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Making the invisible visible: how students make use of carbon footprint calculator in environmental education

Emma Edstrand

emma.edstrand@gu.se

Department of Education, Communication and Learning, University of Gothenburg, Gothenburg, Sweden

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Making the invisible visible: How students make use of carbon footprint calculator in environmental education

E. Edstrand[1]

[a]*Department of Education, Communication and Learning, University of Gothenburg*

Problems concerning carbon dioxide emissions and other climate change related issues are on the global political agenda and constantly debated in media. Such issues are important for individuals to enable active participation in society. This study has a particular interest in the use of carbon footprint calculators (tools for calculating carbon dioxide emissions of human activities) in the context of learning about environmental issues and climate change. More specifically, it contributes with insights into how such tools foster different modes of reasoning about the environment. The empirical data consists of video recordings of 15 Swedish upper secondary students' classroom discussions. The study derived from one specific half-day-lesson with activities related to the use of a carbon footprint calculator. In the first part of the lesson, the students worked individually with the tool for calculating their carbon footprint, and in the second part of the lesson the students discussed their carbon footprints in groups. The focus of the analysis is on the group discussion and on what modes of reasoning and arguing about the environment that are made possible through the students' use of the calculator. The study investigates the students' accounts in relation to how they discuss and compare their carbon footprints. That is, how the students in their discussions explain and justify actions in their everyday lifestyle. The findings indicate that the carbon footprint calculator supports different modes of reasoning and arguing about the environmental impact of actions in students' everyday lifestyle. The carbon footprint calculator offers students a new arena for developing an understanding of climate change and its relationships to human activities. The results shed light on the ways in which students are able to quantify, analyse and compare carbon dioxide emissions both on an individual level but also at a systemic level (across countries) after having used the carbon footprint calculator. The tool thus mediates features of the environment that students otherwise could not perceive; it makes the invisible visible.

Introduction

Problems concerning carbon dioxide emissions and other climate change related issues are on the global political agenda and constantly debated in media. In education, such issues are raised in policy documents and curriculums and are regarded upon as important for individuals to enable active participation in society. However, questions about environmental awareness, for instance the impact of an individual's everyday choices with respect to travel, food, and lifestyle, are not everyday knowledge for young (and not so young) people, but rather a kind of knowledge that requires extensive learning. To give a concrete illustration; the average Swedish person emits 1894 kilogramme carbon dioxide per year linked to transportation habits. But what it implies, concretely in figures to take the car compared to public transportation or to go on vacation by airplane is not common knowledge to most people. Such human lifestyle activities could be visualised as leaving footprints all over the planet. More specifically, to emit 1894 kilogramme carbon dioxide per year due to

[1] emma.petersson@.gu.se

transportation habits results in footprints with global consequences. In terms of visualising people's carbon footprint there are large numbers of calculators available online where people have the possibility to measure their footprint. By using such a cultural tool, in the Vygotskian sense (Vygotsky, 1978) people can calculate their yearly carbon dioxide emissions by answering questions regarding how they transport themselves, their consumption of energy at home, eating habits, purchases and, increase their insight into the environmental impact of their lifestyles. The technology is available in various forms and through a variety of organisations. For instance, The Nature Conservancy[2], EPA[3] (United States Environmental Protection Agency), WWF[4], Center for Sustainable Economy[5], present calculators on their web pages with the explicit idea of helping people calculate their carbon footprint.

This article has a particular interest in Swedish upper secondary students' use of carbon footprint calculators in the context of learning about environmental issues. More specifically, it contributes with insights into how such tools foster different modes of reasoning about lifestyle activities and carbon footprint values. In a sociocultural perspective, a central focus concerns cultural tools and the ways in which people make use of such resources when interacting with the world (Vygotsky, 1978; Wertsch, 1998; Säljö, 2009). Learning, then, becomes a matter of appropriating knowledge and skills through the adoption of cultural tools. In the same manner as carbon footprint calculators are used to measure carbon dioxide emissions, rulers are used when measuring and drawing lines and various calculators when, for instance, calculating how many calories are burnt whilst jogging. In the Vygotskian view, a cultural tool "recreates, reconstructs the whole structure of behaviour" (1997, p. 87). This implies that through using various tools we structure the ways in which we think and act. The tools make it possible for us to master abstract functions such as comparing and analysing, which otherwise would have been very complicated or even impossible. For instance, through using cultural tools, discussions about the length of an object or the number of calories burnt whilst jogging 10 kilometres are made possible. This way, consciousness and awareness arises from reasoning, transforming abstract functions into visible knowledge. A tool-based learning environment therefore allows the students to articulate knowledge through comparisons, integration and synthesising different functions without requiring any specific underlying content acquisition. Rather, as Vygotsky puts it, "The inclusion of a tool /…/ abolishes and makes unnecessary a number of natural processes, whose work is [now] done by the tool" (1997, p. 87).

Digital tools for measuring people's impact on the environment

Large numbers of articles, journals and books deal with issues of the environmental impact of people's actions (e.g. Chowdhury, 2010; Klein-Banai & Theis, 2011; Larsen et al., 2011; Li et al., 2008; Shirley et al., 2012; Wackernagel & Rees, 1996). These types of studies, in most cases, include tools such as carbon footprint calculators and/or ecological footprint analyses with the purpose of measuring environmental impact. Both carbon footprint calculators and ecological footprint analyses are tools for calculating people's footprints within areas of transportation, food, purchases etc., however, they differ in terms of measurement units. This is to say that a carbon footprint calculator calculates carbon dioxide emissions in kilograms or tons whereas an ecological footprint analysis is used as a method of measuring the land area necessary "to produce the goods and services consumed by residents of that country, as well

[2] www.nature.org/greenliving/carboncalculator/index.htm
[3] www.epa.gov/climatechange/ghgemissions/ind-calculator.html
[4] footprint.wwf.org.uk
[5] www.myfootprint.org

as the capacity needed to assimilate the waste they generate." (Kitzes et al., 2007, p. 1; see also Wackernagel & Rees, 1996).

Accordingly, carbon footprint calculators and ecological footprint analyses are both used in several studies with the aim of measuring the environmental impact of activities taking place in different parts of society, such as universities (Klein-Banai & Theis, 2011; Larsen et al., 2011; Li et al., 2008), islands (Shirley et al., 2012), and enterprises (Chowdhury, 2010). For instance, when working at universities, activities such as traveling to conferences by airplane, letting students practising laboratory work are examples of activities, which have an impact on the environment in the form of carbon dioxide emissions and discharges. Even though there are several studies that focus on carbon footprint values of universities, organisations, enterprises etc., there are as yet still not much research on the use of carbon footprint calculators and ecological footprint analyses in instructional settings. Those few studies that have been conducted will be elaborated on in the following section.

Using carbon footprint calculators in instruction
In recent decades, the use of interactive digital technologies has gained increasing importance in teaching and learning activities. This has resulted in new arenas of research questioning how to optimally support both educators and students to discover meaningful ways to utilize such technologies in different instructional settings. The rapid developments within digital media have resulted in a situation where information and knowledge are made accessible in new manners, and our knowing and reasoning to an increasing extent take place in coordination with such external tools. The development of sophisticated and increasingly mobile instruments of reasoning presents challenges to classroom practices, but it also enables interesting possibilities for supporting a wide range of learning activities of an exploratory and analytical nature.

As already mentioned, research on the use of carbon footprint calculators and ecological footprint analyses in instructional settings constitutes a new research field. However, results from the limited number of studies conducted, show that such resources may serve as educational tools that contribute to making people aware of the environmental impact by calculating the effects of their actions (e.g. Hopkinson & James, 2010; McNichol et al., 2011). For instance, in a pilot study conducted by Cordero and his colleagues (2008), the purpose was to explore the students' attitudes towards climate change. The study included approximately 400 college students from two different meteorology courses. The participants took part in a pre- and a post-test. In between the two tests, half of the students in one of the two courses were involved in an ecological footprint activity. These students were surprised by the connection between their personal lifestyle and global warming, and they expressed that they did not know they had such a large impact on the environment. In the post-test, students from the group, which was not involved in the ecological footprint activity, had a higher number of incorrect answers compared to the group involved in the activity (Cordero et al., 2008). In another study, Kemppainen and colleagues (2007) showed that first year engineering students started to take environmental impacts of their designs into consideration. This was the result of learning activities addressing sustainability, calculation of the students' personal energy consumption, carbon footprint and ecological footprint.

Research regarding the use of carbon footprint calculators in education thus points to the advantages of using such tools as a means of making students aware of the environmental impact of their activities (Cordero et al., 2008; Kemppainen et al., 2007). When feeding information into the carbon footprint calculator and answering a question, the students get an immediate response of the impact of their actions on the climate. Furthermore, the tool enables students to manipulate and test their carbon footprints under different circumstances, that is, the students are able to go back and change their answers and see the consequences of alternative behaviours on their carbon footprint (Kemppainen et al., 2007). This implies that a student who answers that her house is heated with solar or geothermal energy may change the answer to say that the house is instead heated with coal and immediately the student can see the change in her carbon footprint. This way, the use of carbon footprint calculators in educational settings provides opportunities for comparisons and analytical exercises in which the consequences of alternative choices may be made visible.

Socio-scientific issues in education

On the basis that carbon footprint calculators are rather new tools in instructional settings it is interesting to investigate them in the context of environmental education activities and the learning of socioscientific issues. Environmental education is becoming increasingly important in schooling in many parts of the world. Environmental education concerns issues about the use of resources, sustainable development and the impact of human activities on the climate. An important element of the curricular goals of environmental education is to make the relationships between individual and collective activities and their impact on the environment transparent (UNESCO, 1975, 1977; see also Fauville et al., 2013). Environmental education is interesting as an area of teaching and learning since the issues addressed are multidisciplinary in nature and require insights into many fields. Thus, environmental education inevitably implies the negotiation of socio-scientific issues whose aim is to prepare students for active participation in society (Sternäng & Lundholm, 2011; Sadler, 2009). Socio-scientific issues are proposed to provide contexts where students can explore ethical principles and negotiate about social complexities that stem from scientific, economic and ethical tensions (Sadler et al., 2004; Sadler et al., 2007; Walker & Zeidler, 2007). Already in 1971 Gallagher discussed the necessity of addressing such issues by considering ways in which science, technology, and society interact:

> It is postulated that learners should be given an opportunity to acquire an awareness of the social interactions of science. For future citizens in a democracy, understanding the interrelations of science, technology, and society may be as important as understanding the concepts and processes of science. An awareness of the interrelations between science, technology, and society may be a prerequisite to intelligent action on the part of a future electorate and their chosen leaders. (Gallagher, 1971, p. 337)

Even if questions about how the everyday actions of citizens in terms of travel patterns, food choices and other features of lifestyle impact on the environment are quite abstract, students are able to position themselves ”as active contributors to society with competencies and willingness to employ scientific ideas and processes, understandings about science and social knowledge (e.g. ideas about economic and ethical influences) to issues and problems that affect their lives” (Sadler, 2009, p. 12).

As pointed out in the introduction, the present study has a sociocultural approach where knowledge and learning are regarded as manifested in social practices. This means that in order to understand students and their approaches to learning and knowledge, the situated character of learning has to be acknowledged (Säljö, 2009; Lave & Wenger, 1991). In this perspective, knowledge and skills do not emerge from within an individual but rather in between people in social interaction (Säljö, 2009). Accordingly, a central part in a sociocultural perspective is the focus on learning as participation, which “is always based on situated negotiation and renegotiation of meaning in the world. This implies that understanding and experience are in constant interaction" (Lave & Wenger, 1991, p. 51). Access to various digital media tools, which produce information in different representational forms, enables possibilities for supporting a wide range of learning activities in line with the participatory metaphor. The use of such resources opens up for possibilities for students to investigate and develop an understanding of socio-scientific issues when engaged in various group activities (cf. Petersson et al. (2013); Furberg & Arnseth (2009). In this study, students are considered as actively participating within the learning activities of calculating their carbon footprints and analysing their results.

In this study, carbon footprint calculators are regarded upon as tools for mediating information about environmental consequences of students' lifestyle activities, visualised as carbon footprints. Carbon footprint calculators open up for the possibility for students to document, reason, compare and analyse their activities in an environmental education context. Since, students surround themselves with different kinds of digital tools they are, in most cases, familiar with various types of interfaces. Consequently, students would likely have competence in using a carbon footprint calculator to solve issues such as documenting transportation- or eating habits, i.e. the students have knowledge about how to proceed in such digital media environments. Furthermore, when it comes to issues of the personal carbon footprint, most people have an idea that carbon dioxide emissions have negative consequences for the environment. Accordingly, reasoning about carbon footprints often needs "some accounting procedures" (Mäkitalo, 2003, p. 497), i.e. the students need to account for choices and actions in their everyday lifestyle. The analysis is guided by questioning in what way students use the carbon footprint calculator as a resource for reasoning about actions in their everyday lifestyle and how they account for their footprints after using the calculator.

Empirical study

Setting and participants

The present case study is part of a research project, which investigates aspects of the Inquiry-to-Insight (I2I[i]) project. I2I is a large scale, bi-national collaboration between schools in the U.S. and Sweden on issues of climate change. In this specific case study, I have only used empirical material from an upper secondary class in Sweden engaged in activities of using a carbon footprint calculator. The carbon footprint calculator used is described below. The teacher of the Swedish class was introduced to the carbon footprint calculator through collaboration with marine scientists and then the tool was used independently and as part of his regular teaching. This way, the study represents a learning activity taking place in an everyday practice of schooling.

The empirical material presented in this article is part of a longer study (including approximately 21 hours of video recordings following a Swedish upper secondary class), which seeks to investigate the role of digital media in environmental education activities and how learning about socioscientific issues may be promoted through the use of digital tools. The participants included in this case study were 15 students engaged in environmental education activities. The study is derived from one specific half-day-lesson with activities related to the use of a carbon footprint calculator. In the first part of the lesson, the students worked individually with the carbon footprint calculator for calculating their carbon footprints, and in the second part of the lesson the students discussed their carbon footprints in groups of three to four students. The focus of the analysis is on the group discussions. The group discussions were guided by questions formulated by researchers within the research project in collaboration with marine scientists from the I2I project. The questions concerned the amount of carbon dioxide emissions that was caused through the students' choice of transportation, home energy, food and purchases and how they could contribute to reduce their emissions. Some of the students brought their computers with their results to the discussion while others had written down their results of their carbon footprint on paper. The teacher and the researchers were not present when the students discussed their carbon footprints.

Data and analysis

In this study I have analysed approximately two and a half hours of video documentation of students reasoning about their carbon footprints and environmental issues in the context of using a carbon footprint calculator. The cameras were positioned on tripods in front of the groups in order to capture students' interactions (speech and non-verbal activities). The students' interaction with each other as well as the activities with other resources (computer, notes etc.) were transcribed. In order to understand the students reasoning and arguing in depth, the students' interactions have been analysed in detail (cf. e.g. Heath et al., 2010; Rogers et al., 2011). In order to investigate how the carbon footprint calculator becomes a resource for students in their reasoning about their carbon footprints, the analysis aims at focus on student's accounts (Scott & Lyman, 1968; Mäkitalo, 2003; Furberg, 2009), which is defined by Scott and Lyman (1968) as "a linguistic device employed whenever an action is subjected to valuative inquiry" (p. 46). This implies that the analysis concerns how students in discussions about their carbon footprints explain and justify their own actions related to their everyday lifestyle.

Figure 1: Illustration showing students discussions after working with the carbon footprint calculator.

Carbon footprint calculator

In order to understand the logic of the study, the digital tool carbon footprint calculator will be presented and described. The tool is supposed to offer possibilities for students to learn to analyse issues related to their emissions. This way, the carbon footprint calculator could be seen as a recourse that mediates analytic practices. The students are to answer 50 questions related to: a) transportation; b) home energy and appliance; c) food, and d) personal purchases. When the students enter the carbon footprint calculator they type in their name as well as the country they live in. After doing that the digital tool provides the students with information regarding the average carbon dioxide emission for the country chosen, calculated in kilograms for one year.

The questions about transportation include how students get to school, to friends, to after-school activities etc. For example, whether the students travel by bike, bus, train or car. The questions within the area of transportation also concern number of airplane flights or other ways of travelling (by car, bus, train) in relation to students' vacation habits over the last year. The area of home energy and appliances include questions about the students' home, for example, if the students live in a house, apartment or townhouse and also the number of people living together. In this area of energy and appliances there are also questions about how the home is heated, the use of air condition or fan in the summer, shower habits, the use of washing machine and dishwasher, time spent in front of the TV and computer etc. Questions concerning the students' habits in relation to food concern the amount of calories the students eat per day, if they are vegan, vegetarian or non-vegetarian, if they eat organic food, how many times a week they eat take away food etc. The final questions are about the students' personal purchases. Examples of questions are if the students choose tap water or if they buy water in the shop, bring their own basket when shopping, how often they buy new electronics, if they recycle etc.

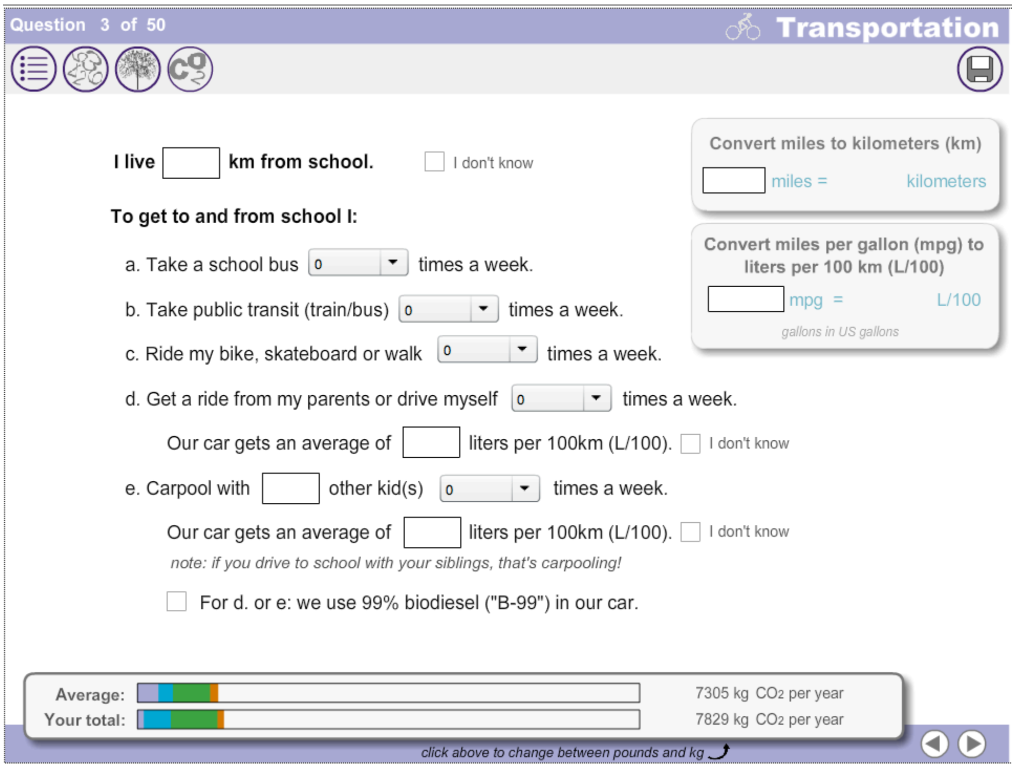

Figure 2: Screenshot from the transportation part of the carbon footprint calculator

Having the students answered all questions the result of the students' personal carbon footprint appears in the bar *your total.* This result is also shown to the students as they are engaged in answering the questions, in so-called *average bars*. This average bar allows the students to monitor how their values compare to a typical person in their country (see figure 2). The value in the average bar changes in relation to what country the students select. For instance, the value of the average carbon footprint of Sweden differs from that of the USA.

Results

Three excerpts have been chosen as they show frequently occurring patterns in the empirical material of how the carbon footprint calculator supports different modes of reasoning about carbon footprint values. As will be illustrated, the students' carbon footprints in my study was in general lower than the average person in Sweden, for example due to the students' age and the fact that most of them did not have a car or even a driving license. Consequently, when they reasoned about their carbon footprints, several students found it difficult to realize what they could change in their lifestyle in order to reduce their environmental impact. Instead they stressed that they already had low carbon footprints. How the students accounted for carbon footprint values in terms of personal values and average values of their country as well as other countries will be illustrated, focusing on the role of the carbon footprint calculator as a mediating cultural tool in students reasoning about carbon footprint values.

Accounting for other countries average emissions

In the excerpt below, Elias, Simon and Philip discuss what actions they could take to improve their carbon footprints. However, as mentioned above, these students already have low carbon footprints and consequently find it hard to come up with any suggestions. As Simon puts it: `there's nothing we can do we should actually eat much more`, pointing to that they have lower footprints than that of the average Swedish person when it comes to their eating habits. This discussion moves forward through Elias' suggestion of comparing the average carbon footprint in Sweden with the U.S. In excerpt 1, Elias, Simon and Philip have re-entered the carbon footprint calculator in order to discover how the U.S. keeps up with the emission values.

Excerpt 1.

```
01. Elias:  but they didn't really eat that much more
02. Simon:  no:
03. Elias:  but they transport themselves really bad and lived
             really bad
04. Philip: but it's only because listen e::h americans (.)
             they just ((looks at Elias)) instead of well go out
             for a walk (.) I go out and (.) dri- take- eh take my
             ca:r for a drive
05. Elias:  yea:h               [there are people who just
06. Simon:  ((looks at Philip)) [take the car to the mailbox hh
07. Philip: no: but=
08. Elias:  =there are people who [who do even
09. Simon:                        [hehe yea:h
10. Philip: okey ((looks at Simon)) but well it's not that common
             but (.) it is common that an American (.) takes the car
             for a drive=
11. Elias:  ((looks at Philip)) =yea:h
12. Philip: instead of just going for a walk
13. Elias:  it costs like a dollar per gallon it's like
14. Simon:  ((looks at Elias)) six and fifty [Swedish kronors]
15. Elias:  yea:h and what is it like three litres (pause) it's
            rea:l-
16. Simon:  really cheap ((shakes his head))
17. Elias:  °cheap°
```

The carbon footprint calculator provides the students with figures of their carbon dioxide emissions. Through this calculation, Elias, Simon and Philip establish the fact that they must have low carbon footprints since their values are below the average value of Sweden. Consequently, when they are done discussing actions of turning off the computer while not using it, drinking tap water instead of buying water in the shop, switching off the light when leaving the room etc. they find it hard to come up with further suggestions. In several instances in the overall material the students express that they already have environmentally friendly habits and do not know what more they can do to improve their footprints. This way, instead of comparing their footprints within the group it seems to be more interesting to compare these values with people in the U.S. Consequently, the students in excerpt 1, decide to compare themselves with Americans since, as Philip in utterance 10 puts it: `it is common that an american take the car for a drive`. Through the possibility of observing other countries' footprints the students shift focus from their own responsibility and instead focus on other countries having a higher impact on the environment in terms of carbon dioxide emissions. In this manner, the students make accounts for no need to change their life style habits to a great extent since there are countries that have much higher average carbon dioxide emission values.

Elias has an idea that people in the U.S. have higher average carbon footprints than that of people in Sweden when it comes to carbon dioxide emissions caused by their eating habits. However, when Elias uses the carbon footprint calculator in order to confirm his idea he finds that the two countries have about the same average in the food section. This turns out to be a little surprising to Elias as he points out: `but they didn't eat that much more`. The assumption that the average person in the U.S. has a higher consumption of food and consequently causes more emissions than that of the average person in Sweden turned out to be wrong. Instead, Elias compares the two countries' average carbon footprints in the transportation section as well as the home energy and appliance section. In utterance 3, Elias emphasizes `but they transport themselves really bad (.) and lived really bad`. Through using the feature of the tool, which makes it possible to select and observe carbon footprints of any country in the world, Elias is able to confirm his idea of the people in the U.S. as having a non-environmentally friendly average lifestyle. Accordingly, the carbon footprint calculator triggers the students to reflect on why the U.S. have such high value regarding transportation. For instance, in utterance 4, Philip explains this by saying: `but it's only because listen e:h americans (.) they just ((looks at Elias)) (.) instead of well go out for a walk (.) I go out and (.) dri- take- eh take my ca:r for a drive`. This way, Philip exemplifies an issue that is described by the carbon footprint calculator. According to Vygotsky (1997), this means that Philip, by observing the values originating from the U.S., is able to reason about the differences of the average emission values of the countries. In utterance 13, Elias continues the reasoning about the higher footprints of the U.S. as he takes the prices of fuels into consideration: `it costs like a dollar per gallon (.) it's like- six and fifty`. In utterance 16, Simon concludes the discussion by saying that the gallon is `really cheap`. This way, the students account for the higher amount of carbon dioxide emissions by pointing to the cheap fuel prices as one way of explaining why people in the U.S. take the car almost everywhere.

In excerpt 1, the students reason about carbon footprint values on a systemic level as they compare average values between two countries. In the next excerpt, we meet another group of students who instead reason about carbon footprints on an individual level where they account for activities and choices in their lifestyle.

Accounting for travelling by plane
Elsa, Paula, Emma and Jacob have compared their carbon footprints from the transportation part of the carbon footprint calculator. Following this, the students are about to answer a question concerning actions they would be willing to take in order to decrease their carbon footprint.

Excerpt 2.

```
01. Elsa:  ((reads from a paper with the questions to discuss)) how could
           we contribute to the decrease of the total amount of carbon
           dioxide emissions
           (pause)
02. Paula: walk to egypt hhh
03. Jacob: yeah exactly [hh
04. Elsa:               [hh
```

```
05. Emma:  well if its like you walk then well its- you already walk so
           damn much well I think I contribute pretty much cause the only
           time I take- well I go by I take the bus
06. Elsa:  m:
07. Emma:  that’s like- that’s all I go by
08. Elsa:  yea:h
09. Emma:  I never go by car
10. Jacob: well when you fly then you have a reason to fly [if you’re not
           going to spend half a year getting there
11. Elsa:                                                  [yea:h
12. Emma:  [yea:h for sure
13. Elsa:  [but (.) [it’s-
14. Emma:           [so how much more can we contribute
           (pause)
15. Elsa:  but we contribute rather well after all (.) since we don’t
           sort of drive to the shop and these short drives
```

In excerpt 2, Paula, in utterance 2, suggests that one way to contribute to the decrease of the total amount of carbon dioxide emissions would be to `walk to egypt`. The reason why Egypt serves as an example might be because of an earlier discussion where Jacob told his group members that he travelled to Egypt the year before. Paula finishes her utterance with a laugh indicating that this was not a serious proposal. Also Jacob and Elsa laugh as a response to Paula’s utterance. Jacob, in utterance 10, answers Paula by saying `well when you fly then you have a reason to fly [if you’re not going to spend half a year getting there`. By this utterance, Jacob accounts for travelling to Egypt by plane as he claims that such travels often imply that the travellers have a purpose with that trip (Scott & Lyman, 1968). Accordingly, Jacob justifies long distance trips by including the rationale of making it to the destination within a reasonable time frame.

The example of travelling to Egypt by foot is taken up by the students as something funny and maybe also as something quite unrealistic. Interesting here, is that the students seem to argue that they compensate for this by having rather low average emission values, since they walk almost everywhere (utterance 5) and do not drive to the shop (utterance 15) or other short distances. As the tool visualises the difference in carbon dioxide emissions between going on vacation by airplane, train or bus the students need to account for activities that normally do not require that kind of discussion. The students do not discuss actions such as changing their habits of going on vacation to places including airplane flights, rather the students orient themselves towards their overall low carbon footprints. Emma, in utterance 5, opens up for a way to approach the moral dilemma of travelling by airplane by saying: `you already walk so damn much well I think I contribute pretty much cause the only time I take- well I go by, I take the bus`. Through the orientation towards the overall low carbon footprints it is possible for the students to focus on their personal needs rather than on what would be best for the environment from a global perspective (cf. Sternäng & Lundholm, 2011, on climate change and morality). Accordingly, this function of the tool seems so to be a justifying resource that enables the students to master abstract functions by using the average bar as a guide for interpreting their actions as good or bad for the environment (cf. Vygotsky, 1997). Furthermore, this way of reasoning would not have been possible for the students without having worked with such a tool since these kinds of comparisons between transportation alternatives are structured around outputs (carbon dioxide emissions measured in kilograms) from the carbon footprint calculator.

The next excerpt is another example of how the students reason about emission values on an individual level. In excerpt 3, we meet a student who accounts for one specific activity –

practice driving – in a detailed manner.

Accounting for taking the car
In the excerpt below, Peter is sharing his experience of practice driving with his group members. Peter's reasoning is developed from a discussion where the group members compare their footprints by means of the transportation part of the carbon footprint calculator. Peter's value is about three times higher than that of the other group members.

Excerpt 3.

```
01. Peter: I drove- drove from strömsta this weekend (.) strömsta to
           gothenburg (.) it's almost- it has to be like eighteen miles
           [Swedish miles, 180 kms] or something that we drove
02. Tom:   m m m m
03. Peter: that's quite a lot of carbon dioxide (.) we were three persons
           in the car
04. Tom:   m:
05. Peter: although a volvo v seventy [V70] diesel I think it runs forty-
           eight something per mile [10 km]
           ((Albin and Jim look at each other and laugh))
06. Peter: so it's kind of less than if it would've been a gasoline car
           (.) older model this is then a newer volvo v seventy [V70]
07. Tom:   m m m
08. Peter: best would've been biogas
09. Tom:   m m m
10. Peter: we had that previously but then they removed that model
11. Tom:   m:
12. Peter: so we couldn't add- it's a company car then so we couldn't add
           that
13. Tom:   m:
14. Peter: e:h but diesel it uses less and it's sti:ll (.) it's not
           renewable (.) but it's (.) fossil fuel
15. Tom:   but maybe it's=
16. Peter: =unlike from biogas=
17. Tom:   =m:
18. Peter: still I've heard that they mix natural gas with biogas fifty
           fifty and natural gas isn't too good either
19. Tom:   no: m:
```

Before the conversation in excerpt 3 all students, except for Albin, stress to their group members how much they would want to own a car when having their driving license. Although the students are aware of the environmental impact of taking the car instead of using public transportation, they still would want to own a car. After having calculated his carbon footprint Peter is able to visually observe (in the form of carbon dioxide emissions measured in kilograms) the environmental consequence of his experience of practise driving. In doing so, Peter takes several different components into consideration when he is talking about his practice driving. For instance, in his reasoning Peter starts by taking the distance between the two cities into consideration which is something that he reflects on in utterance 3, as he stresses that such a drive implies `quite a lot of carbon dioxide`. However, almost immediately after this reflection Peter continues by saying that they were three persons in the car, a point that makes explicit that this reduces the average carbon dioxide emissions of the trip. Peter proceeds by explaining to his group members the model of the car (a Volvo V70 diesel), how much fuel the car uses and he compares this to a gasoline driven car. In a context of learning about environmental issues and climate change the wish of wanting to own a car needs accounting procedures (Mäkitalo, 2003). In his reasoning, Peter accounts for taking the car between Strömstad and Gothenburg through using different components as a way of justifying the activity. Furthermore, the different elements from which Peter builds his reasoning are to be found in the transportation section of the carbon footprint calculator. In this section the students answer questions regarding how they transport themselves. If the students respond that they use the car they also have to answer questions concerning distance, how many people they were in the car, type of fuel and how much fuel the car uses. As we can see in the excerpt, these components are also included in Peters reasoning. For instance, in utterance 5, Peter explains to his group members the model of the car: `although a volvo v seventy [V70] diesel I think it runs forty- eight something per mile`, pointing to how much fuel the car uses and continues, in utterance 6, by stressing: `so it's kind of less than if it would've been a gasoline car (.) older model this is then a newer volvo v seventy [V70]`. Through picking up questions included in the carbon footprint calculator, Peter finds a way of analysing his practice driving in a detailed manner where he generates specifications and qualifications relevant to the environmental consequence of driving a car. Peter is using the questions from the carbon footprint calculator as resources for understanding the environmental impact of his actions. More precisely, Peter is using these questions as he accounts for his practice driving in specific manners, i.e. in ways of pointing to the model of the car, fuel type etc.

Peter continues to justify taking the car as he goes on discussing different kinds of fuels in relation to his family's choice of car. Peter stresses that the best choice regarding fuel would be biogas. Then he continues by explaining that the family had a biogas driven car before but when changing to a new car the family could not choose this kind of car. Here, Peter presents relevant accounts of why his family does not have a biogas driven car as he refers to circumstances over which his family had limited control: `so we couldn't add- it's a company car then so we couldn't add that` (utterance 12). Finally, in utterance 18, Peter argues: `but I've heard that they mix natural gas with biogas fifty fifty and natural gas isn't too good either`. In this utterance, Peter is yet again weighing pros and cons of his practise driving. In terms of Scott and Lyman (1968), Peter, justifies this activity by putting forward "its positive value in the face of a claim to the contrary" (p. 51). In other words, in the excerpt Peter argues for the positive features of his family's car (Volvo V70 diesel) as well as he also points to problems related to biogas driven cars. This way, Peter accounts for his higher value due to his practise driving by imposing and reflecting on different aspects – it is not enough to justify it only by the wish to have a drivers licence.

Discussion
The findings from this study indicate that the carbon footprint calculator supports different modes of reasoning and arguing about the environmental impact of actions in students' everyday lifestyle. The results shed light on the ways in which students are able to quantify, analyse and compare carbon dioxide emissions both on an individual level but also at a systemic level (across countries) after having used the carbon footprint calculator. The result imply that the tool enables the students to a) make comparisons with the average emission values of their own country as well as other countries, b) justify their own lifestyle choices by making accounts for having a low footprint value in other areas, and c) quantify, analyse and discuss pros and cons in relation to their emissions in concrete figures. These three main modes of reasoning will be discussed below.

National and international comparison
A manner in which the carbon footprint calculator was found to support students reasoning was in terms of their way of comparing their carbon footprints to the average footprint of Sweden as well as other countries average emission values. In doing so, the students used the

average bar (showing the average carbon footprint of the country selected) as a resource for reasoning about themselves, or other countries, as environmentally friendly or not. This way, the tool does not solely make the personal impact visible but also makes it possible for the students to explore and analyse other countries' average carbon footprints. Similar to what is argued by Kemppainen and colleagues (2007), the findings from this study indicate that the design of the tool in terms of offering the possibility for the users to go back and forth and manipulate values, supported the students in their reasoning about how other countries keep up with the values. Since, the students regarded themselves as environmentally friendly they found it difficult to think in terms of what more they could do for the environment in order to decrease their footprint. In such instances in the material the students shifted focus from their personal responsibilities and instead observed values of other countries and engaged in discussions of why, for instance, the average American person emit more carbon dioxide emissions due to transportation habits compared to their own or the average Swede's carbon footprint.

Justifying by making accounts for low values in some areas
The carbon footprint calculator makes it possible for the students to observe their total carbon footprints but also their footprints in each of the four different sections (transportation, home energy and appliance, food and personal purchases). Additionally, the results from this study show that the students also used this function in order to compensate for non-environmentally friendly actions such as practice driving or going on vacations by airplane by emphasising their in general low emission values in other areas. For instance, in such discussions, the students did not see any problems with going on vacation including airplane flights since they regarded themselves as environmentally friendly in other areas. This way, the carbon footprint calculator facilitated the students' way of justifying their own lifestyle choices, render it possible for them to make accounts for having a low footprint value in other areas. Through using the tool in this manner the students could quantify something that is rather abstract and visually be aware of the environmental impact of their actions in concrete figures. For Vygotsky (1997), such an external arena provides material for students to "direct and realize the psychological operations (memorizing, comparing, selecting, etc.) necessary for the solution of the problem" (p. 86) in a systematic way. Accordingly, the carbon footprint calculator visualises and mediates something that the students otherwise could not observe and offers them a new arena for developing an understanding of climate change and its relationships to human activities.

Quantifying, analysing and discussing pros and cons
In accordance with earlier studies (Cordero et al., 2008; Hopkinson & James, 2010; Kemppainen et al., 2007; McNichol et al., 2011), and as displayed before, this study shows that through using the carbon footprint calculator the students are able to quantify and analyse their carbon footprints and get an immediate insight into how many kilograms of carbon dioxide emissions their choice of actions result in. The tool also enabled the students to discuss and elaborate pros and cons in relation to the different choices. In this manner the carbon footprint calculator was found to be a structuring resource for the students in their understanding of the environmental impact of actions that are related to transportation, home, food and purchases. What is shown in the group discussions is that the students have a wide range of experiences that they integrate in this environmental discourse. An example of this is how one of the students uses the activity of practise driving as a way of analysing society through his personal experience. When reasoning about his practice driving, the student makes several distinctions in ways of quantifications, comparisons, petrol, diesel, distance etc. which enables him to give accounts for taking the car. These distinctions are also incorporated

in the tool in the form of its questions and answer choices. This way, the tool draws the students' attention to different aspects of transportation that is relevant to consider when reasoning about the environmental impact of driving a car.

Conclusions

As argued in the introduction section, socioscientific issues are relatively new phenomena in contemporary education (Sadler et al., 2007). The characteristics of socioscientific issues imply that they consist of dilemmas including a multitude of questions, which the students can interpret in different ways. The carbon footprint calculator makes the personal environmental impact explicit for the students in terms of how the questions are focused on actions in students' everyday lives. It is evident from this study and others (cf. eg. Kemppainen et al., 2007; Cordero et al., 2008; Hopkinson & James, 2010; McNichol et al., 2011) that when the students are engaged in activities of reasoning and analysing their carbon footprints they realize dilemmas connected to the environmental impact of actions in various areas in society. In this manner, students' work with the carbon footprint calculator targets an understanding of problems related to carbon dioxide emissions and in what ways these could be approached in order to find solutions (Sadler et al., 2007; Säljö et al., 2011). For instance, the analyses illustrate that the tool triggers students to take moral aspects of actions into consideration that generally are not required in an everyday context. This is illustrated by this study, in how the students accounted for taking the car or going on vacation including airplane flights. These accounts were based on students' observations of carbon dioxide emissions and through their ways of scrutinising the relationships between their personal actions and experiences and the value showing in their carbon footprint. Hence, the quality of cultural tools influences the learning situation, as for example, the acquisition of a carbon footprint calculator, constitutes crucial content for the students' appropriation of knowledge (Wertsch, 1998).

To conclude, the results indicate that the conceptual constructions that are integrated into the carbon footprint calculator provide "short-cuts" for the students' reasoning. Put differently, the digital tool incorporates a range of conceptual distinctions and operations that the students may gain without fully mastering them in their original scientific form (Vygotsky, 1997). The measurements unfold discussions and reflections among the students regarding their use of, transportation, electronics etc. that render possible the examination of their achieved values in terms of kilograms. Based on these values, the students are scrutinising the activities behind their actions, for instance what it implies to go by airplane to Egypt every year or to choose to use the car over public transportation. In this sense, the students' thinking and conceptual understanding are scaffolded by the carbon footprint calculator, that make complex relationships accessible to the user. The tool, thus, enables "access points" (Giddens, 2002; cf. Säljö, 2010) that make such discussions possible, that is, the contextual use precedes an understanding of the conceptual constructions, which are built into the tools. Through having skills in how to use digital tools of the kind of the carbon footprint calculator, students can avail themselves into the literacy of carbon footprints, which makes it possible for them to use the tool as a resource for reasoning about the environmental impact of various actions. Through using a carbon footprint calculator, students can relate to climate change in a new way, where issues relevant from a science perspective as well as from a citizenship point of view may be addressed. The tool thus mediates features of the environment that students otherwise could not perceive; it makes the invisible visible.

References

Chowdhury, G. (2010). Carbon footprint of the knowledge sector: What's the future? *Journal of Documentation, 66*(6), 934-946.

Cordero, E. C., Todd, A. M., & Abellera, D. (2008). Climate change and the ecological footprint. *Bulletin of the American Meteorological Society, 89*(6), 865-872.

Fauville, G., Lantz-Andersson, A., & Säljö, R. (2013). ICT tools in environmental education: reviewing two newcomers to schools. *Environmental Education Research*. doi:10.1080/13504622.2013.775220.

Furberg, A. (2009). Socio-cultural aspects of prompting student reflection in Web-based inquiry learning environments. *Journal of Computer Assisted Learning, 25*(4), 397-409.

Furberg, A., & Arnseth, H. C. (2009). Reconsidering conceptual change from a socio-cultural perspective: analysing students' meaning making in genetics in collaborative learning activities. *Cultural Studies of Science Education, 4*(1), 157-191.

Gallagher, J. J. (1971). A broader base for science education. *Science Education, 55*(3), 329-338).

Giddens, A. (2002). *Runaway world: How globalisation is shaping our lives.* London: Profile Books.

Heath, C., Hindmarsh, J., & Luff, P. (2010). *Video in qualitative research. Analysing social interaction in everyday life*. London: SAGE.

Hopkinson, P., & James, P. (2010). Practical pedagogy for embedding ESD in science technology, engineering and mathematics curricula. *International Journal of Sustainability in Higher Education, 11*(4), 365-379.

Kemppainen, A. J., Veurink, N. L., & Hein, G. L. (2007, October). *Sustainability in a common first year engineering program.* Paper presented at the 37th ASEE/IEEE Frontiers in Education Conference, Milwaukee, United States.

Kitzes, J., Peller, A., Goldfinger, S., & Wackernagel, M. (2007). Current methods for calculating national ecological footprint accounts. *Science for Environment & Sustainable Society 4*(1), 1-9.

Klein-Banai, C. & Theis, T. L. (2011). An urban university's ecological footprint and the effect of climate change. *Ecological Indicators, 11*(3), 857-860.

Larsen, H. N., Pettersen, J., Solli, C., & Hertwich, E. G. (2011). Investigating the Carbon Footprint of a University – The case of NTNU. *Journal of Cleaner Production,*

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate Peripheral Participation.* Cambridge: Cambridge University Press.

Li, G. J., Wang, Q., Gu, X. W., Liu, J. X., Ding, Y., & Liang, G. Y. (2008). Application of the componential method for ecological footprint calculation of a Chinese university campus. *Ecological Indicators, 8*(1), 75-78.

McNichol, H., Davis, J. M., & O'Brien, K. R. (2011). An ecological footprint for an early learning centre: Identifying opportunities for early childhood sustainability education through interdisciplinary research. *Environmental Education Research, 17*(5), 689-704.

Mäkitalo, Å. (2003). Accounting practices as situated learning: dilemmas and dynamics in institutional categorization. *Discourse Studies, 5*, 495-516.

Petersson, E., Lantz-Andersson, A., & Säljö, R. (2013). Virtual labs as context for learning – continuities and contingencies in student activities. In E. Christiansen, L. Kuure, A. Mørch, & B. Lindström (Eds.), *Problem-based learning for the 21st century. New practices and learning environments* (pp. 161-189). Aalborg, Denmark: Aalborg University Press.

Rogers, Y., Sharp, H. & Preece, J. (2011). *Interaction Design. Beyond Human-Computer Interaction. 3rd Edition*. West Sussex: Wiley.
Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, *45*(1), 1-42.
Sadler, T. D., Chambers, F. W., & Zeidler, D. J. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education, 26*(4), 387-409.
Sadler, T.D., Barab, S.A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education*, *37*(4), 371–391.
Scott, M., & Lyman, S. (1968). Accounts. *American Sociological Review, 33*, 46-62.
Shirley, R., Jones, C., & Kammen, D. (2012). A household carbon footprint calculator for islands: Case study of the United States Virgin Islands. *Ecological Economics, 80*, 8-14.
Sternäng, L., & Lundholm, C. (2011). Climate change and morality: Students' perspectives on the individual and society. *International Journal of Science Education, 33*(8), 1131-1148.
Säljö, R. (2009). Learning, theories of learning, and units of analysis in research. *Educational Psychologist, 44*(3), 202-208.
Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: technologies, social memory and the performative nature of learning. *Journal of Computer Assisted Learning*. 26, 53-64.
Vygotsky, L. S. (1997). The instrumental method in psychology. In R. Reiber & J. Wollock (Eds.), *The collected works of L. S. Vygotsky; Volume 3. Problems of the theory and history of psychology.* London: Plenum Press.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
Wackernagel, M., & Rees, W. (1996). *Our ecological footprint: Reducing human impact on the earth.* Philadelphia, PA: New Society Publishers.
Walker, K. A., & Zeidler, D. L. (2007). Promoting discourse about socioscientific issues through scaffolded inquiry. *International Journal of Science Education, 29*(11), 1387-1410.
Wertsch, J. V. (1998). *Mind as action*. New York, NY: Oxford University Press.
United Nations of Education Scientific and Cultural Organisation (UNESCO). (1975). *The International Workshop on Environmental Education Final Report, Belgrade, Yugoslavia.* Paris: UNESCO/UNEP.
United Nations of Education Scientific and Cultural Organisation (UNESCO). (1977). *First Intergovernmental Conference on Environmental Education Final Report, Tbilisi, USSR.* Paris: UNESCO.

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[i] The Inquiry-to-Insight (I2I) project started in November 2008, and is a collaboration between Stanford University, California, USA and the university of Gothenburg, Sweden and their respective marine stations; Hopkins Marine Station and Sven Lovén Center for Marine Sciences-Kristineberg. I2I offers an educational program combining ICT, social networking and pedagogy directed at environmental issues. The I2I idea is to pair classes from different countries within a social network. The students compare views, attitudes and life styles around three environmental issues (climate change, environmental pollution and habitat preservation) and will increase their understanding of those issues with different educational tools mainly based on ICT. http://i2i.stanford.edu/