Knowledge, Value and Personal experience

Upper secondary students’ resources of supporting reasons when arguing socioscientific issues
Nina Christenson

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Abstract

This thesis focuses on upper secondary students’ use of resources in their supporting reasons when arguing socioscientific issues (SSIs). The skills of argumentation have been emphasized in science education during the past decades and SSIs are proven a good context for learners to enhance skills of argumentation and achieve the goal of scientific literacy. Research has shown that supporting reasons from various resources are embedded in students’ argumentation on SSIs, and also that multi-perspective involvement in reasoning is important for the quality of argumentation. To explore the reasons used by students in arguing about SSIs in this thesis, the SEE-SEP model was adopted as an analytical framework. The SEE-SEP model covers the six subject areas of sociology/culture, economy, environment/ecology, science, ethics/morality and policy, which are connected to the three aspects of knowledge, value and personal experience. Two studies covering four SSIs (global warming, GMO, nuclear power and consumption) explore how students construct arguments on one SSI topic chosen by them. In paper I, I investigated students’ use of resources in their informal argumentation and to what extent students made use of knowledge. The results showed that students used value to a larger extent (67%) than knowledge (27%). I also found that the distribution of supporting reasons generated by students varied from the different SSIs. In paper II, I explored students’ use of resources in relation to students’ study background (science majors and social-science majors) and gender. The results showed that social-science majors and females generated more numbers of reasons and also showed a larger amount of multi-disciplinary resources in their supporting reasons. From the findings of this thesis, the SEE-SEP model was established as a suitable model used to analyze students’ resources of supporting reasons while arguing about SSIs. Furthermore, the potential for applying the SEE-SEP model in teachers’ SSI-teaching and students’ SSI-learning is suggested. The implications to research and teaching are also discussed.
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Preface

"Democracy is a participating sport” (Walrath & Walrath, 2010). I heard this when I was watching an American documentary about bottled water on television and immediately I thought: that is what it’s all about. But to be able to participate in a democratic society, we need some knowledge and skills. What is that knowledge and what are those skills people ought to possess? That is what this research is about.

In my work as an upper secondary teacher, teaching biology, geography and general science, I find myself often struggling with trying to motivate my students. In the beginning of every course I have a discussion with my students in order to understand their experience and expectations of science and science education. Many students said that they find science boring. This surprises me a lot, since I find science a very exciting and engaging field. When I asked my students why they feel that science is boring, they answered that it is not about science itself, but the way that science is taught they don’t like. Furthermore, my students thought of science as something boring and out of date, not engaging, giving them no opportunity to discuss. Science was seen as something fixed and not something one can have opinions about. Science teaching is characterized as something authoritarian both in its context and the way of work. Even the practical laboratory work, they felt had been rigid in its setting without any own innovative aspects. My students asked for more engaging discussions and also wished for including existential and emotional perspectives of science.

This was the starting point for my research; how can we teach science in a way that make students engaged and at the same time fulfill our mission as science educators to teach the scientific content knowledge and also promote citizens to be able to make well-founded decisions? One day, through an informal conversation with a colleague at my institute, I was told about a research field called “socioscientific issues”. I realized it could be used to engage my students’ and increase their learning interest in science. Consequently, I chose this research topic as my licentiate work.
List of papers

Paper I
Using the SEE-SEP model to analyse upper secondary students’ use of supporting reasons in arguing socioscientific issues. Christenson, N., Chang Rundgren, S-N. & Höglund, H-O.
Submitted to Journal of Science Education and Technology

Paper II
Does students’ study background or gender matter? - Analyzing the reasons used in arguing socioscientific issues. Christenson, N. & Chang Rundgren, S-N.
Manuscript
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Introduction

There are many reasons for why the skills of making informed decisions should be included in school education. In order to have a democratic society, citizens need to be able to express their opinions, and that is the foundation upon which a democracy relies. Science education has an important role in conveying scientific knowledge, making students practice the skills of argumentation, critical thinking and decision-making, and developing social responsibility (Gustafsson, 2007). According to Jiménez-Aleixandre & Erduran (2008), democratic participation requires debate among different views rather than acceptance of authorities. To have sustainable development, we need to make sure that people can make decisions based on the better outcome that could be foreseen in the future for the world. This demands a lot of support from educational systems worldwide not only to emphasize the importance of socioscientific decision-making, but also to make students experience scientific concepts in authentic practice and meaningful contexts, i.e. issue-based teaching. The skills of decision-making are also recognized in the notion of scientific literacy, which include processing scientific content knowledge, applying content knowledge in problem solving and developing the ability to think critically (Norris & Phillips, 2003). One way to make students practice decision-making is to use socioscientific issues (SSIs) in science education. SSIs give students opportunity to actively reflect on issues and how they relate to personal life and society (Driver, Newton, & Osborne, 2000; Kolsto, 2001; Kolsto, 2006; Sadler, 2004a; Zeidler, 2007; Zeidler & Keefer, 2003).

In the following introduction, to address the importance of SSIs, the aspects of scientific epistemology and scientific literacy are delineated. Education for sustainable development (ESD) is outlined as well as the relevant parts of the Swedish curricula for upper secondary school to show the connection of SSIs and Swedish context. Since SSIs play an important role in this thesis, SSI-research done in science education is described with a focus on the important skills of informal reasoning and argumentation. Furthermore, to know how much knowledge and different resources students use when arguing about SSIs, the SEE-SEP model (Chang Rundgren & Rundgren, 2010) is introduced and serves as an analytical framework in the two papers in this thesis. Finally, the reasons for choosing the four SSI topics used in the studies of this thesis are also presented.

Epistemology in science education

Learning science includes epistemic understanding, the achievement of practices associated with producing, communicating, and evaluating knowledge (Duschl, 2008). According to Sandoval and Millwood (2008) are epistemic practices defined as the specific ways of how knowledge is proposed, justified, evaluated, and legitimized within a disciplinary framework. Wu and Tsai (2010)
define scientific epistemology as beliefs about the nature of scientific knowledge and beliefs about the nature of knowing science. Furthermore, Sandoval and Millwood (2008) stress the social nature of science epistemology, namely that epistemic criteria for justifying and evaluating knowledge can be developed and related to social context. In connection with the importance of scientific epistemology, SSI can provide an epistemological context for students’ conceptual understanding for scientific and social importance as well as a way for the formation of character and provide opportunity to develop a reflective judgment (Zeidler, 2007). The use of SSI in science education emphasizes on the justification of claims and the relation of claims and evidence, and can support the development of epistemic criteria, thus promoting effective participation in decision-making processes and the ability to interpret scientific claims relevant to students’ lives (Jiménez-Aleixandre & Erdurian 2008). According to Wu and Tsai (2010), students involved in SSI discourse have to apply what they have learned in science education and this include both their acquired knowledge about the issue itself and their epistemological views toward science and scientific knowledge.

The development of the capacity to choose among theories or positions is part of epistemic criteria. In the articles presented in thesis we investigate students’ resources of their supporting reasons and this can be perceived as part of students’ epistemological ideas of science in SSI context. The arguments presented by the students can be seen as reflections of epistemological ideas they might have about the nature of claims, and the evidences and justifications that make the claims reliable.

Scientific literacy

In the proceeding of the Linnaeus Tercentenary Symposium (Linder, Östman, & Wickman, 2007), the authors raise a number of concerns. One such concern is the matter that school science does not make any real sense or offer any meaningful exploration of issues that relate to personal and social contexts. They continue by making the claim that, although our lives are increasingly influenced by science and technology at both individual and societal levels, this is still largely unaddressed in school science. School science should equip students to be able to participate in a democratic and open society.

Roberts (2007) suggest that scientific literacy can be divided into Vision I and Vision II. Vision I is about the laws and theories of science and also its processes such as hypothesizing and experimenting. From this perspective, school science should focus on the knowledge and skills that enable students to approach and think of situations as a professional scientist would. According to Vision II, school science should enable students to approach and think of science as members of society, and school science should educate students in terms of developing their knowledge and skills accordingly. In other words,
Vision II advocates that school science should look outward at situations in which science has a role, and this include decision-making on SSIs. Roberts (2007) especially emphasizes that scientific literacy ought to include an understanding of the norms and methods of science, that is, the nature of science (NOS). NOS commonly refers to the values, assumptions and characteristics of scientific knowledge (Lederman, 1992, Wu & Tsai, 2010). 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 SSIs. Moreover, NOS in a social setting is also involved in socioscientific decision-making and interacts with other areas such as economics, as well as environmental, social, political and moral and ethical aspects (Nuangchalerms, 2010; Holbrook & Rannikmae, 2009). Research has documented that using SSIs in teaching could promote students’ understanding of NOS (Khishfe & Lederman, 2007; Walker & Zeidler, 2007). Moreover, Albe (2008a) points out that the use of SSIs in science education can give students an opportunity to question the authority of science and to reconsider the various interpretations of scientific facts. It can also put focus on scientists’ disagreements; give an opportunity to deal with the uncertainty in contemporary scientific research and knowledge of research methods and ways of establishing scientific knowledge (Albe, 2008a). Based upon the aforementioned statements, it is not hard to perceive the importance of using SSIs in order to achieve the goal of scientific literacy.

**Education for sustainable development**

In December 2002, the United Nation General Assembly declared the United Nation Decade of Education for Sustainable Development (DESD) from 2005 – 2014. The DESD aim is to change the approach of education in order to integrate the values, principles and practices of sustainable development.

The DESD promotes (UNESCO, 2010):

- Interdisciplinary and holistic learning rather than subject-based learning.
- Value-based learning.
- Critical thinking rather than memorizing.
- Multi-method approaches: word, art, drama, debate etc.
- Participatory decision-making.
- Locally relevant information, rather than national.

In Education for Sustainable Development (ESD), a holistic perspective on sustainable development is put forward. It means that education should highlight the complexity and interdependence of three aspects; society (includes culture perspective), economy and environment (UNESCO, 2010). A conclusion is that the UN puts forward that there is a need for democratic literacy and civic participation in order to be able to fully understand the concept of sustainable development (Björneloo, 2007) and this can be
facilitated through teaching the skills of argumentation on SSIs in schools. It implies the importance of making decisions based on scientific information and increasing people's awareness of how their personal choices can be influential in facilitating sustainable development. The aforementioned perspectives on ESD are well in line with teaching and learning in SSI context.

The Swedish curricula

The curriculum for the non-compulsory school contains the guidelines for upper secondary schools in Sweden (grade 10-12) (The Swedish National Agency for Education, 1994a). The curriculum states tasks, guidelines and goals for the schools. There are many perspectives related to teaching and learning about SSIs mentioned in the curriculum.

Regarding scientific literacy and democracy, the curriculum states that it is the schools' obligation to:

“… develop the pupils’ ability and willingness to take personal responsibility and participate actively in civic life” and, moreover, “The school shall impart the more unvarying forms of knowledge that constitute the common frame of reference that all in society need. Pupils shall train themselves to think critically, to examine facts and their relationships and to see the consequences of different alternatives. Pupils shall have the opportunity of reflecting over their experiences and applying their knowledge.” (The Swedish National Agency for Education, 1994a, p. 5-7).

This is all in line with the aim of developing scientific literacy and educate for democracy. Furthermore, the ethical perspective is also recognized as well as the ability to develop personal standpoints:

“Ethical perspectives are of importance for many of the issues that are taken up in school. For this reason teaching in different subjects shall deal with this perspective and provide pupils with a basis as well as support their ability to develop personal standpoints” and further, “the school should strive to ensure that all pupils further develop their ability to consciously adopt ethical standpoints based on knowledge and personal experience.” (The Swedish National Agency for Education, 1994a, p. 6 and 13).
An environmental perspective is stressed in relation to sustainable development and also that the pupils should develop a personal standpoint and understand how our living affects the environment:

“An environmental perspective in education provides students with insights so that they can not only contribute to preventing harmful environmental effects, but also develop a personal position to major global environmental issues. Education should illuminate how the functions of society and our ways of living and working can best be adapted to create the conditions for sustainable development.” (The Swedish National Agency for Education, 1994a, p. 6).

In relation to pupils’ understanding of NOS, the Swedish curriculum states that schools should:

“…provide an historical perspective, which inter alia enables pupils to develop their preparedness for the future, an understanding of the relativity of knowledge as well as develop their ability to think in dynamic terms.” (The Swedish National Agency for Education, 1994a, p. 6).

In addition, schools should also strive to ensure that all pupils:

“Can use their knowledge as a tool to:
-formulate and test assumptions as well as solve problems
-reflect over what they have experienced
-critically examine and value statements and relationships

Regarding the ability of taking part in democratic decision-making, discussing, taking standpoints and critical thinking, the curriculum states that the school should ensure that all pupils:

-“satisfy the preconditions for taking part in democratic decision-making processes in civic and working life,
-have the ability to critically examine and assess what they see, hear and read in order to be able to discuss and take a standpoint in different questions concerning life and values and
-can observe and analyze the interaction between people in their surroundings from an economic and ecological perspective.” (The Swedish National Agency for Education, 1994a, p. 12).
Regarding gender equality in schools, teachers shall:

“make sure that education in terms of its contents and its structure reflect both male and female perspective.” (The Swedish National Agency for Education, 1994a, p. 13)

All of the aforementioned statements from the Swedish curriculum for the non-compulsory school are related to the research presented in this thesis. The curriculum explicitly states that schools are obligated to equip the students with knowledge and skills in order to be prepared for taking active part in a democratic society, which is consistent with the purpose of this thesis.

SSI-research in science education

Several science educators have promoted embedding SSIs in the science curricula due to their potential to create a more realistic image of scientific activity and for achieving scientific literacy (Chang & Chiu, 2008; Chang Rundgren & Rundgren, 2010; Kolsto, 2001; Millar & Hunt, 2002; Sadler & Zeidler, 2004; Zeidler & Keefer, 2003). According to Driver, Newton, & Osborne (2000), it is important to empower students to be able to both construct and analyze arguments related to the social applications and implications of science. The discussion of SSIs in the classroom has been shown to be useful both in learning about the process of science, NOS, scientific content, as well as in promoting the students' cognitive, social, ethical, moral and political development (Kolsto, 2001; Reis & Galvão, 2009; Sadler, 2004a). In addition to achieving the goal of scientific literacy, Chang Rundgren & Rundgren (2010) conclude that using SSIs in school education has many different functions, i.e. transferring content knowledge and skills to daily life issues; promoting decision-making, critical thinking and science communication; inducing students' learning interests; and providing cross-disciplinary concepts.

In our technology-dominated society, students’ ability to transfer scientific knowledge in their decision making is of great importance (Patronis, Potari & Spiliotopoulou, 1999). Research has shown that an individual’s conceptual understanding has a significant influence on informal reasoning on SSIs (Klosterman & Sadler, 2010; Sadler, 2005; Sadler & Zeidler, 2005b). The use of SSIs in school education has been shown to help students to transfer content knowledge to real life contexts (Chang Rundgren & Rundgren, 2010). It has also been revealed that the attitudes and opinions expressed in arguing SSIs are related to students’ understanding of the context and scientific knowledge that underpins the issue (Lewis & Leach, 2006). This shows the importance of making students capture the central scientific concepts related to the specific SSIs. Holbrook and Rannikmae (2009) state that SSIs need to be included in
school education in order to provide relevance for responsible citizenship and that conceptual knowledge should be introduced on a need to know basis accordingly.

Several science education researchers have argued the need for, and have emphasized the significance of decision-making in science teaching (Aikenhead, 1985; Kolsto, 2001; Newton, Driver, & Osborne, 1999; Zeidler, Sadler, Simmons, & Howes, 2005). Science education should provide something more beyond the knowledge of scientific facts. It needs to include values and put emphasis on the process of critical reasoning and enable students to understand science as a way of knowing (Driver, Newton, & Osborne, 2000; Sadler, 2004b; Zeidler, Sadler, Simmons, & Howes, 2005). Research has shown that the ability to evaluate evidence and think critically can be promoted through using SSIs in school education (Albe, 2008a; Kolsto 2006; Lee, 2007). Moreover, how evidence is used in order to construct explanations and to examine the data and warrants that are the basis of scientific ideas and theories should be focused, and to understand the criteria used when evaluating evidence in science is of importance as well (Simon, Erduran, & Osborne, 2006).

A number of studies have found a positive effect on students’ interest and motivation related to SSI instruction (Albe, 2008b; Bulte, Westbroek, De Jong, & Pilot, 2006; Harris & Ratcliffe, 2005). In a review by Sadler (2009), he concludes that there is empirical evidence supporting that SSI-related interventions are useful as contexts for promoting effective outcomes among learners. This can, in part, be explained by the authentic features of SSIs that make students motivated and interested in learning science as these are issues they might confront in their daily lives, and also the ill-structured context could make students talk more open-mindedly (Chang Rundgren & Rundgren, 2010; Le, 2007; Zeidler, Sadler, Appelbaum, & Callahan, 2009). Therefore, choosing authentic SSIs is important in order to induce students’ learning interest and motivation in school science.

When using SSIs in school education there are many perspectives involved (Chang Rundgren & Rundgren, 2010), e.g. moral and ethics (Sadler, 2004b; Sadler & Zeidler, 2009; Zeidler et al., 2005; Zeidler et al., 2009), ecology and economy (Patronis et al., 1999) and social aspects of science (Walker & Zeidler, 2007). According to the UN Decade of Education for Sustainable Development education should include interdisciplinary and holistic learning rather than subject-based learning and also a multi-method approach (UNESCO, 2010). Given the multiple perspectives involved in SSIs, they are suitable as cross-disciplinary projects in school.

In summary, the use of SSIs in education gives an opportunity to create learning contexts including both conceptual connections towards science, and the features of ill-structured and challenging problems that could engage learners in discussions, decision making and critical thinking.
The skills of informal reasoning and argumentation in school science

During the past decades, a body of research has been done in relation to SSIs. SSIs provide a context in which people can engage in informal reasoning and informal argumentation (Chang & Chiu, 2008; Driver et. al., 2000; Kortland, 1996; Zohar & Nemet, 2002). Informal reasoning serves as the core, and the performance is highly related to the quality of decisions-making on SSIs (Chang & Chiu, 2008). Informal reasoning involves the generation and evaluation of positions in response to complex issues, which very often lack definite solutions. The evaluation of claims and to perceive the limit and extension of the claim is also addressed in the skills of informal argumentation (Chang & Chiu, 2008). Accordingly, through embedding argumentation teaching in the SSI context, students are given the opportunity to present their ideas in a systematical way and thereby promote their skills in communicating science (Chang Rundgren & Rundgren, 2010).

Living in the modern age, people should know how to engage in informal reasoning, ponder causes and consequences and know how to take different positions and make alternative considerations (Means & Voss, 1996; Zohar & Nemet, 2002). Several science education researchers point out that argumentation is an important discourse practice which should be promoted in the science classroom (Duschl & Osborne, 2002; Jiménez-Aleixandre, Rodriguez, & Duschl, 2000; Kelly, Crawford, & Green, 2001; Zohar & Nemet, 2002). According to Kolsto & Ratcliffe (2008), there are three goals when including argumentation in science education: 1) knowledge about the nature of science; 2) developing citizenship, and 3) developing higher order thinking skills. In addition, Jiménez-Aleixandre & Erduran (2008, p. 5) propose several dimensions of the introduction of argumentation in 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 into the practices of the 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.

Argumentation in scientific topics can be defined as the connection between claims and data through justifications or the evaluation of knowledge claims of evidence (Jiménez-Aleixandre & Erduran, 2008), and in relation to the SSI context, different resources of supporting reasons and the possible claims compose the hard core (Chang & Chiu, 2008). In this thesis, argumentation was utilized as an articulation to explore students’ use of reasons in arguing about different SSI topics through students’ written arguments on SSIs. In order to
analyze students’ reasons in arguing about SSIs in this thesis, the SEE-SEP model presented below was applied.

The SEE-SEP model

In the research presented in this thesis the SEE-SEP model (Chang Rundgren & Rundgren, 2010) plays an important role. It functions as an analytical framework in both studies. The SEE-SEP model represent a holistic view due to the multi-dimensional perspectives involved in various SSIs and covers six subject areas including 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 personal experience (P), generating 18 codes that were used in the analysis of this research (Figure 1). Some examples are shown below to describe the features the codes developed in the SEE-SEP model.

Figure 1. The analytical framework based on the SEE-SEP model (Chang Rundgren & Rundgren, 2010).
The aspects of knowledge, value and personal experience

1. Knowledge

Conceptual knowledge is often embedded as a resource in argumentation on SSIs. The Swedish curriculum emphasize that students should be able to use their knowledge acquired in school as a tool to formulate independent standpoints based on empirical facts (but also with rational and ethical considerations). Students should also be able to critically examine facts to see the consequences of different alternatives (The Swedish National Agency for Education, 1994a). One example of the frequent use of knowledge among the participating students in the research:

"The emissions of carbon dioxide causes some of the heat radiation from earth to bounce right back again, instead of out into space, and this leads to increasing temperature on earth." 531MNV3Br

This is an example from a male science major student using knowledge when arguing on global warming. In this case, the aspect of knowledge is connected to the subject area of science, generating the code ScK.

2. Value

In addition to the DESD (UNESCO, 2010) which promotes value-based learning in schools, the Swedish curriculum also stress the importance of values, in which school should encourage pupils to embrace and express the common values of our society (The Swedish National Agency for Education, 1994a). Values were the most common aspect used by the students in arguing about SSIs in this research:

"If using the GMO-technique can contribute to the society by, e.g. making the food cheaper, I think this is a positive thing, and then it can promote the development of societies and increase the social-welfare." 502FSP3Tg

This is a female social-science major student arguing for the use of GMO. Here, the aspect of value is connected to the subject area of sociology/culture, generating the code SoV.

3. Personal experience

The aspect of personal experience was the least used among the participating students in the research. In the Swedish curriculum, personal experience is stressed and schools shall strive to ensure that all pupils develop their ability to develop their standpoints based on knowledge and personal experience.
When I go shopping for food and other supplies, I want to buy ecological produced but I find it way too expensive.” 204FSP3Tg

This is an example from a female social-science student who made use of her personal experience of shopping when arguing on the SSI topic about consumption. In this case, the aspect of personal experience is connected to the subject area of economy, generating the code EcP.

The subject areas of sociology/culture, economy, environment/ecology, science, ethics/morality and policy

1. Sociology/culture
SSIs are issues including social aspects. The Swedish curriculum states that schools should ensure that all pupils understand and respect other people and cultures (The Swedish National Agency for Education, 1994a). In the notion of ESD, the social aspect is also addressed as one of the three dimensions of environment, economy and society (Atkinson, Dietz, & Neumayer, 2007). In this research, the subject area of sociology/culture was frequently used by the students in their argumentation.

“The human population is now somewhere between 6 and 7 billion people and a large portion of these are very poor and threatened by famines.” 282MNV3Ag

This example was made by a male science-major student about the pros and cons of GMO. The subject area here is sociology/culture connected to the aspect of knowledge, generating the code SoK.

2. Economy
As mentioned previously, economy is one of the three dimensions included in sustainable development (Atkinson, et al., 2007) and also closely related to the SSIs used in this research, especially in the topic of consumption. The Swedish curriculum (The Swedish National Agency for Education, 1994a) states that it is the responsibility of schools to develop pupils’ ability to observe and to analyze the interaction of their surroundings from an economic perspective.

“In my opinion it is wrong to strive towards economic growth, it is simply not a healthy thing.” 444FSP3Tg

This was an example from a female social-science students arguing about consumption. The subject area of economy is connected to value, generating the code EcV.
3. Environment/ecology

Environment is one perspective in sustainable development (Atkinson, et al., 2007), and in the SEE-SEP model, this also includes ecological perspectives (Chang Rundgren & Rundgren, 2010). The Swedish curriculum points out that it is the responsibility of schools to develop pupils’ ability to observe and analyze their surroundings from an ecological perspective and also emphasize that the school should include an environmental perspective in education (The Swedish National Agency for Education, 1994a).

“In an environmental perspective, nuclear power energy production is much cleaner than energy produced by coal power plant, it generates far fewer emissions.” 623MNV3Br

This was a male science-major student’s augmentation on the use of nuclear power as an energy resource. In this case, the subject area of environment/ecology is connected to the aspect of knowledge, generating the code EnK.

4. Science

Science plays an important role in SSIs and includes different disciplines, i.e. chemistry, physics, medicine and technology, in the SEE-SEP model (Chang Rundgren & Rundgren, 2010). The Swedish curriculum states that the school should provide pupils with an understanding of the tentativeness of knowledge (The Swedish National Agency for Education, 1994a) and this is related to NOS.

“I think it is hard to know what causes global warming, or if it even exists, since the scientists don’t seem to agree among themselves and don’t even know how to interpret their data.” 611MSP3Tg

This was a male social-science student who made his argumentation about global warming. The subject area of science is connected to the aspect of value, generating the code ScV.

5. Ethics/morality

The subject of ethics occurs repeatedly in the Swedish curriculum. It state that teaching in different subjects shall deal with an ethical perspective, and furthermore, to develop the pupil’s ability to consciously adopt ethical standpoints (The Swedish National Agency for Education, 1994a).

“It is terrible how much suffering and misery there is in a pair of jeans” 404FNV3Ag

This came from a female science-major student’s argumentation on the issue about consumption. She wrote earlier in her report about a movie that they have seen in school. The movie shows how denim jeans are produced and the working conditions among the people manufacturing this product. She
described child labor, the low salaries, how the workers become ill from the pesticides used in the cotton fields and don’t get anything to drink while working in the heat of the sun all day. The subject area of ethics/morality is connected to the aspect of value, generating the code EtV.

6. Policy

Sometimes students refer to policies and laws made by authorities in society, i.e. the government, when making arguments on SSIs.

“In order for GMO to be sold here (in Europe) it must be approved by the EU and they have a very restrictive policy on GMO.”

This was a male science-major student who made argumentation on GMO. The subject area of policy is connected to knowledge, generating the code PoK.

The SSI topics used in this research

Four different SSIs were used to conduct this research. Students were asked to choose one of them to make arguments. The four SSIs addressed in this research are all related to the notion of sustainable development. The SSI topics include global warming, nuclear power, genetically modified food (GMO) and consumption. Most of these SSI topics have been investigated in earlier research. The reasons to choose these four SSI topics in this thesis are presented as follows.

SSI 1: Global warming

Sadler and Klosterman (2008) present one of many studies using global warming as an SSI topic in their presentation of an activity to help high school students conceptualize the sociopolitical complexity of global warming. Global warming is a contemporary issue with an ongoing debate, both in Sweden and globally, on the possible causes of this phenomenon. It is one of the most critical issues facing today’s society, and it has fundamental connections to science dealing with the physical, chemical and biological systems of Earth. It is also an issue closely related to society, since a climate change will inevitably affect societies all around the world and that it gives rise to great sociopolitical challenges in the efforts to reduce the causes and effects. This is a topic included in several courses in the Swedish upper secondary school, e.g. the, for all programs, mandatory general science course, Science studies A (The Swedish National Agency for Education, 2010b).
**SSI 2: Nuclear power**

Yang and Andersson (2003) conducted a study investigating upper secondary school students’ preferred type of information (social or scientific) when presented with an issue related to nuclear power plant construction in Taiwan. In Sweden, the use of nuclear power as an energy resource is an issue with an ongoing debate. In 1980 there was a popular vote on whether to keep using nuclear power as energy recourse resulting in a decision that all reactors should be phased out by the year of 2010. But in February 2009, the Swedish government decided that this law was to be repealed and now it will be possible to build new reactors and keep getting energy from nuclear power (Sjörmstedt, 2010). The issue of nuclear power as an energy resource is included in the mandatory science course, Science studies A (The Swedish National Agency for Education, 2010b), and it has obvious connections to science, e.g. physics, but also social aspects.

**SSI 3: GMO**

The issue of GMO is also included in the Swedish upper secondary school. The participants of the studies included this thesis have either taken Biology A course, were genetics is included or the Science studies B course, also including genetics, and both of these courses embrace teaching of GMO (The Swedish National Agency for Education, 2010c, 2010d). This is an issue that has recently been debated in Sweden, both concerning the use of GMO in agriculture and the occurrence of GMO in food. This issue has clear connections to the subject of genetics and also social aspects are involved. Several researchers have used SSIs about gene technology and genetically modified food, (e.g. Chang & Chiu, 2008, and Lewis & Leach, 2006).

**SSI 4: Consumption**

Consumption has connections to science, especially environmental science, and is an issue included in Science studies A (The Swedish National Agency for Education, 2010b). The major environmental challenges facing humans today are due to consumption patterns, particularly in western societies. In the syllabus for the course of Science studies A one of the goals that pupils should have attained on completion of the course is: “have a knowledge of the importance of lifestyle for the environment and sustainable ecological development” (The Swedish National Agency for Education, 2010b) and this should be done both from a scientific perspective but it is also stressed that this course aims to equip students with the skills necessary to be able to participate in debates from a social perspective as well as make standpoints from an ethical perspective. Consumption is an issue that is clearly cross-disciplinary in its nature.
Purpose and research questions

The overall aim of this research was to find out if the SEE-SEP model is a suitable framework in analyzing the resources of students’ argumentation on SSIs. In addition, I aimed to investigate the resources used by students, to what extent knowledge was involved, and compare the differences related to students’ study backgrounds and gender, when arguing SSIs.

Research purpose:

I. What resources do students use in their informal argumentation on SSIs?
II. Do students’ study backgrounds and gender influence the use of resources of supporting reasons in arguing about SSIs?

The research questions in paper I are:

1. How is the distribution of supporting reasons presented 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. Are there any differences in choices of SSIs to argue in relation to students’ study backgrounds and gender?
2. Are the numbers of supporting reasons different among students with different study backgrounds and genders?
3. Are there any differences in the aspects of knowledge, value and personal experiences used by students in relation to their study backgrounds and genders?
4. Are there any differences in the six subject areas (of sociology/culture, economy, environment/ecology, science, ethics/morality and policy) used by students with different study backgrounds and genders?
Methodology

Written communication could be a way to articulate claims, evidence and warrants. In the research presented in this thesis, students were invited to make their argumentation on one of their chosen SSI topic through written reports. In the previous research regarding students’ reasoning abilities, group discussions have been found useful (Sadler, 2004a). However, in group discussions, the social demand of the group might be influential, since people may depend on the social interaction among the group members through the participants’ voice and opinions (Albe, 2008b). Accordingly, we wanted all students to make arguments without having the social demands which may come from the group discussions and affect the results. Accordingly, written arguments were chosen to explore students’ reasons while arguing about SSIs individually in this research. In addition, participants were asked to choose one out of the four SSIs to make arguments on, since we wanted students to argue something they felt comfortable with and which was engaging for them. A mixed-method approach is used in this thesis, including a combination of quantitative and qualitative research methods. According to Johnson and Onwuegbuzie (2004) the advantages of using a mixed method in research are many (e.g. that words and narratives can be used to increase the significance of numbers and that numbers can be used to add precision to words, pictures and narratives) and that many research questions are best and most fully answered through using such an approach. In this research quantitative methods have been used in order to calculate and quantify the resources used by students in their argumentation and statistics have been used to some extent for comparison. A qualitative approach has been used in the initial coding process and for providing narratives to add meaning and exemplify the numbers.

Participants

Students from three upper secondary schools participated in the two studies. Two of the schools are situated in a medium-sized town and the third school is located 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 (see table 1 for the detailed information). Among the participating students in the second study, there were 103 students from a science program and 105 from the social-science program. The students from the science program had taken courses of chemistry, biology, physics and mathematics to a high extent. The students from the social science program had studied less mathematics, chemistry, biology and physics than the science majors. Both groups of students had taken the mandatory general science course, including topics like ecology, energy and environmental science. The data collection was done during the last month before the students graduated from their upper secondary schools. All students were informed
about the purpose of the studies and joined voluntarily. This study was approved by the research ethical committee at Karlstad University.

Table 1. Participants of the first and second studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Total</th>
<th>Gender</th>
<th>Study background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>Social-science major</td>
</tr>
<tr>
<td>First study</td>
<td>80</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td>Second study</td>
<td>208</td>
<td>124</td>
<td>84</td>
</tr>
</tbody>
</table>

Data analysis

As mentioned, the SEE-SEP model was adopted as an analytical framework in the two studies presented in this thesis. Based on the SEE-SEP model, SSIs could cover six subject areas including 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 personal experience (P). Accordingly, there are 18 codes generated (Figure 1) and applied to analyze students’ written reports. For both studies, I performed qualitative analysis first followed by a descriptive analysis and T-test to compare students’ performance and the differences among students’ study backgrounds and gender. For a deeper description of the codes, definitions, data analyzes and validation, see paper I and II.

Methodological concerns

The data collecting process was conducted in a classroom setting and this might influence the students’ reports in a way that affects the results. Being in a school setting can make students feel that this is a school assignment and act accordingly, not feeling that they can state their opinions as freely as I wanted them to. However, to prevent this influence as much as possible, the students were informed before the data collection took place that their reports were only going to be used for research purposes, and the students were also informed about the aim of the research. The data was collected during students’ lessons due to the practical reason of availability. Accordingly, during the time that data was collected, students were supposed to be dedicated to mathematics, social science and physics, which might have some influence on students’ generating more reasons from e.g. science.
Summary of the papers

Paper I

In this paper I used the SEE-SEP model to analyze 80 upper secondary students’ (40 science majors and 40 social-science majors) informal argumentation on four SSIs, including global warming, GMO, nuclear power and consumption. The purpose was to explore students’ use of supporting reasons and to what extent they could use scientific knowledge in their arguments using the SEE-SEP model as an analytical framework. In the theoretical framework I provide a definition of SSI and a description of the concept of informal argumentation. Since the SEE-SEP model was used to analyze students’ use of resources in supporting their arguments, the SEE-SEP model was delineated in the paper. The results showed that the SEE-SEP model is a suitable analytical framework to analyze students’ reasons used in constructing their informal argumentation, since all the resources used by student was covered by the model. I disclosed that students in this study could use many different resources in their informal argumentation. The value aspect was the most commonly used; about 67% of students’ supporting reasons were based on values. Knowledge was used for 27% of the supporting reasons, which indicated that it was difficult to apply knowledge to argue in these SSIs. Only 6% of the resources used by students were connected to personal experience. I discussed that science educators need to address evidence- and knowledge-based teaching in school education and to let students have the opportunity to transfer what they have learnt from school to daily-life context, and that SSIs are suitable contexts to make such connections. The scarce use of personal experience could be explained by that students might not be used to refer to their own experience when making arguments or students might not have any experience in relation to the SSI topics in this study. When looking at students’ performance on the individual SSI, the value aspect was applied to the same extent (67%) in all the four topics. Knowledge was applied more in discussing GMO and nuclear power topics, but less in global warming and consumption issues. The aspect of personal experience was most common in the consumption issue and this could be due to the fact that we are all consumers. Concerning the subject areas students applied in their informal argumentation, environment/ecology and science were the most common resources used. In the topics of nuclear power and GMO students mainly used resources from the science subject area. The issue of global warming was argued more based upon the subject area of environment/ecology and the consumption topic retrieved resources from the subject areas of sociology/culture, environment/ecology and ethics/morality, almost to an equal extent. My findings support that the different SSIs could influence students’ choice of supporting reasons when constructing their arguments. I also argued that adopting the SEE-SEP model in teaching SSIs is applicable to not only make teachers from different subject areas work together, but also to help students perceive a multidisciplinary viewpoint.
In this paper, more students (N = 208) were invited to participate, and as mentioned in paper I, the SEE-SEP model was used to investigate the resources of reasons in students’ argumentation in four SSIs including global warming, GMO, nuclear power and consumption. The main difference from paper I was that I wanted to compare the different performances in relation to students’ study backgrounds and gender. The results showed that social-science majors and females generated more numbers of reasons and also provided reasons of a multi-disciplinary nature. An explanation for this could be that SSIs are an uncommon practice in the science classroom due to a number of reasons delineated in the article, e.g. teachers feel that the time they have for teaching science content in the curricula is too limited to include the discussions of SSIs or lack of skills to manage classroom discussions. Regarding the gender differences, I referred to the field of cognitive psychology, which supports the findings that females provided more reasons in their argumentation explained by better verbal reasoning abilities. The aspect of value was found to be used most in students’ argumentation without differences among study backgrounds and genders, and reasons from the subject area of science were presented most in the topic of nuclear power and GMO, with no difference found among study backgrounds and genders. Reasons from the subject area of ethics/morality were generated less among the four SSIs, but relatively, females provided more than males. A further analysis of ruling out the confounded effect of students’ study backgrounds and gender in this study is necessary. Moral issues have been emphasized in science education research and my results indicate that school education need to focus more on the use of ethics/morality in arguing SSIs. I conclude by advocating that explicit instruction of providing multi-disciplinary recourses in discussing SSIs is needed in school education, especially the ideas from the subject area of ethics/morality. Evidence and knowledge-based argumentation also needs to be addressed as well as engaging students’ personal experience in the discussions of SSIs.
Discussion

Multiple resource qualities

In this thesis I have used the SEE-SEP model as an analytical framework when investigating the students’ informal argumentation. My results show that the students augmenting on the SSIs included a variety of aspects that cover many fields and all of these were covered by the model. This shows the great potential for using this model when investigating resources used in argumentation.

Furthermore, the SEE-SEP model includes and systematizes the desirable aspects that e.g. the Swedish curriculum states that students should be able to achieve through education, for example the importance of values, understanding of other people and cultures, the importance of an environmental perspective etc. (The Swedish National Agency for Education, 1994a). All of these qualities can be found in the model and can be scrutinized and analyzed by using it.

In a body of the previous research made in relation to argumentation of SSIs, the researchers have been focused on something specific, e.g. Sadler and Zeidler (2009) focus on moral and ethics, Patronis, Potari & Spiliotopoulou, (1999) focus on scientific knowledge. When using the SEE-SEP model in the studies presented in this thesis, we could grasp multiple aspects, focusing on the numerous resources students use when discussing SSIs. By using the SEE-SEP model, a much broader area of students’ resources can be covered, allowing for a more comprehensive examination of argumentation.

Resources vary with SSI

In the first study, I found that the distribution of resources used by students varied among the different SSI topics. The aspects of knowledge, value and personal experience showed only small variations, value was used to the same extent in all of the four SSIs (67%), knowledge varied between 23% and 32% and on the aspect of personal experience the results varied from only 1% on the issue of nuclear power to 10% on the issue about consumption. Sadler and Zeidler (2005b) found a positive relationship between content knowledge and the quality of students’ informal reasoning (on the topic of genetic engineering). My study showed that students use relatively little resources from the aspect of knowledge. This stress the importance of practicing the use of content knowledge in argumentation and also that the students need more science related experience. If argumentation quality is related to students’ familiarity and understanding of the context of the issue, as found in a study made by von Aufschnaiter, Erduran, Osborne and Simon (2008), the reason for the scarce use of knowledge by the students in this thesis might be that the students did not feel sufficiently acquainted with the SSIs adopted in the study. I tried to
minimize this by letting students chose one out of four SSIs to make their arguments, and moreover, all the SSIs used in this research are included in the objectives and aims of the Swedish curriculum and syllabuses. This leads to the conclusion that more practice in arguing SSIs in school education is of great importance and needs to be emphasized.

Regarding the subject areas in the SEE-SEP model (So, Ec, En, Sc, Et, Po), the subject areas of environment/ecology (En) and science (Sc) were the most common resources used. The use of resource in students’ argumentation was found related to the SSI topic. For example, when making arguments on the SSI about global warming, students used more reasons from the area of environment/ecology (En) than on the other SSIs, but when making arguments on the topics of about GMO and nuclear power students used more reasons from the science (Sc) subject area. These results support the findings of Chang and Chiu (2008) that different attributes of SSIs could influence students’ supporting reasons from different subject areas.

Importance of study background and gender

The students from the science program used fewer supporting reasons than the social science major students. This might because students attending the social-science program are more familiar with argumentative practices (Levison & Turner, 2001), and that the discussion of SSIs in the science classroom is an uncommon practice (Reis & Galvão, 2009), although this needs to be further investigated in a Swedish context. I also found that females provided more supporting reasons than males. This can be explained by research in the field of cognitive psychology showing that females have better abilities in verbal reasoning (Calvin, Fernandes, Smith, Visscher, & Deary, 2010; Kuhn & Holling, 2009).

Regarding students’ learning interests in science, the ROSE study found that girls were more interested in ethics in science than boys (Sjøberg & Schreiner, 2010) and this could explain that we found more reasons from the subject area of ethics/morality (Et) used by female students, regardless of what SSI was chosen to argue. As mentioned previously, the Swedish curriculum (The Swedish National Agency for Education, 1994a) explicitly states that education should reflect both male and female perspectives, both in terms of its content and structure. Therefore, the research of how students of different gender may argue differently is of great interest. However, more research is needed on how gender affects students’ argumentation on SSIs to fully understand the influential factors involved.
Further research

In studies by Sandoval and his colleague (Sandoval, 2003; Sandoval & Millwood, 2005) students often failed to provide sufficient warrants for their claims. In my studies, by using the SEE-SEP model, I showed that students were able to support their reasons using resources from multiple aspects and subject areas. However, I also found that they used knowledge to a rather low extent in their argumentation. Thus, investigating why knowledge is not used to a greater extent needs to be further investigated.

Group discussions are often used by researchers (e.g. Albe, 2008b, Jiménez-Aleixandre et al., 2000) investigating argumentation on SSIs. In my studies, the investigation of students’ argumentation of SSIs was made on students individual written reports. It would be of great interest to apply the SEE-SEP model as an analytical framework when analyzing argumentation of SSIs in other discursive practices, such as group discussions, and also in larger contexts like debates, oral and written.

Previous research indicate that various dimensions are involved in the process of students’ informal reasoning and informal argumentation about SSIs, such as scientific knowledge (Chang & Chiu, 2008; Ekborg, 2008; Jallinoja & Aro, 2000), or a combined perspective such as individuals’ personal experience, value, ethical concerns, or governmental policy (Chang & Chiu, 2008; Sadler, 2004a, b; Zeidler et al., 2005). The SEE-SEP model represents a holistic view embracing the aforementioned dimensions. In the studies included in this thesis I found differences in the use of resources in students’ argumentation related to the different SSI topics used in this research. It would be interesting to investigate more, different, SSIs.

Implications for teaching

It can be hard for teachers to find the appropriate SSI in teaching and to be sure to cover the desired perspectives that needs to be considered. In the first study I investigated whether different SSI made students use different resources in their argumentation and found this to be the case. Following, the SEE-SEP model could be developed and used by teachers as a tool to find suitable SSIs for their teaching. It can also be used to make teachers aware of the missing aspects of students’ argumentation and be helpful when preparing lessons in the beginning of a new course by investigating students’ prior knowledge.

The SEE-SEP model can also be used directly by students. Halverson, Siegel and Freyermuth (2009) argue that students must be given opportunities to reflect upon their own views and recognize differences between perspectives (e.g. ethical, economic, religious and scientific) when making arguments on SSIs. To accomplish this, Halverson and his colleagues point out that students must be informed about the different involved perspectives which they are
currently arguing. The SEE-SEP model can be used as a template to enable students to construct and analyze their arguments.

Moreover, the SEE-SEP model can also be used in teaching with a cross-disciplinary focus in the science classroom. Teachers from different disciplines could design SSI-instruction together in order to provide students with a more holistic view in science education. However, the possible and positive aspects of co-teaching are needed to be investigated further. In order to facilitate the use of argumentation and also include multiple perspectives in co-teaching, which may involve teachers from the humanities together with science teachers, the SEE-SEP model could be beneficial. A similar suggestion was made by Tal and Kedmi (2006), who found, in their study of classroom culture and students’ performances through SSI-teaching that co-teaching could support the teachers shifting from traditional teaching towards teaching including argumentation on SSIs.
References


Wu, Y.-T., & Tsai, C.-C. (2010). High school students' informal reasoning regarding a socio-scientific issue, with relation to scientific epistemological beliefs and cognitive structures. *International Journal of Science Education, First published on: 03 March 2010 (iFirst).*


This thesis focuses on upper secondary students’ use of resources in their supporting reasons when arguing socioscientific issues (SSIs). The skills of argumentation have been emphasized in science education during the past decades and SSIs are proven a good context for learners to enhance skills of argumentation and achieve the goal of scientific literacy. Research has shown that supporting reasons from various resources are embedded in students’ argumentation on SSIs, and also that multi-perspective involvement in reasoning is important for the quality of argumentation. To explore the reasons used by students in arguing about SSIs in this thesis, the SEE-SEP model was adopted as an analytical framework. The SEE-SEP model covers the six subject areas of sociology/culture, economy, environment/ecology, science, ethics/morality and policy, which are connected to the three aspects of knowledge, value and personal experience. Two studies covering four SSIs (global warming, GMO, nuclear power and consumption) explore how students construct arguments on one SSI topic chosen by them. In paper I, I investigated students’ use of resources in their informal argumentation and to what extent students made use of knowledge. The results showed that students used value to a larger extent (67%) than knowledge (27%). I also found that the distribution of supporting reasons generated by students varied from the different SSIs. In paper II, I explored students’ use of resources in relation to students’ study background (science majors and social-science majors) and gender. The results showed that social-science majors and females generated more numbers of reasons and also showed a larger amount of multi-disciplinary resources in their supporting reasons. From the findings of this thesis, the SEE-SEP model was established as a suitable model used to analyze students’ resources of supporting reasons while arguing about SSIs. Furthermore, the potential for applying the SEE-SEP model in teachers’ SSI-teaching and students’ SSI-learning is suggested. The implications to research and teaching are also discussed.