard to categorize and can be classified into multiple categories, which weakens the reliability of the use of TAP (Sampson & Clark, 2008).

Some researchers using TAP, including Bell and Linn (2000), have found that students tend to rely on data to support their claims but seldom include warrants and backings in their arguments. In another study using TAP as an analytical framework, Jimenez-Aleixandre, Rodriguez, and Duschl (2000) found that students constructing arguments about genetics focused on making detailed claims but did not support them with data or warrants.

Several researchers have modified TAP in different ways to better suit their analysis. Inter alia, Erduran et al. (2004) simplified it and proposed a difference between the *first-order elements* of an argument (claims, grounds and rebuttals) and the *second-order elements* (data, warrants and backings, the grounds for claims). They also developed a five-level scale of argument quality and called for a "reliable systematic methodology for (a) identifying argument and (b) assessing quality" (p. 1015). In addition, since TAP only takes into account the presence or absence of the different elements in the pattern, the accuracy or relevance of the content of the argument is not measured and neither are the logical structure and coherence of the justification nor if the argument as a whole makes sense or not (Sampson & Clark, 2008).

Structure and content

There is great variety among the frameworks developed to study students' argumentation in scientific contexts (e.g. Kelly & Takao, 2002; Sandoval, 2003; Sandoval & Millwood, 2005; Schwarz, Neuman, Gil, & Ilya, 2003; Toulmin, 2003). In a review article by Sampson and Clark (2008) about frameworks developed in science education research to assess arguments in science education, two main aspects can be discerned, namely the *structure* or the complexity of the argument in the context of science (i.e. the components of an argument) and the *content* of an argument (i.e. the adequacy or accuracy of the components in the argument from a scientific perspective). They define two groups of analytical frameworks; domain-general and domain-specific. Domain-general frameworks can be used to analyze argumentation quality both inside and outside the field of science whereas domain-specific frameworks focus on argumentation within the field or subfield of science-specific contexts. I would like, in line with Zeidler (2014), to call the domain-general analytical frameworks "structure-oriented", since these mainly focus on different components and their presence within arguments and don't consider the content and the context. I will also call the domain-specific frameworks content-oriented since these frameworks mainly focus on the content of arguments. In line with Sampson and Clark (2008), Sandoval and Millwood (2005) conclude that in terms of helping students learn to construct arguments, analytical frameworks that make it possible to ensure *both* that students are making the right kinds of arguments (structure-oriented) *and* that such arguments make sense (content-oriented) are important.

Review of analytical frameworks

In the following section, I review literature on analytical frameworks and focus on the quality criteria of socioscientific argumentation that the authors present in their frameworks. The purpose of the review is to explore the quality aspects that analytical frameworks include in order to assess students' socioscientific argumentation (papers included in this review: Chang & Chiu, 2008; Grace, 2009; Osborne, Erduran, & Simon, 2004; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Tal & Kedmi, 2006; Wu & Tsai, 2007; Zohar & Nemet, 2002). The result of the review is presented in Table 1.

Table 1. The reviewed studies and their quality criteria.

Study	Focus of paper	Scoring rubric	Components of analytical framework	Indicators of high-quality socioscientific argumentation
Chang & Chiu, 2008	To develop an analytical framework based on Lakatos work and analyze students' argumentation about GMF	Not explicit	Claim Supporting reasons (with special focus on the resources in the reasons) Counterargument Qualifier Evaluation arguments	The presence and number of components in the analytical framework
Grace, 2009	To explore the possibility of decision-making discussions as means to develop students' reasoning and if there are features that are common to high-quality discussions which teachers can identify	A level 1-5 grade scale (level 5 can be divided into two levels)	Non-justified arguments Non-functional, partly justified arguments Non-functional, justified arguments with no consideration of alternatives Non-functional, justified arguments considering alternatives Functional, justified arguments considering alternatives	Presence of functional reasoning (highest quality), consideration of alternative solutions (adds to the quality) and justification of views (basic grade of quality) in students' arguments The complexity and quality are determined by the presence of these components
Osborne et al., 2004	To assess students' progression on	A level 1-5 grade scale based on the presence and	Based on TAP Data Claims	Level 5 arguments display an "extended" argument with more than one rebuttal (extended means

	argumentation after focused intervention on socioscientific or scientific argumentation	absence of TAP components	Warrants Backings Qualifier Rebuttals (counterargument) Counterclaim	that the argumentation includes a series of claims with data, warrants and backings as well as counterclaims)
Sadler & Donnelly, 2006	Investigate how content knowledge and morality contribute to the quality of SSI argumentation	A 0-2 score on three different assessment criteria; position and rationale, multiple perspective-taking and rebuttal	Position and rationale: claim with grounds or claim without grounds or no clear claim Multiple perspective: expression of multiple perspectives on own initiative or at interviewers' explicit request or inability to do so Rebuttal: student challenges the grounds of a counter-position or student presents a counter-position but does not challenge its grounds or student is unable to present or point out weaknesses or address counter-position directly Consider students' use of content knowledge (correct content knowledge, superficial or revealing misconceptions) and takes into consideration if students use moral aspects and	Claim with grounds Expression of multiple perspectives on own initiative Student challenges the grounds of a counter-position

			personal choice	
Sadler & Fowler, 2006	How individuals make use of scientific content knowledge in socioscientific argumentation	A 0-4 point rubric on justification quality	Number of justifications Score on justification quality: 0: No justification 1: Justification with no grounds 2: Justification with simple grounds 3: Justification with elaborated grounds 4: Justification with elaborated grounds and counter-position	Number of justifications and justification quality where the highest-quality justification includes elaborated grounds and a counter-position
Tal & Kedmi, 2006	To examine the culture of a teaching unit dealing with authentic socioscientific issues and how this affects students' higher-order thinking skills	Three different criteria; each can score between 0 and 4 (the different criteria could have different maximum scores) In addition the arguments containing a moral judgment are classified as being value- based	Number of justifications Use of scientific knowledge (categorized as superficial, general or specific) Number of aspects Synthesis (counterarguments and rebuttals)	For the highest-quality assessment of reasoning the arguments should have three or more justifications, use specific scientific knowledge, have at least four aspects and include a counterargument and rebuttal, yielding a complex, coherent idea
Wu & Tsai, 2007	To examine learners' informal reasoning on	Not explicit	The analyses of students' arguments are divided into qualitative indicators (decision-	High levels of reasoning and inclusion of different reasoning modes are considered as high-quality

	socioscientific issues by using an integrated analytical framework		making mode, reasoning mode and reasoning level) and quantitative measures including: Total number of reasoning modes (social-, ecological-, economic- or science-oriented modes) and assessment of reasoning level based on: Number of supportive arguments Number of counterarguments Number of rebuttals and Total number of arguments (the total number of supportive arguments, counter-arguments and rebuttals)	reasoning
Zohar & Nemet, 2002	Examine the outcomes of a unit that integrates explicit teaching of general reasoning patterns into teaching about dilemmas in human genetics	Not explicit	Measure of content knowledge applied in students' arguments: No knowledge considered Incorrect consideration of knowledge Consideration of non-specific knowledge Correct specific knowledge considered The categories of the analysis of arguments:	Greater application of correct specific knowledge as well as high number of justifications and other indicators (categories) of arguments, the higher the quality of arguments

			explicit conclusion justification concession implicit conclusion opposition and counter-opposition	

The literature on analytical frameworks focus on both content and structurally oriented quality aspects (Chang & Chiu, 2008; Grace, 2009; Osborne et al., 2004; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Tal & Kedmi, 2006; Wu & Tsai, 2007; Zohar & Nemet, 2002). The most common quality criteria used by the authors are related to structural aspects such as the ability to provide a justification together with a claim (Chang & Chiu, 2008; Grace, 2009; Osborne et al., 2004; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Tal & Kedmi, 2006; Wu & Tsai, 2007; Zohar & Nemet, 2002). The ability to provide a counter-argument, showing an alternative view, is also perceived to be of great importance. These three, claim, justification and counter-argument, are the most common structure-oriented aspects presented among the articles included in this review and to be able to include more (in numerical terms) of these structural aspects strengthens the argument. Considering content-based aspects of quality of SSI argumentation, the provision of data or content knowledge to justify the claim is included in many of the analytical frameworks (Osborne et al., 2004; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Tal & Kedmi, 2006; Zohar & Nemet, 2002). The inclusion of an evaluation of content knowledge as scientifically correct is also seen as important; the knowledge used in the justification should not be superficial or a misconception. Showing consideration of and including multiple perspectives in the argumentation of SSI is seen as a quality aspect by some researchers (Chang & Chiu, 2008; Wu & Tsai, 2007) as are ethics and morality, if the arguer can show an expounded moral judgment and an understanding of the broader consequences of the chosen standpoint (Sadler & Donnelly, 2006; Tal & Kedmi, 2006). One thing these analytical frameworks have in common is that they were developed for research purposes and therefore are relatively complex.

The Swedish curriculum from the perspective of SSI and argumentation in science education

The Swedish curriculum (Swedish National Agency for Education, 2011a), GY2011, provides the most influential guidelines for upper secondary school (grades 10 to 12) in Sweden. It states the general obligations and goals for the schools. This curriculum is focused on both Vision I and Vision II regarding scientific literacy.

The Swedish upper secondary school programs and steering documents

There are 18 national programs to choose from in Swedish upper secondary school, each lasting three years. Twelve of the programs are vocationally-oriented and six are higher education preparatory programs. The steering documents relating to Swedish upper secondary schools that are presented in GY2011 exists on three levels.

- Program objectives detail the aim and goals of the program, the structure of the program including the courses offered as well as the different options. All programs include the foundation subjects English, history, physical education and health, mathematics, science studies, religion studies, civics and Swedish language (or Swedish as a second language). In the Science Program, science studies is replaced by biology, physics and chemistry and in the Technology Program by chemistry and physics. The foundation subjects' history, civics, science studies and mathematics are represented by different courses depending on the program they are included in. Each program also has subjects unique to that program, orientations, program specializations and a diploma project.
- The section "Aims of the subject" specify the aims of the subject and also related goals. The aims are unique to specific subjects and describe what knowledge students should have the opportunity to develop. This section also express aims that will not be included in assessment, like basic values and development of students' own capabilities.
- The subjects are taught in different courses which all have specific syllabi. The syllabi detail the objectives and aims of each course and also indicate what skills and knowledge students are expected to have acquired upon completion of the course. Grading criteria for each course are provided within each syllabus.

The curriculum

There is apparent support in the curriculum for preparing students to become active citizens and that knowledge and values should be imparted and passed on accordingly. This is related to the notion of citizenship embedded in socioscientific argumentation and corresponds to the aims and outcomes of teaching socioscientific argumentation.

- The task of the school is to encourage all students to participate actively in society.
- Emphasize the importance of forming personal views and provide opportunities for doing this.
- Develop students' ability to think critically, examine facts and relationships, and appreciate the consequences of different alternatives.

Critical thinking, decision-making, discussion and developing a standpoint are all skills associated with teaching and learning socioscientific argumentation and also included in the curricula.

- All individual students should have the ability to critically examine and assess what they see, hear and read in order to be able to discuss and take a view on different issues concerning life and values.

Assessment guidelines

The science subjects chemistry, biology and physics have many of the same objectives and goals supporting SSI activities and socioscientific argumentation (Swedish National Agency for Education, 2011b).

In the syllabi for chemistry, biology and physics:

- teaching should help students participate in public debates and discuss ethical issues and views from a scientific perspective.

When a student has completed a course the level of proficiency she/he has achieved is assessed. The grades in the Swedish school system are on an ascending scale and have five pass levels E, D, C, B and A and a fail grade F. Knowledge requirements are specified for three of the grades, E, C and A. Hence, the grading scale does not specify knowledge demands for D and B.

In the criteria for grade A in chemistry, biology and physics that are the first science courses the students at the Natural Science Program encounter.

- Students discuss in detail and in a balanced way complex issues concerning the importance of chemistry/biology/physics for the individual and society. In their discussions, students put forward well grounded and balanced arguments and give an account in detail and in a balanced way of the consequences of several possible viewpoints.

In the syllabus for the first course in Swedish language that the students encounter there is support for teaching argumentation (Swedish National Agency for Education, 2011c).

- Teaching in the course should cover argumentation techniques and written communication of argumentative text.

In the instructions for grading the course in Swedish, grade A.

- Students can write argumentative texts that are coherent, comprehensible and well structured and adopted to purpose, recipient and communication situation. The structure of the written work is clearly discernable.

Given the statements about the importance of including critical thinking, ability to discuss societal issues from a scientific perspective, active participation in society and democratic values, it can be argued that socioscientific argumentation should be an important component in science education in Swedish schools in order to fulfill the intentions of the curriculum.

Assessment in a Swedish context

The Swedish curriculum is relatively short and the content is stated in general terms at all levels, giving teachers a lot of freedom. The autonomy of teachers in the Swedish school system is extensive; it is up to the teachers to decide on teaching methods.

Moreover, it is the individual teacher's responsibility to operationalize the general statements on the grading criteria into assessment of the activities. The grades are aggregated from not only written summative tests and exams, but also from other types of activities in the classroom such as oral presentations, inquiry skills, argumentation skills, etc. This is not an easy task and several researchers have shown that teachers interpret the curriculum differently for various reasons (Selghed, 2004; Tholin, 2006).

The policy-makers' intentions when introducing a criterion-referenced grading system were that teachers, in professional and collegial dialogue, would discuss how to interpret the grading system instructions and reach a consensus (Karlefjärd, 2011; Skolverket, 1996). However, this consensus has been hard to reach and research shows that teachers have been given insufficient instructions on how to interpret and implement the grading system and not enough time for collegial discussions (Selghed, 2004; Tholin, 2006).

Methods

The overall aim of this thesis is to investigate various aspects of quality in students' socioscientific argumentation, including how teachers consider these aspects in their assessment. An equally important aim is to develop a framework making it possible to consider both structural and content aspects of socioscientific argumentation. For this purpose several research methods were applied in the four studies that are included in this thesis, and these will be described in detail in this section.

Paper I and Paper II

The methods for Paper I and II are outlined together since they have much in common.

The research questions in Paper I are:

1. How is the distribution of supporting reasons represented in students' informal argumentation?
2. Do the distributions of supporting reasons differ among the four topics of SSI?
3. Are there any alternative conceptions presented in regard to knowledge in students' informal argumentation?

The research questions in Paper II are:

1. How do science and social science major students make justifications in their written arguments on SSI?
2. Are there any differences in the aspects of knowledge, value, and experiences used by students in relation to their discipline backgrounds?
3. Are there any differences in the justifications connected to six subject areas (sociology/culture, economy, environment /ecology, science, ethics/moral, and policy) used by students with different discipline backgrounds?
4. What is the nature of differences that may exist in the kinds and number of justifications used by students in relation to their discipline backgrounds?

Data collection

The data reported in Paper I and II consist of written reports. For the first study 80 reports were collected and for the second study another 128 reports were added; hence a total of 208 reports were included in Paper II. The data collection was done during the last month before the students graduated from their upper secondary schools and followed the same procedures in both studies. The data collected in the first paper were also included in the second, along with more reports collected in the same way, one year later. The students were asked to articulate their opinions in writing and respond to an SSI. The students could choose between four different SSI: global warming, genetically modified organisms (GMO), nuclear power and consumption. The prompts including the four SSI are outlined below. The data collection was done in classroom settings and the classrooms could be designed for various subjects, not necessarily science. The students were informed that none of their teachers would read their report and that it would not be included in any kind of school assessment. I was present during most of the data collections, where I introduced myself, the purpose of the task and read the SSI aloud and asked if any clarifications were needed. However, I was for practical reasons absent during two data collections, which were done by a teacher reading the introduction I normally gave. There was no time limit for completing the task and the average time spent was 30 minutes. The prompts were successfully piloted by two classes of students (approximately 50 students), to see if the instructions were clear and that the students understood the task. The students wrote by hand and all reports were transcribed into digital form before the material was coded.

The four SSI prompts students could choose were as follows.

Topic 1: Global Warming
Recently there has been a debate on whether global warming depends on anthropological factors or if it is due to natural processes. Do you believe that climate change is due to natural processes or to human activities? Please write down your opinion as clearly as possible, and try to make your arguments the best you can.

Topic 2: GMO
GMO (genetically modified organisms) means genetically modified plants, animals and microorganisms. They have had their genes changed by using methods that do not exist naturally. Genetically modified agricultural plants are, since the end of the 1990s, common in North- and South America, where many of the soy, corn and cotton crops are genetically modified. In

the rest of the world, GMO- "farming" is scarce. Do you agree that GMO should be produced and sold? Please write down your opinion as clearly as possible, and try to make your arguments the best you can.

Topic 3: Nuclear Power
According to the new energy agreement made by the current national government, Sweden is keep going to depend on energy from nuclear power. The law that stated that all nuclear power in Sweden should be terminated has recently been changed, so that it will be possible to build new reactors, which has been forbidden since 1980. Do you agree that Sweden should use and invest on developing nuclear power as a source of energy? Please write down your opinion as clearly as possible, and try to make your arguments the best you can.

Topic 4: Consumer Consumption
Our way of consuming, for example clothes and food, has an impact on the environment and society, at both local and global levels. Some people believe that our consumption is far too excessive and affects our environment in a negative way, whilst others state that consumption is the best way to increase trade, which creates benefits and stimulates the development of environmentally sound technologies. What are our responsibilities as consumers, in your opinion? Please write down your opinion as clearly as possible, and try to make your arguments the best you can.

Participants

Students from three upper secondary schools participated in the first two studies (reported in Papers I and II). Two of the schools are situated in a medium-sized town and the third in a small-sized town in Sweden. In the first study, a total of 80 upper secondary students' reports were collected and analyzed, and 208 students' reports were analyzed in the second study, including the first 80 (see Table 2). Among the participating students in the second study, there were 103 students from the science program and 105 from the social science program. The students from the science program had taken advanced courses in chemistry, biology, physics and mathematics. The students from the social science program had studied mathematics, chemistry, biology and physics less than the science majors. Both groups of students had taken the mandatory general science course, including topics like ecology, energy and environmental science.

Table 2. Participants in the first and second studies.

Participants / Study	Total	Gender		Study background	
		Female	Male	Social science major	Science major
First study	80	58	22	40	40
Second study	208	124	84	105	103

Data analysis

The SEE-SEP model (Chang Rundgren & Rundgren, 2010) was developed from an extensive literature review and is the analytical framework used in Paper I and Paper II to investigate the aspects and subject areas that are included in students' socioscientific argumentation. It recognizes the multi-dimensional perspectives involved in various SSI and covers six subject areas comprising sociology/culture (So), economy (Ec), environment/ecology (En), science (Sc), ethics/morality (Et) and Policy (Po). These subject areas are connected to the three aspects of knowledge (K), value (V) and experience (E). This generates 18 codes (see Figure 2).

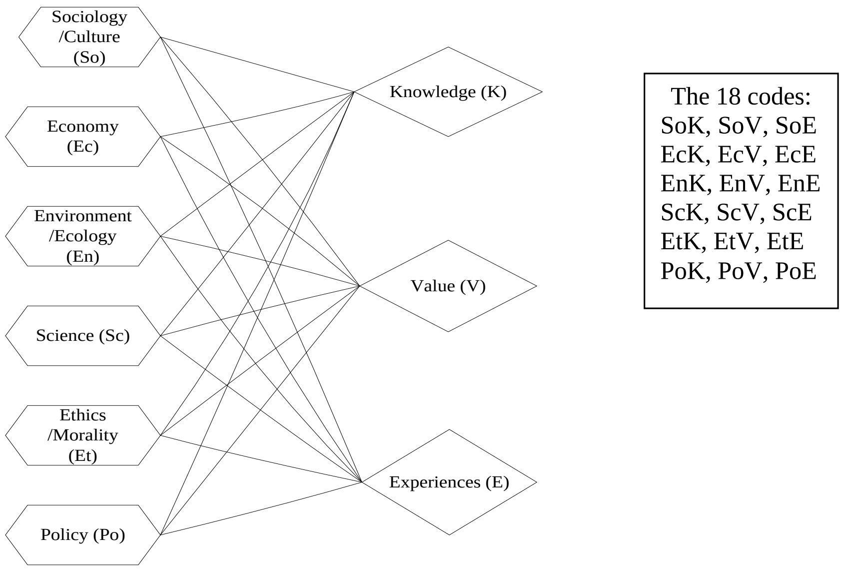

Figure 2. The SEE-SEP model and the 18 codes (Chang Rundgren & Rundgren, 2010).

The SEE-SEP model is a content-oriented framework. The aspects of knowledge, value and experience are central to this model and need some clarification. The term knowledge, according to the authors, includes concepts, theories, laws or evidence within subjects, in other words, the content knowledge of a subject. The value concept is related to students' attitudes (a positive or negative evaluation) and their affective (concerning the emotions) domain. This is predicated on the idea that SSI cannot be fully justified by scientific knowledge only, there will always be values guiding the student's decision. Values are the principles that guide action; students value some object or circumstance more than another and make their decision accordingly (Nielsen, 2012). As Nielsen (2012) points out, the knowledge - value distinction is important for students' ability to assess scientific knowledge claims critically and to be mindful of balancing scientific facts and human values. The SEE-SEP model also acknowledges that students use their experiences in their socioscientific argumentation. The use of experience in the arguments is especially evident when the issue is close to students' everyday lives and "when there is no certain evidence found" (Chang Rundgren & Rundgren, 2010, p. 12).

The analytical procedure was deductive since the categories from the SEE-SEP model were given beforehand. In a deductive analysis the process starts with a theoretical model, in this case the SEE-SEP model, which was used for coding the written reports. The analytical unit was sentence-based; however, there were sentences that were not coded, as they did not contain any content that could be considered as a supporting reason. However, it must be noted that the criteria for what qualified as a supporting reason were very inclusive. Sometimes a sentence contained more than what could be counted as one code in the SEE-SEP model, and consequently two codes were applied. After coding of the students' reports, the mean and the frequency of the justifications linked to each aspect and subject of the SEE-SEP model were calculated. In Paper II a Mann-Whitney U test was used to investigate the difference in the number of justifications used by the science and social science students, which related to their disciplinary background.

Coding according to the SEE-SEP model posed some problems. Assessing if students use their experience in their informal argumentation is something that needs deeper investigation; reading a subsequent written report does not always reveal this. Accordingly, students' supporting reasons only received the code for experience when the student *explicitly* wrote that she/he had referred to an experience she/he had encountered. Another difficulty in coding according to the SEE-SEP model is the distinction between the codes En (Environmental/ecology) and Sc (Science). Ecology is a part of science and one of the domains in biology. This distinction was originally made to match the notion of sustainable development and highlight the importance of environmental and ecological aspects of SSI.

Paper III

The aim in Paper III is to:

- Develop and present an analytical framework that could be adapted to school practice including both structural and content aspects.

Development of the framework

In Paper III no novel data were collected. However, the framework developed and presented in the paper was based on quality aspects of socioscientific argumentation identified by a literature review and tried out on ten written reports on the GMO issue collected as data in Papers I and

II. These ten reports were used in order to test the feasibility of the framework.

A literature review was conducted in order to investigate the quality criteria included in analytical frameworks of socioscientific argumentation in published scientific articles. These criteria were, together with the demands of the curriculum for secondary and upper secondary schools (Swedish National Agency for Education, 2011a, 2011d) and national tests in science, the grounds for the development of the new framework. The aim was to include the most important criteria, i.e. the most commonly occurring criteria, found in the research literature in the framework, consider curriculum aspects, but at the same time keeping things simple and user-friendly for teachers. An extended version of the review included in Paper III is presented in this thesis (see Table 1) and in order to identify papers to include in this review several strategies were applied. Databases were searched by using several keywords including socioscientific issues (in various spellings), framework, model, analysis/analytic, and argumentation. Manual searches for relevant articles were also conducted in published issues of leading journals. Efforts were made to sample as many relevant papers as possible containing quality aspects of socioscientific argumentation; however, this is not a comprehensive synthesis of all research in this area.

Paper IV

The research questions in Paper IV are:

1. What criteria do science and Swedish language teachers consider when assessing socioscientific argumentation?
2. Do the teachers participating in this study consider both content and structural aspects in their assessment of socioscientific argumentation?
3. What, if any, are the differences between science teachers and Swedish language teachers in terms of assessing socioscientific argumentation?

Data collection

The empirical data in Paper IV were collected by semi-structured interviews to investigate teachers' assessment of students' socioscientific argumentation. The interview of the teachers followed a semester-long

SSI-driven project, including two classes of science major students, which had a focus on global warming. In semi-structured interviews the questions are planned in beforehand but there is also room for unexpected ideas to occur during the interview and follow-up on these (Kvale & Brinkman, 2009). Consequently, no two interviews are the same. However, to obtain the answers to the research questions an interview guide was used. The guide included three themes that the interview dealt with:

- motives for teaching SSIs and argumentation skills;
- experiences from the SSI project;
- how to assess socioscientific argumentation.

It is the last theme, how to assess socioscientific argumentation, that is the focus of the paper. To make sure that the interviews with the participating teachers had the same starting-point, one of the student examination reports was used as a foundation for the interview. This report included a clear claim, with several justifications containing content knowledge from biology and chemistry. Moreover, there was a counterargument, even though it was not very explicitly developed. The text had an introduction and a conclusion and a fairly clear exposition. Grammar was not flawless, but the meaning of the student's text was clearly expressed. The student referred twice to references to support the fact that the earth's temperature rose during the twentieth century and described how rising temperature causes changes in weather systems globally. The student included no elaborated reasoning about ethics or morality. The teachers were asked to take some time to read the student report during the interview and explain how they would grade it and, most importantly, on what grounds. The focus was on *what* they found in the report to use in their assessment. I also asked about what they did not find in the report and would have liked to see in order to further improve the student's text. There were also some questions about aspects that were not included by the student in the text but, according to the analytical framework and research literature, could still be considered as aspects of high-quality socioscientific argumentation, e.g. value-based reasoning. The interviews took place at the teachers' workplace and were audio recorded and transcribed. The participants gave their permission for the interview to be recorded and use of the recording for research purposes. The interviews lasted for approximately 40 to 60 minutes.

Participants

Five teachers participated in the SSI project in the fourth study. They all work at an upper secondary school in a small town in the middle of Sweden. Three of the teachers are science teachers (chemistry and biology) and two teach the Swedish language (the students' first language). For more detailed information about the participants, see Table 3.

Table 3. Participants in the fourth study.

Teacher	Subject	Class taught	Years of teaching experience
Teacher 1	Chemistry	Class 1	16
Teacher 2	Biology	Classes 1 and 2	8
Teacher 3	Chemistry	Class 2	4
Teacher 4	Swedish language	Class 1	11
Teacher 5	Swedish language	Class 2	12

Data analysis

The first step of the analysis of the interviews with the teachers, was to sort out from the transcripts the central theme of this study, how to assess socioscientific argumentation. In order to analyze teachers' views of assessing socioscientific argumentation both a deductive and an inductive approach were applied. The categorization was developed in alignment with the framework of assessment of the quality of socioscientific argumentation presented in Paper III. Hence, the deductive approach, (meaning that the analysis was guided by theory - the framework) was applied to the material. In addition, categories not addressed in the assessment framework as quality criteria of socioscientific argumentation were added when the data indicated in order to be sure that all possible aspects of teachers' assessment of socioscientific argumentation were covered, representing an inductive approach. (In an inductive approach the categories come from the data as perceived by the researcher.) Hence, I read the transcripts several times and whenever a respondent made a statement in the interview relating to assessment of socioscientific argumentation this was marked. If the marked statement fitted in the framework (see Figure 3) it was categorized accordingly; if it didn't relate to anything included in the framework it was still seen as valuable and noted. All statements not correlating with any of the categories developed from the framework were thoroughly studied and grouped, leading to new categories. Figure 3 shows an overview of the categories developed from the framework and the inductively developed categories.

Categories from the framework	Categories developed inductively from the empirical material
• Scientifically correct subject content knowledge • Scientific concepts • Multiple perspectives • Values – grounded ethical considerations • Claims • Justifications/reasons (pros) • Counter arguments (cons)	• Content knowledge related to relevant reference • Diction • Grammar • Disposition

Figure 3. Categories developed from the framework and categories developed inductively from the empirical material.

Validity and reliability of the results

Initially the authors of Papers I and II conducted an investigator triangulation whereby 20 reports were coded individually. The differences were then discussed until consensus on coding was reached. Next, to ensure inter-rater reliability, seven science educators were invited, after a presentation of the SEE-SEP model by the first author, to code ten excerpts. The inter-rater reliability was calculated through the agreed codes being divided by the total number of codes (agreed and disagreed) generated by the first author and the seven educators, resulting in 95% inter-coding agreement and indicating high agreement of the coding scheme developed from the SEE-SEP model. The remaining codes were discussed and agreed upon by the seven science educators and the first author. In addition, Papers I and II received comments from independent reviewers, as well as research colleagues who provided important feedback.

In Paper III I developed a new framework for the purpose of contributing to teachers' assessment of socioscientific argumentation. With respect to the validity of this study, the framework was based on findings of several experienced researchers in the field of socioscientific argumentation in science education. In addition, the framework was discussed in the research group, at international conferences and received comments from independent reviewers.

In Paper IV, the analytical processes, development of categories, and interpretation of the results was discussed by research colleagues and the authors of the paper. Initially, the first author developed the categories and sorted the results accordingly. Then, the two other authors examined and discussed the analysis so that consensus was reached. In addition, two independent researchers, experienced in the field of science education research, took part in the analytical process to make sure that the analysis of the data was reasonable. Several research colleagues as well as one independent experienced science education researcher also reviewed Paper IV.

Ethical considerations

All participants in the different studies were informed about the purpose of the research and joined voluntarily. They were also informed that they could withdraw participation at any time, read and signed an informed consent form. All participants agreed to let their statements (in their written reports or from the interviews) be included in presentations at conferences and in published papers; however, they were promised full confidentiality. The Ethical Research Committee of Karlstad University approved all studies.

Results- summary of papers

Paper I

I investigate students' use of different supporting reasons when making written arguments on SSI with the SEE-SEP model (Figure 2) as an analytical framework. First, the importance of including SSI and informal argumentation in science education to enhance students' decision-making competence and promote the ability to formulate independent informed standpoints is outlined. The concept of SSI, which are open-ended, often ill-structured and controversial issues in the interrelationship of science and society, is defined. Using SSI in education focus on the interaction between science and society, including not only the science behind the issues but also, inter alia, social, economic, ethical and political challenges. Informal argumentation is defined as an informal version of formal argumentation, being less rigid in its structure and more appropriate for student discourse on SSI. Informal argumentation allows people to provide various premises from their personal beliefs, knowledge and information from media or their own personal experiences.

The results showed that the distribution of the different supporting reasons as well as a few examples of students' alternative conceptions found in the data. The main findings were that value was the main aspect used by students in their supporting reasons, that different SSI retrieve students' supporting reasons from different subject areas and that the SEE-SEP model is a suitable analytical framework for investigating the content of supporting reasons. It was discussed whether students' choice of SSI had been influenced by media coverage and that students' familiarity with the issues probably mattered. The finding showing that students used various aspects and subject areas in their supporting reasons in different SSI highlights the importance of teachers' careful choice of SSI to include in instruction due to what content that should be learned. The study also identified students' low use of some areas that have been pointed out in previous research as important regarding teaching and learning about SSI in science education. For example, it has been stressed that ethical concerns are important, and the results showed that students used ethics to a low degree in their supporting reasons on the GMO and nuclear power issues. It is therefore suggested that the SEE-SEP model could be used in education as a tool to promote the multidisciplinary character of informal argumentation on SSI.

Paper II

In the second study I investigate possible differences among science and social science major students' justifications in their informal argumentation on SSI. In the introduction SSI are defined as complex, contemporary issues that not only require scientific knowledge for informed decisions but also have ties to moral, social and several other aspects. SSI in science education can engage students in discussion, promote their active participation, critical thinking, decision-making and develop their argumentation skills. Many studies have pointed out that SSI are valuable contexts in school education to achieve the goal of scientific literacy. However, previous research on students' argumentation on SSI shows inconclusive results regarding possible differences in students' argumentation with respect to their disciplinary background. Research also shows that pedagogical approaches among teachers in humanities and science differ, indicating that teachers in the humanities are more used to managing discussions on contemporary issues. Science teachers, on the other hand, rely more on authoritarian and non-dialogical practice in their instruction. Moreover, the importance of encouraging students to reason from multiple perspectives in order to improve the quality of argumentation on SSI is outlined.

Most of both science and the social science major students preferred to argue on the global warming issue and the consumption issue was the second most popular issue. The social majors generated more justifications than the science majors on all four SSI. The aspect of value was the most commonly used aspect regardless of students' disciplinary background and the justifications from the subject area of science were most often presented on nuclear power and GMO issues. The reason why social science majors on average used more justifications than the science majors was not confirmed in this study. However, it is possible, given results from previous research, that the students attending the social science program were more familiar with constructing and advancing arguments. It was also posited that it is important to practice and encourage students to use content knowledge when justifying their arguments. Because of the importance of the multidisciplinary aspects of SSI it is argued that requiring teachers from different subjects to co-operate when teaching argumentation on SSI could be of great value, both for science and social science major students.

Paper III

In the third study I present a new framework for teachers' assessment of SSI argumentation. The importance of equipping all students with the skills of argumentation, critical thinking and decision-making is outlined. Moreover, socioscientific decision-making is important for students to experience scientific concepts in real-world contexts, making science education more meaningful. Previous research has found that assessing the quality of students' SSI argumentation is a challenging task for science teachers. This study aims at facilitating teachers' assessment of SSI argumentation by introducing a new assessment framework that represents a low degree of complexity and exemplifying it by applying it to students' written SSI argumentation concerning GMO. This framework focuses on both the content and structural aspects of SSI argumentation. A review of research concerning the quality of SSI argumentation is presented, revealing that the skill of providing a justification together with a claim is important as well as providing a counterargument. Providing data/content knowledge in the justification that is perceived as scientifically correct is important, as are multiple perspectives in the SSI argumentation. Values or ethical considerations are also indicators of high-quality SSI argumentation, according to the reviewed articles.

In the new framework there are two main components relating to structural aspects: claim (decision) and justification (with pros and cons). The pros and cons are the justifications that the arguer states in favor of her/his own claim and the justifications against that claim. The justification can consist of value statements when the arguer expresses values on the issue and/or knowledge statements when the arguer uses conceptual knowledge to support the claim. The content aspects can be categorized into different subject areas depending on the requirements of the assessing teacher. There is also an opportunity to scrutinize the content knowledge and divide it into three different categories depending on whether it is relevant and scientifically correct content knowledge, non-specific general knowledge, or incorrect. The values can be divided into two sub-categories depending on whether they are grounded or non-grounded. A non-grounded value is not expounded, unlike a grounded value justification where the arguer expounds the moral judgment and shows an understanding of the broader consequences of the chosen standpoint. The feasibility of the framework was tested by using it to analyze ten transcripts of students' SSI argumentation on GMO, and two of these are presented in the article. It is of importance to note that the use of the framework does not in itself produce a grade, albeit it helps teachers to scrutinize students' SSI argumentation so they can identify the quality indicators their assessment requires. Assessment of SSI argumentation is highly context-dependent and it is important that the teacher takes into consideration the SSI that is in focus and what can reasonably be expected of the students.

Paper IV

The fourth study aims at investigating and comparing how science and Swedish language teachers participating in an SSI-driven project assess students' written socioscientific argumentation about global warming. The worldwide promotion of students' socioscientific argumentation in science education is presented. It is also recognized in the Swedish curriculum for upper secondary schools implemented in 2011. However, teaching socioscientific argumentation is not an easy task for science teachers and among the difficulties to be overcome is the assessment of students' socioscientific argumentation. A comparison with how Swedish language teachers assess argumentation is made as they have a long tradition of doing this and therefore it is of interest to compare science and Swedish language teachers' assessment. Research regarding assessment of the quality of socioscientific argumentation is outlined and the framework presented in the third paper of this thesis is presented and functions as an analytical tool.

The results showed that the teachers focused on three main, overarching categories when assessing students' socioscientific argumentation; content, structure and language (Figure 3). Science teachers focused on students' content knowledge within their subject whereas the Swedish language teachers included students' ability to use content knowledge from references, the structure of the argumentation and language aspects, including grammar, diction and disposition. It was concluded that the Swedish language teachers' assessment correlates more with previous research about the quality of socioscientific argumentation than the science teachers' assessment, and it is suggested that closer co-operation between science and Swedish language teachers could be beneficial but also that the science teachers need professional development and that assessment of socioscientific argumentation should be included in teacher education.

It is concluded that both content and structural aspects, as well as language issues, are important for the assessment of socioscientific argumentation. However, this might be too demanding for science teachers and more research is needed on this.

Discussion

Content aspects of socioscientific argumentation

SSI are complex issues drawing on a wide range of subjects. Hence, they are multidisciplinary and it is important that students can recognize these features and consequently use multiple subject areas in their socioscientific argumentation in order to improve their decision-making skills (e.g. Chang Rundgren & Rundgren, 2010; Patronis et al., 1999; Wu & Tsai, 2007). In Papers I and II I used the SEE-SEP model (Figure 2) to investigate which subject areas students include in their argumentation and found that they are able to rely on several. Considering the importance of recognizing the multidisciplinary features of socioscientific argumentation it is important to encourage students' use of different subject areas in science education. However, this is not a simple task. The pressure on the teachers is high, and it is important to note that teachers don't need to be experts on all aspects of an SSI. It is also hard for teachers to be up to date on the most recent scientific developments (Ekborg et al., 2013; Harris & Ratcliffe, 2005). This requires a shift from more traditional science teaching whereby "science is best taught by transferring knowledge from teacher to students" (Tsai, 2002, p. 774) to a more student-centered view whereby students and teachers work together to investigate the various aspects of an issue (Zeidler, 2014).

Students' ability to include justifications from multiple subject areas can differ depending on whether they base their arguments on scientific or socioscientific issues. Sandoval and Millwood (2005) found that students tended to rely on one single piece of data in support of their claim and failed to provide data from multiple resources when adducing arguments about natural selection, a scientific issue. In my studies the students supported their claims with nine justifications on average and covered a wide range of subject areas. This could be because they could choose which SSI to argue on (out of four) and consequently felt more comfortable with the issue. Moreover, the issues used in my research are SSI where there is no correct answer, and so the argumentation is socioscientific in its nature and is not as strict and rigid as scientific argumentation. If students feel less tied to the strict and rigid rules of scientific argumentation they may draw from several subjects in their socioscientific argumentation. Therefore socioscientific argumentation is a suitable context for learning to justify claims.

I also found that different SSI made students retrieve diverse subject areas to a different degree. If teachers want to focus on engaging their students and have them practicing socioscientific argumentation with focus on certain subject areas they need to choose the SSI accordingly. In addition, the SEE-SEP model can be used in practicing to use multiple subject areas when socioscientific argumentation is included in science instruction. Instructions for how this can be done are provided in Chang Rundgren (2011) and describe how students can be encouraged to present justifications from a wide range of subjects.

How and if the ability to use content knowledge in socioscientific argumentation is related to high-quality scientific argumentation has been debated by researchers (e.g. Means & Voss, 1996; Osborne et al., 2004; Sadler & Donnelly, 2006; von Aufschnaiter, Erduran, Osborne, & Simon, 2008). However, there *are* indications suggesting a relationship between content knowledge and the quality of socioscientific argumentation (Sadler & Zeidler, 2005b). The Swedish curriculum, national tests and science educators alike acknowledge the importance of students' ability to use their content knowledge in their socioscientific argumentation (Sadler, 2004, 2009; Swedish National Agency for Education, 2011a, 2011d). In addition, it is seen as important that students use relevant and scientifically correct content knowledge (e.g. Tal & Kedmi, 2006). In Papers I and II the aspect of knowledge used by students in their socioscientific argumentation was investigated with the SEE-SEP model that allows students' justifications to be categorized as knowledge, value or experience (Chang Rundgren & Rundgren, 2010). However, it is important to note that it was not investigated whether the knowledge used was relevant and scientifically correct. The science teachers in the fourth study are explicit about that they consider students use of scientifically correct content knowledge as the most important aspect for high quality in students' socioscientific argumentation. The importance of content knowledge is also recognized in the framework presented in Paper III. This mirrors my conviction that content knowledge is important in socioscientific argumentation; it is important for students (as it is for all of us) to possess some basic scientific content knowledge for the development of the ability to critically assess the messages that surround us and to be able to make well-grounded, informed decisions.

In Paper IV, the Swedish language teachers also focused on students' ability to include content knowledge in their socioscientific argumentation in their assessment. However, they did this differently from the science teachers, focusing on whether students could use content knowledge from references in their justifications. Simon, Erduran, and Osborne (2006) emphasize that the ability to comprehend and interpret the meaning of scientific texts and use this in argumentation develops students' ability to evaluate claims and evidence. If this skill can be transferred to other contexts as well then it is a valuable skill indeed, especially today when content knowledge is easy to access through the Internet.

Moreover, content knowledge is not the only aspect of importance in students' socioscientific argumentation. A position on an SSI can never be fully justified by scientific knowledge alone, and there will always be values supporting the position. Values are "principles that guide actions; persons value some objects, or circumstances, more than others and they choose their action accordingly" (Nielsen, 2012, p. 227). Nielsen (2012) states that the fact-value distinction is important and helps students become less prone to fallacious reasoning. Moreover, if students are to learn to invoke scientific content knowledge in their socioscientific argumentation the fact-value distinction needs to be made explicit during the learning process.

In Papers I and II I found that both the science major and social science major students tend to rely to a large extent on values in their justifications, so it is clear that they can support their arguments by using values. I also recognize the importance of values in the framework presented in Paper III, where a distinction was made between grounded and non-grounded values. This distinction was inspired by Reiss (2010), corresponding to his discussion of progression in ethical thinking whereby more advanced ethical thinking includes consequences for others on a longer-term and broader scale. In the SEE-SEP model this distinction is not made; both more and less advanced thinking is categorized as the same level of values. In response to this, the idea of the framework in Paper III is that grounded values represent higher quality in students' socioscientific argumentation. Hence, students should be encouraged to include grounded values in their socioscientific argumentation.

In Paper IV I found that the science teachers that participated in the study don't include students' values in their assessment of students' socioscientific argumentation although values are included and considered important in the Swedish curriculum. According to the curriculum for the upper secondary school every subject should cover and support students' ability to develop ethical perspectives (Swedish National Agency for Education, 2011a). Teachers' reluctance to include values in their assessment of socioscientific argumentation may derive from their epistemological beliefs (Tsai, 2002). Research has shown that teachers' beliefs about socioscientific argumentation depend on their epistemic orientation (e.g. Jones & Leagon, 2014). In a traditional view, science teaching is seen as transferring knowledge from teachers to students, learning science as reproducing knowledge from credible sources, and viewing scientific knowledge as correct answers or established truths (Tsai, 2002). However, my study did not aim at investigating these teachers' epistemological views of science teaching and learning or scientific knowledge, but the results indicate that the teachers at least to some degree hold what can be perceived as a traditional view.

In Papers I and II the results indicated that the social science students included more justifications than the science majors in their socioscientific argumentation. My explanation was that the social science students were more used to argumentative practices since this is a more common activity included by teachers from the humanities compared with science teachers (e.g. Borg, 2011). Borg (2011) found that Swedish science teachers to a large extent used traditional lectures and also held the view that science education should be fact-based and value-free. The social science teachers in the same study were, on the other hand, found not only to utilize various teaching approaches (i.e. group discussions and classroom debates) in their teaching but also felt more comfortable including ethical and social aspects in their teaching.

Content and structure

In this thesis I investigate content and structural aspects of students' socioscientific argumentation. In the first two papers content aspects were the main focus, with one exception; in Paper II the numbers of justifications included by the students was one of the factors investigated and this related to structure. In Paper III the importance of including both content and structural factors in socioscientific argumentation was the premise for the development of the new framework. In Paper IV it was revealed that the science teachers focused on content aspects only and did not include structural aspects in their assessment of students' socioscientific argumentation. Traditionally, focus has been on content in science education, and structural aspects of socioscientific argumentation are relatively new in the curriculum (Swedish National Agency for Education, 2011a). If both content and structure *are* important aspects in terms of the quality of students' socioscientific argumentation, as I claim, this is problematic. However, this division and focus on only one aspect is also found in the research literature. In a comprehensive review by Sampson and Clark (2008) about frameworks that science education researchers use to assess scientific argumentation, they found that the frameworks mainly focused on either domain-specific or domain-general frameworks. The domain-general frameworks focused on structure, such as making a claim, justification, constructing counterarguments and other structural aspects and were context-independent. The domain-specific frameworks focus on the accuracy and relevance of the components in the arguments and are context-dependent. The authors' state:

> …as with structure and content, our field has developed frameworks that tend to atomize arguments so that we see the proverbial trees, but not the proverbial forest composed of trees. In other words, we now need frameworks that allow us to analyze the overarching patterns of justification as related to both to the content and structure of arguments (Sampson & Clark, 2008, p. 468).

Since the review in Sampson and Clark's (2008) article focuses on frameworks assessing *scientific* argumentation I investigated articles with focus on frameworks assessing *socioscientific* argumentation and found the same trend. Moreover, in the Swedish curriculum (Swedish National Agency for Education, 2011a) as well as in national tests (Swedish National Agency for Education, 2011d) *both* structural and content aspects are included as valuable indicators of students' socioscientific argumentation. This was the rationale for developing a new framework with a more holistic approach for assessing socioscientific argumentation. The framework stresses the importance of including both content and structure in students' socioscientific argumentation. Of course, this framework needs to be tested by teachers in educational settings. The framework also intended to be used by students in class for practicing high-quality socioscientific argumentation.

Implications

The results of the studies included in this thesis indicate that co-operation between science teachers and teachers from other domains would be beneficial when it comes to teaching and learning socioscientific argumentation in science education. There are several reasons for this: e.g. aid in coping with the multidisciplinary features and the structural aspects of socioscientific argumentation. When including SSI and socioscientific argumentation in an interdisciplinary manner in science education, the students get to use relevant knowledge without regard to disciplinary boundaries. The real world is integrated and an interdisciplinary approach provides a context for learning that is student-centered (Czerniak & Johnson, 2014).

As mentioned earlier, science teachers cannot be expected to know about all aspects involved in different SSI and co-operation with teachers from the humanities means that they can cover more subjects. In addition, in Paper IV it is shown that Swedish language teachers possess the knowledge and skills for teaching and assessing structural as well as language aspects of socioscientific argumentation and this could also be beneficial for science teachers in an interdisciplinary co-operation. Interdisciplinary co-operation means that the teachers not only perform projects together, sharing students and practical issues, but that they also plan and share the pedagogical approach in a genuine collaboration (Harris & Ratcliffe, 2005).

A distinction can be made between multidisciplinary and interdisciplinary co-operation. In multidisciplinary co-operation the participating subjects are only "added" to each other, each subject stays well within their boundaries and the level of co-operation is low, as it is the students that are left to make the connections (Alvargonzález, 2011). This can lead to a fragmentized view of knowledge. In interdisciplinary co-operation the integration between the subjects is stronger, and the subjects function as tools for the students in their learning (Alvargonzález, 2011). This leads to increased opportunities to learn about complex issues, such as SSI and the skill of socioscientific argumentation. This kind of teaching aims at educating students for responsible citizenship.

Yet, there are obstacles to be overcome if interdisciplinary co-operation is to be developed between science, social science and Swedish language teachers. Research has shown that teachers can feel reluctant to embrace interdisciplinary co-operation, having concerns about not covering all the content in the curriculum if using an integrated approach since the curriculum is packed with content covered by the separate subjects (Czerniak & Johnson, 2014; Ekborg et al., 2013). Integrated, interdisciplinary work does involve several logistic problems. In my fourth study, the teachers shared practical aspects of the project, such as the introduction of the project to the students and the examining task. However, they did not share any pedagogical ideas but stayed well within their subjects' boundaries. In addition, school is organized so that the students meet the subject separately and the content is taught in isolation. Moreover, classrooms are designed for hosting specific subjects, making management more difficult. The structure of the schedule can also make it hard for teachers, allowing for students to work with several subjects at the same time, and it can be difficult for teachers to meet and have time to plan joint projects. These are all obstacles that need to be overcome. Working with SSI and employing the skills of socioscientific argumentation in an interdisciplinary manner would give students greater opportunities "to gain critical thinking and problem-solving skills, as well as to develop a general core of knowledge necessary for success in the future" (Czerniak & Johnson, 2014, p. 395). However, it is crucial that this is also in alignment with the teachers' own wishes and needs.

If socioscientific argumentation is to become a prioritized part of science education there are several challenges to be addressed and overcome. The initial challenge is to articulate the significance of socioscientific argumentation in the promotion of scientific literacy among science teachers and this must be done with regard to both in-service and pre-service teachers. As stated by Sadler, Amirshokoohi, Kazempour, and Allspaw, (2006) "a greater emphasis on the links between SSI and the idealized aims of science teaching must be made in pre-service teacher education" (p. 373). Hence, if socioscientific argumentation is fundamental to scientific literacy, then the standards in science should address this just like any other content deemed important for science learning. Moreover, promoting socioscientific argumentation in teaching requires teacher training programs and resources. More supportive material to help pre-service and in-service teachers to include socioscientific argumentation in their teaching needs to be developed. The framework presented in Paper III could be one such tool. However, more material needs to be developed, implemented and evaluated. In addition, more empirical research that explores the potential to embed traditional science content in an SSI-driven framework is called for, since research has shown that a common concern among science teachers is the reduced canonical content if socioscientific argumentation is to take place in science education (e.g. Ekborg et al., 2013).

Changing teachers' educational practice towards including more socioscientific argumentation in their teaching requires the will to change, a driving force and appropriate knowledge and opportunities for change. Ekborg et al. (2013) suggest that

> …maybe the difficulty of teaching SSI is not due to content, work form or a demand for argumentation, but a more fundamental change- to dare follow the students' thoughts and ideas not knowing where they are leading (p. 614).

Although I believe that teacher training is one key to successful implementation of socioscientific argumentation in science teaching, some research indicates that teachers may have reservations about teaching socioscientific argumentation even after participating in workshops and in-service professional development (e.g. Gray & Bryce, 2006). This may be related to teachers' view of teaching, learning and knowledge, their epistemology. When we take this into account it is clear that transforming pedagogy is difficult.

Lee and Witz (2009) point to the importance of coherence between teachers' deeper values, ideals and curricular reforms if the content of the curriculum is to be implemented by teachers in a successful manner. The teachers need the opportunity to develop their own approaches to teaching socioscientific argumentation. In addition, they need time and education for assessing and grading socioscientific argumentation. The intentions of the policy-makers in Sweden when implementing a criterion-referenced grading system were that teachers, engaged in professional and collegial dialogue, would discuss how to interpret the grading system instructions and reach a consensus (Karlefjärd, 2011; Skolverket, 1996). However, it has been hard to attain a consensus among teachers and research shows that the instructions on how to implement the grading system are insufficient and teachers have not had enough time for discussions with colleagues (Selghed, 2004; Tholin, 2006). Hence, strategies for supporting teachers both to teach and assess socioscientific argumentation are important and time for teachers' mutual discussions seems to be an important factor for success.

There is a great deal of research on how to teach and implement socioscientific argumentation in science education. But how can this research be transferred to teachers' practice and knowledge development in their practical work? It is not enough to have access to publications or information about research; it is also important that teachers get the opportunity to use, discuss and reflect about this research in relation to their own teaching practice. Teachers do not have easy access to research results or information about research. There are several factors needed; 1) development and assembly of relevant and trustworthy research; 2) this research needs to be made available for teachers in a systematic way and in an easy format; 3) teachers need opportunity, support, and time to take part in the research and discussions with colleagues. The school structure also needs to be supportive of teachers trying out new ideas and approaches; the school culture needs to welcome and support such initiatives. In my research I have shown that students as well as teachers need support in including and teaching socioscientific argumentation and that facilitating high-quality socioscientific argumentation is complex. It is my hope that the results presented in this thesis contribute to knowledge about teaching and learning high-quality socioscientific argumentation.

Further research

In this thesis I have explored various aspects of students' socioscientific argumentation, developed and presented a framework for assessment of students' socioscientific argumentation and investigated what science and Swedish language teachers consider in their assessment of socioscientific argumentation. I discuss how teachers' co-operation is of great importance and that there is a need to include how to teach and implement socioscientific argumentation in science education in both teacher education and teachers' professional development. However, more research is needed on how pre-service and in-service teacher programs can best develop to support teachers' identities and approaches towards socioscientific argumentation in education. It is also important to investigate how research results can reach teachers active in schools and how the results from research can be of practical use in science education.

Conclusion

I conclude that both content and structure are important for the quality of students' socioscientific argumentation and that both these aspects need to be included in teachers' assessment practice. I also suggest that interdisciplinary work and co-operation between teachers from different disciplines are beneficial when teachers are working with socioscientific argumentation in science education. I have developed a framework emphasizing the importance of content and structure for the quality of students' socioscientific argumentation and in my last paper a third aspect, language, was inductively found to be important for argumentation quality along with use of content knowledge from references, something that we need to investigate further. I also conclude that instruction of how to include and teach socioscientific argumentation needs to be included in teacher education and professional development for in-service teachers.

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Socioscientific argumentation

Socioscientific argumentation has shown to be a feasible educational framework for promoting citizenship and scientific literacy. In this thesis I investigated various aspects of quality of students socioscientific argumentation and how teachers assess this. The results showed that different SSI led students to use different subject areas in their justifications and that the number of justifications provided by the students is related to their discipline background. Moreover, to promote students high-quality arguments I have presented a framework for analyzing and assessing both content and structural aspects. I also investigated how science and language teachers assess students' socioscientific argumentation and found that the science teachers focused on students' ability to reproduce content knowledge, whereas language teachers focused on students' ability to use content knowledge from references, and the structural and linguistic aspects of argumentation. The complexity of teaching socioscientific argumentation makes it difficult to teach and assess comprehensively. In order to promote quality and include both content and structural aspects, I suggest that a co-operation among teachers of different disciplines is beneficial.

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