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Understandings of climate change articulated by Swedish secondary school students

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ABSTRACT

This study investigated beliefs about climate change among Swedish secondary school students at the end of their K-12 education. An embedded mixed method approach was used to analyse 51 secondary school students' written responses to two questions: (1) What implies climate change? (2) What affects climate? A quantitative analysis of the responses revealed that 'Earth', 'human' and 'greenhouse effect' were frequent topics regarding the first question, and 'pollution', 'atmosphere' and 'Earth' were frequent regarding the second. A qualitative analysis, based on a 'conceptual elements' framework, focused on three elements within responses: atmosphere (causes and/or consequences), Earth (causes and consequences) and living beings (humans and/or animals and their impacts on climate change). It revealed a predominantly general or societal, rather than individual, perspective underlying students' responses to the second question. The ability to connect general/societal issues with individual issues relating to climate change could prompt students to reflect on the contributions of individuals towards climate change mitigation, thereby constituting a basis for decision-making to promote a sustainable environment. Although the students did not discuss climate changes from an individual perspective, their statements revealed their understanding of climate change as a system comprising various components affecting the overall situation. They also revealed an understanding of the difference between weather and climate.

KEYWORDS

Climate change; secondary school; climate literacy; Science Education; Students' beliefs

1. Introduction

This study explores perspectives on climate change among secondary school students, viewed as tomorrow's decision-makers. Advancing knowledge about climate change within society is an important goal, affecting all living beings on Earth. The question of how this can be done is an important social issue, and while education plays a significant role in fostering care for our planet among future citizens (Nurse 2016), this process cannot be confined to school settings. In education, Wals et al. (2014) discern the current trend as 'more attention is now being given to an understanding of the learning processes and the capacities of individuals and communities needed to help resolve complex socioecological issues' (583). DeBoer (2000, 582) has argued that:

> … instead of defining scientific literacy in terms of specifically prescribed learning outcomes, scientific literacy should be conceptualized broadly enough for local school districts and individual classroom teachers to pursue

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the goals that are most suitable for their particular situations along with the content and methodologies that are most appropriate for them and their students.

In this study, we have assumed that scientific literacy and, more specifically climate literacy, play an important role in understanding how education can be framed to support future decisions on climate change. One method used for improving connections between the more general community level and the personal impact on climate change is the 'ecological footprints' methodology used by Cordero, Todd, and Abellerra (2008). This approach has been successfully used for young students to point out the biocapacity of nature, namely the relationship between supply and demand on nature (McNichol, Davis, and O'Brien 2011). In higher education, Wachholz, Artz, and Chene (2014) have studied college students' attitudes to climate change. They claim that: 'minimal personal action is being taken by students and their friends to reduce greenhouse gas emissions' (137). In this study, we aimed to develop a deeper knowledge of the beliefs students have about what implies climate change, to understand how education may promote a better understanding of climate change and effect changes in behaviour.

1.1. Scientific literacy

Scientific literacy is considered an important asset for developing responsible future decision-makers to promote sustainable development (Lau, Ho, and Lam 2015). The Programme for International Student Assessment under the Organisation of Economic Cooperation and Development (OECD) defines scientific literacy as 'the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen' (OECD (Organisation of Economic Cooperation and Development) 2015, 4). It is essential for humanity to grasp what climate change is, and in what ways we can make changes, as a society, to assume responsibility for our actions and decrease our negative impacts on the environment. The term 'scientific literacy' was coined as far back as the late 1950s in the context of the need for USA to respond to the launch of Sputnik by the Soviets (Hurd 1958; Laugksch 2000; Bybee 2015). This study focuses on the phenomenon of climate change, which students often encounter outside of school through news media and the Internet (Britt, Richter, and Rouet 2014). However, journalists reporting news on climate change do not necessarily describe the contradictions and uncertainty around the interpretation of results. This constrains readers' potential to develop their scientific literacy. The extent of an individual's participation in societal discussions about climate change varies according to their knowledge about the field (Eilks, Nielsen, and Hofstein 2014). Further, to enhance this discussion, the gap between academic and lay science needs to be reduced (Hurd 1998).

1.2. Climate literacy

Climate change is usually defined as an unexpected change in the typical or average weather pattern of a region or city. For example, there can be a change in an area's average annual rainfall or temperature for a given month or season (Pielke 2004). A recent Norwegian study, published in *Nature Climate Change*, found that citizens' opinions were crucial for prompting action (Tvinnereim and Fløttum 2015). It further revealed that Norwegian citizens emphasise societal aspects to a greater degree than do US and British citizens. Further, a recent review of communication on climate change indicated that its goal is to 'reduce climate change impact through public engagement' (Wibeck 2014, 404). However, climate literacy is required to reduce the effect of climate change (Harrington 2008) within a society characterised by both interest in and knowledge of how to engage in such work. Therefore, how we educate our students is crucial to this effort. Shepardson et al. (2012) have studied how secondary school students conceptualise climate change. They found a perception among students that global warming impacted only temperature, exerting a lower impact on precipitation and leading to much higher temperatures (Shepardson et al. 2009, 2012; Shepardson, Niyogi, and Choi 2011). They also found that students did not distinguish between global warming and climate change. Nor did they recognise the various impacts of climate change on climates in different parts of the world. Moreover, they did not recognise the difference between short- and long-term climate change (i.e. the difference between weather and climate).

The authors further noted that while few studies have been conducted on students' understanding of the carbon cycle in relation to the greenhouse effect, their findings indicate that students demonstrate a simplistic understanding of natural processes affecting the cycle, and of the linkages between the carbon cycle and the greenhouse effect. Consequently, Shepardson et al. (2012) have argued that it is important that students analyse historical and contemporary climate data and grasp how they relate to each other from a climate system perspective. Papadimitriou (2004) has questioned the prevalent use of closed-ended questionnaires with statements eliciting agreement or disagreement in studies on students' ideas about environmental issues. Instead, she used open-ended questions to ascertain the beliefs of 172 prospective primary teachers regarding climate change, its causes and actions that can be taken to slow it down. She included the following five items: respondents' beliefs on whether climate change was underway, its causes, how to slow it down, the greenhouse effect and compounds responsible for ozone layer depletion. Even though the questions were open-ended, they served to guide respondents towards a focus on certain aspects that they may not otherwise have focused on. The results indicated that these prospective primary teachers confused the greenhouse effect with ozone depletion. They were unaware of appropriate actions for slowing down climate change, and believed that 'ozone depletion, acid rain, and pollution in general are conducive to climate change' (Papadimitriou 2004, 299). Given their limited of understanding of climate change induced by global warming, their understanding of the actions required to slow it down was correspondingly impaired. However, their responses may have been affected, to some extent, by the framing of items in the questionnaire, as the concepts 'greenhouse effect' and 'ozone layer depletion' were provided in the text.

Cordero, Todd, and Abellera (2008) studied another group of 400 college students taking courses on climate and weather. Although these respondents demonstrated greater awareness of scientific explanations for climate change than those in the previous study, they also demonstrated some misunderstanding. Adopting what Papadimitrou (2004) has claimed is the most commonly used survey method, Cordero, Todd and Abellera (2008) developed a questionnaire with 39 items using a Likert response scale of 1–5. The questionnaire was administered as a pre-test and post-test before and after respondents had undertaken a 15-week course. The questionnaire focused on the following topics: the cause of global warming and ozone depletion, the relationship between global warming and ozone depletion and the link between energy use and greenhouse gas emissions. The results showed that the even after the course, the students still confused ozone depletion with global warming. Furthermore, Cordero, Todd and Abellera (2008, 871) noted that: 'Our results demonstrate that students who completed a relatively simple action-oriented learning activity designed around their ecological footprint significantly improved their understanding of the connection between personal energy use and global warming'.

Tvinnereim and Fløttum (2015) have conducted a large-scale quantitative study. These researchers collected 2115 answers to the following open-ended question: 'What comes to mind when you hear the words 'climate change'?' The ages of the respondents varied and none were school-going. The result of the study showed that the societal aspects of climate change were emphasised more by Norwegian citizens than they were by respondents in previous studies conducted in USA and UK. An interesting finding of this study concerned the effect of education on participants' responses. Individuals with a university education chose to focus on the 'future/impact' frame rather than the 'money/consumption' frame. This indicates the value of education in contributing to wise decision-making that is not based on short-term economic outcomes in the future. The research question in this study is: What characterises students' expressed beliefs about climate change at the end of their K-12 education?

2. Research design and methodology

2.1. Participants

Our study was conducted with Swedish secondary school students whose major subject was science. The participants were 51 secondary students from two grade-12 classes within the same urban secondary school in Sweden. Approximately 10–15% of the annual student cohort followed the science

programme that the students were pursuing. There are 18 programmes offered in Grades 10–12, constituting three years of upper secondary school. The participants in this study were from the natural sciences education programme, which is foundational for higher or university-level education in the natural sciences, mathematics and technology (The Swedish National Agency for Education 2013).

2.2. Data collection and analysis

On one occasion in April 2013, the students were provided with two open-ended questions, in written form. The first question (Q1) was definitional: 'What implies climate change? Mention as many aspects as possible'. The second (Q2) queried the causes of climate change: 'What affects climate? Mention as many aspects as possible'. An embedded mixed-methods approach was used to analyse the extracted data (Creswell 2014). The same data-set was used to embed a quantitative analysis of the frequency of word occurrence within a qualitative design, aimed at locating meaning clusters among the students' responses to the two questions.

The responses were analysed qualitatively and quantitatively (Johnson and Onwuegbuzie 2004). The analysis explored the students' understandings of climate change to develop recommendations for education on sustainable initiatives relating to climate change. The quantitative analysis consisted of descriptive data such as frequency of word use in the students' responses. This was performed using the Word Analysis tool in Text Finder (2007). The results of the quantitative analysis guided the qualitative analysis by revealing the key categories featuring in the students' responses as a focus. The qualitative analysis was performed to identify the main topics and subgroups for describing what characterises the students' expressed beliefs. Responses to the two questions were first read independently, several times, by each of the two researchers, and subsequently they were read jointly to analyse qualitative differences in the students' expressed understandings of climate change within the main identified categories. These meaning clusters were also validated against a framework developed by Shepardson et al. (2012) that describes a progression of conceptual elements for contextualising climate change. The conceptual framework for this study was based on students' conceptions as a framework of their understanding of the climate system. This consisted of 11 conceptual elements for explaining the climate system, namely: climate systems, climate and weather, Earth's energy, feedback, the Earth, the Sun, atmosphere, ice and snow, oceans, land, and vegetation. Each element encompassed three progressive levels (1–3), signifying a progression from the least developed (1) to the most developed understanding in relation to each conceptual element An example is the conceptual element 'feedback' in climate change, meaning that what we do, or what happens in nature, can be regarded as feedback on human or environmental actions. Shepardson et al. (2012, 334, 343) noted that:

> Changes in the Sun, atmosphere, oceans, ice, land, and vegetation cause the Earth's climate system to change. These changes may be natural or caused by humans […] Human activities such as burning fossil fuels and deforestation also cause the climate system to change. The net impact of the changes in one system on the overall climate will depend on the feedbacks with other components of the climate system.

Within the same category, but at the third level, the conceptual element could be understood as follows:

> Changes in one component of the climate system may cause changes in other components, changing the system and influencing the equilibrium of the system. These changes or feedbacks may be either negative or positive and natural or human caused. For example, changes in the Earth's orbit and rotation and solar flares cause the Earth's climates to vary naturally. Human activities such as burning fossil fuels and deforestation also cause the climate system to change. The net impact of the changes in one system on the overall climate will depend on the feedbacks with other components of the climate system. (343)

3. Results

This section presents written responses to each question, which are then compared to the climate system framework (Shepardson et al. 2012) to gain a better understanding of the students' articulations.

3.1. Descriptive results

The results of the quantitative analysis show that the 51 responses received from the students contained 4462 (m = 85.81) words and 4837 (m = 93.01) words for Q1 and Q2, respectively. Tables 1–3 reveal the frequent use of several words. Out of 9299 words, 'Earth', the most frequently used word, was observed 56 times (0.6%). Words such as articles, prepositions and conjunctions ('and', 'with', 'if', 'a' and 'this') were excluded. Words repeated from the question were also excluded. Table 1 shows that the three most frequently used words for answering Q1 were: 'Earth', 'human' and 'greenhouse effect', while the most frequently used words for Q2 were 'pollution', 'atmosphere' and 'Earth' (Table 2).

Earth was the most frequently used element for defining climate changes, which seems obvious. The main explanation provided for this was the greenhouse effect that is apparent in melting ice and higher temperatures. When expressing the *causes* of climate change, different words were used. These focused more on important climate-related concepts such as pollution, atmosphere and carbon dioxide. Earth was still frequently used, but to a lesser degree.

Table 1. Word count of frequently used words in students' responses to (Q1).

Frequency	Word
46	Earth/'s
20	Human/s
19	Greenhouse effect
17	Melt
16	Temperature
15	Hotter
15	Animals
11	Atmosphere
10	Air
10	Sea

Table 2. Word count of frequently used words in students' responses to (Q2).

Frequency	Word
29	Pollution
25	Atmosphere
23	Earth
23	Carbon dioxide
17	Greenhouse gases
14	Radiation
14	Temperature
14	Sun
12	Human
11	Nature

Table 3. Word count of frequently used words in students' responses to (Q1 + Q2).

Frequency	Word
56	Earth
47	Human/s
47	Greenhouse effect
45	Temperature
39	Carbon dioxide
37	Pollution
36	Atmosphere
26	Sun
20	Nature
20	Animals
18	Melt
18	Sea
17	Radiation

Our analysis revealed that 'greenhouse effect', 'temperature' and 'carbon dioxide' were frequently used by students to articulate their understanding of climate change.

The results of the quantitative analysis showed three focal themes in the student responses: 'Earth', 'Atmosphere' (including greenhouse effect) and 'Humans', constituting major categories.

3.2. Results of the qualitative analysis

For the qualitative analysis, the first question was analysed hierarchically, from the least developed to the most developed articulations on what climate change is. For the second question regarding causes, we focused analytically on the three main categories obtained from the quantitative analysis: atmosphere (causes and/or consequences), Earth (causes and consequences), and living beings (humans and/or animals and their impacts on climate change).

The analysis of students' responses to Q1 – 'What implies climate change?' – revealed their different interpretations. These outcomes were analysed based on the 'conceptual elements' framework developed by Shepardson et al. (2012). There were differences relating to the described aspects: human-related aspects were foregrounded, whereas aspects relating to the natural environment were relegated to the background or not mentioned at all. Some statements did not express any position regarding which elements affect climate change.

> … a change in the climate, such as temperature or weather patterns that is more or less permanent. Day to day change is not counted, but a general change such as the average temperature over a year counts in this case. (Student 45)

This view accords with the level-one conceptual element, 'climate and weather', described by Shepardson et al. (2012, 341):

> Weather is the day-to-day conditions of the atmosphere: temperature, precipitation, humidity, and wind. Climate is the average of these conditions over long time periods.

Despite mentioning natural changes, Student 1, quoted below, did not take a position on the origin of climate change. However, this student evidently had a negative view of climate change:

> Negative, natural and extreme climate changes mean a devastating impact on planet Earth and its inhabitants. For example, melting ice around the world contributes to sea levels, which in itself makes it difficult for low-lying islands and countries. It can lead to islands being submerged in the middle of the ocean, which means lost homes and jobs for a large number of inhabitants and a suffering population. Further aspects are how climate change can adversely affect human health. For example, exposure to pollution provides proven greater vulnerability to serious diseases. Climate change has a huge impact on the ozone layer as well, which protects humans from the sun's strong radiation. The layer has been slowly depleting, which puts us in a more vulnerable position, and the sun's rays could have a fatal impact. (Student 1)

This excerpt relates to the same conceptual element described by Shepardson et al. 2012, 341), but on the third level:

> Weather is the day-to-day conditions of the atmosphere (troposphere): temperature, precipitation, humidity, and wind. Climate is the long-term (multidecadal) average and variability of these weather conditions. There are differences in climate at the local, regional, and global scale[s] and for different time intervals due to changes in the climate system.

Some responses also considered natural climate change in light of the speed of the change:

> The climate has always had a small variation. Often when talking about climate change, it is the rapid changes that are negative for the Earth. (Student 6)

Last, some responses included the different reasons behind climate change without ascribing a value to them, as well as the temporal aspect:

> Climate change includes all events involving a permanent change in temperature, weather, air quality, water and more. These changes can have both natural and unnatural causes. We do not think so much about the natural causes such as the motion of continents or volcanic eruptions. The first thing that pops into your head is the changes caused by humanity's wasteful use of resources. The danger with these changes is that they take place at such a fast pace that the Earth's ecosystems do not have time to adapt. Instead, there is a risk that many species of animals and plants will disappear completely. (Student 7)

In the excerpt below, the student not only describes climate change, but also analyses and reflects on each individual's contribution to climate change. At the same time, the student acknowledges natural changes.

> Climate change means changes in the climate. The climate means weather, heat, wind … well anything that has to do with the climate. The greenhouse effect affects the heat of the Earth and thus the carbon dioxide content of the atmosphere around the Earth. This allows the ocean volume to expand and ice to melt, causing floods. Some scientists claim that this is due to increased emissions of CO_2 without sun that have different levels of activity during different years. However, in recent times, the true emissions curve is more consistent with the increased temperature of the Earth. Climate change can also be local. For example, it could start raining in the desert. This in turn affects the animals and plants and many species that specifically evolved to live in these circumstances are dying out. Some habitats have better resilience against climate change, but unfortunately many habitats cannot handle such changes. Climate change is a problem in today's society and many people are still not fully aware of how their everyday actions ultimately affect their own lives or the future population. (Student 48 on the climate system as a conceptual element at the third level)

The second question on the factors affecting climate was intended to guide the students to think about the causes of climate change. The question was formulated in an open-ended way to give respondents an opportunity to come up with responses without their self-expression being influenced. The excerpt below entails a typical response to this question. The rationale is mainly at a macro level, positing humans as the cause of climate change. However, this was rarely expressed from a personal or individual-level perspective. The few expressions found were related to the feedback conceptual element (Shepardson et al. 2012).

> Humans are the biggest climate villains on Earth! Our vehicles' exhaust, food that is thrown away and overproduction. We take the Earth's resources, but what we do not think of is to 'give back or add'. We are currently using more than we actually produce. The population is steadily increasing and we are spreading over more and more of the Earth's surface. We have not only spread out on land, but also at sea, for example, the fisheries. The only areas still not fished are the Arctic and Antarctic, but it's just a matter of time before fishermen start fishing there. (Student 3)

Of the 51 answers, only three referred to what each individual could contribute towards the reduction of adverse climate change. The remaining responses concerned what humans as collectives could do. Respondents seemed to regard society as being responsible at a macro level for adverse climate change and discounted individual responsibility. The quote below is an exception, as the student refers to choices that each individual has to consider while acting ethically to protect the climate:

> Our choice of foods. We buy locally or [import] meat from Brazil and apples from Isle of Man. We choose to take the car, bike or walk to where we're going to. French, instead of Swedish apples? You close the tap and [plug the] drain when you shampoo and condition your hair, or turn off the water. Turn off the lights in unoccupied rooms or light up the whole house? Take advantage of the food that is uneaten, or should it be thrown away? (Student 50)

However, although such answers were rare, a comparison of the students' statements with the findings of Shepardson et al. (2012) revealed a more nuanced way of perceiving an individual's ways of handling daily life situations within the data. The students strongly emphasised energy from fossil fuels, but they also noted other aspects and demonstrated a systematic way of thinking about climate change, integrating various components:

> Carbon dioxide emitted by cars and industries is involved in global warming, which, in turn, causes the ice at the poles to melt. This in turn leads to larger bodies of water and colder seas, and to greater differences between warm and cold fronts (when the water cools the surrounding air). This results in more extreme weather such as storms, hurricanes and floods. Other climatic factors are eutrophication, the incredible amount of artificial fertilizer that we pour out over our fields and so on. (Student 36)

4. Discussion

This study applied an embedded mixed-method approach (Creswell 2014), whereby the same data were subjected to quantitative as well as qualitative analyses. The students' written responses were quantitatively analysed to reveal the main themes therein. The identified themes subsequently underwent further qualitative analysis in relation to what climate change is. This analysis progressed from the least

developed to the most developed answers in concert with the framework developed by Shepardson et al. (2012). The results of the quantitative analysis indicated three main categories related to the causes of climate change. These were further analysed to determine qualitative differences in the students' beliefs.

Although this study was limited in terms of the number of participants and the selection of a sample comprising just one Swedish school, it nevertheless revealed some interesting findings. Climate change education importantly entails promoting awareness about how each citizen can contribute to slowing down climate change. The students in this study did demonstrate an understanding of several aspects of climate change such as the distinction between climate change and weather. However, their responses to the question of what causes climate change were mainly at a societal level. This finding is in line with the argument made by Cordero, Todd and Abellera (2008) that teaching should be aimed at inculcating environmental responsiveness and not just imparting scientific knowledge. Papadimitriou's (2004) study revealed a weak understanding of how climate change can be slowed down among prospective primary teachers, who could not identify what aspects affected climate. They, therefore, lacked sufficient knowledge to teach their students how to foster a sustainable environment.

The findings of the current study differed from those of Shepardson et al. (2012) regarding two central concepts in climate change for differentiating between climate and weather. They also differed in their conceptions of climate as a system or as single components. Wise decision-making for fostering a sustainable and healthy planet is based on each citizen's knowledge of what causes climate change and how each person can contribute towards saving our planet. In this study, the participating students were enrolled in a secondary school science programme. However, it is important to note that they had just commenced the science programme after completing general compulsory studies. In contrast with the findings of Shepardson et al. (2012), this study revealed that students articulated varying degrees of knowledge about climate change, and considered both human and natural aspects as well as the difference between weather and climate. They also considered whether or not the changes were historically recurring or rapid ones. The variety of words used for discussing this phenomenon, as well as the number of words, indicated their interest and knowledge in this field. Tvinnereim and Fløttum (2015) noted a mean of 10.1 words. However, their results cannot be compared with the responses obtained in this study (Q1: $M = 85.81$; Q2: $M = 93.01$) because the questions were designed differently. The responses to the question on what affects climate revealed a general or societal perspective, with very few responses reflecting a personal perspective. Developing the ability to connect general or societal issues to individual issues related to climate change could lead to greater reflection among students on the contributions of every individual to addressing climate change. While the students understood climate to be a system, this was represented at a general level. The results indicated that the students had developed some of the knowledge queried by researchers such as Shepardson et al. (2012). However, *which* aspects have had an impact on students' developed beliefs, resulting in an understanding that is qualitatively deep and nuanced, remain to be identified. Cordero, Todd and Abellera (2008), who introduced the 'ecological footprint' method, demonstrated the development of students' knowledge regarding the link between personal energy consumption and global warming. An interesting future research topic would be whether this model for supply and demand on nature could be developed also for fostering an awareness of the impact of personal actions on climate change.

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