TEACHING CLIMATE CHANGE IN MATHEMATICS CLASSROOMS: AN ETHICAL RESPONSIBILITY

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Abstract

Climate change is one of the most urgent human concerns. Mathematics, in various degrees of complexity, is used to communicate climate change to scientists, politicians, policy makers, the general public and children. Drawing on ideas from critical citizenship and critical mathematics education, we ask how incorporating issues of climate change into the teaching and learning of mathematics can be understood as a moral and ethical act? We consider the possible ethical and moral role of mathematics education at large, as well as the role and challenges of individual teachers who consider addressing climate change in mathematics classrooms. We illustrate our discussion with analysis of Canadian and Norwegian mathematics teachers' explanations of their thinking about climate change in their teaching. We conclude that although including climate change in mathematics classrooms can be (and is) viewed as an ethical responsibility of mathematics teachers, in their day-to-day practice their decisions about this issue are complex.

Introduction

We often hear stories related to climate change:

"Shrinking glaciers cause state-of-emergency drought in Bolivia." (The Guardian, Dec, 2016)

"Facing the change: 5 Canadian communities threatened by climate change now" (CBC, Dec, 2016)

As mathematics educators, should we be ethically and morally concerned when the change in the Earth's climate destroys nature and the lives of our fellow human beings? Do we have a responsibility to act?

Mathematical information is at the heart of communicating, predicting, and working with issues related to climate change, whether for politicians, scientists or the general public, to name a few. Yet the complexity of the issue of climate change, as well as the diverse opinions apparent in the media, can result in individual discomfort or even an inability to

respond. Although we acknowledge the challenges that are associated with responding to climate change, we ask whether such reactions—although complex—are part of our ethical and moral responsibilities to our fellow humans and to nature. Drawing on ideas from critical citizenship and critical mathematics education, in this article, we open up the landscape of ethical considerations concerning climate change in the teaching of mathematics. We then discuss the possible ethical and moral role of mathematics education at large, as well as the role and challenges of individual teachers who consider addressing climate change in mathematics classrooms. We illustrate our discussion with examples from a survey of how mathematics teachers in Norway and Canada included issues related to climate change in their classrooms. We conclude that although including climate change in mathematics classrooms can be viewed from a critical mathematics education perspective as an ethical responsibility of teachers, in their day-to-day practice, teachers face challenges that make the inclusion of climate change, and the ethical decision-making behind it, a political, value-laden and complex task.

Context

Climate change is an urgent and complex issue, involving conflicting views and interests: it is an amalgam of environmental, social, political, democratic, and personal aspects. While some are concerned about how humans are disturbing the habitats of the Earth, others deny that climate change can be explained by human influence, and some even deny that climate change is happening at all. The question of how to respond to climate change and which values should be prioritized makes climate change an ethically ambiguous problem.
Mathematics plays a central role in describing, predicting and communicating climate change (Barwell 2013). For example, predictions based on climate models are a core source of information used to inform decision-makers and the actions that they propose to address climate change. The application of mathematics within climate science creates abstractions that influence our way of understanding and thinking about the problem and how we should respond to it (Hauge and Barwell 2017; Barwell 2013). It is argued that one reason we have not been able adequately to respond to the crisis of climate change is that the expectations of what science and mathematical predictions can achieve have been too high (Funtowicz and Strand 2009).

The complexity of the issue of climate change, as well as the wide variety of opinions, information, and misinformation available in public media and online may result in personal discomfort or even an inability to mount a reaction to the issue of climate change (Hulme 2009). Although we acknowledge the challenges that are associated with responding to climate change, in this paper, we discuss two specific issues: (1) whether we, as mathematics teachers and educators, have an ethical and moral responsibility to address how climate change might influence the future of life on Earth and (2) how we, as mathematics teachers and global citizens, should respond to climate change and its embedded uncertainties. Should we take action? And what kind of action should we take?

To discuss these two issues, we draw on the literature on critical mathematics education (CME), with its democratic perspective on mathematics education, critical citizenship and on mathematics education for social justice. On the one hand, mathematics, with its power to describe, predict and model the world, influences our understanding of scientific aspects of climate change (Barwell 2013) and gives us a tool to think about and communicate about climate change. On the other hand, there is substantial uncertainty in mathematical representations and knowledge about climate change and uncertainty in how we best should respond to this knowledge. Conflicts of interest and uncertainty can cause disagreements about how to respond to climate change (which explains why there are climate sceptics). From a democratic point of view, space should be given to conflicting values and argumentation. We reflect on how the ethical dimension of CME can support our discussion of what kind of ethical and moral responsibility mathematics education might have, considering the conflict of interests and the complexity of the topic, both in the educational realm and in that of ecology. We then consider the level of individual classroom practice, where the complexity of ethics and teachers' responsibilities is more immediate.

Much writing on CME implies various political tensions at the heart of mathematics teaching. Thus, a teacher may fear a political minefield if bringing the topic of climate change into her classroom while simultaneously having a concern for the learning environment. She may also experience a tension between her personal political opinions and an aim to include opposing views. A tension can emerge between an ethical responsibility to introduce a topic like climate change and the duty to cover specific curriculum topics. We believe that these tensions complexify the ethical position of teachers at the classroom level. Examples from our survey data illustrates what action mathematics teachers may (or may not) take, what ethical principles underlie their thoughts and inform their actions, as well as how the incorporation of climate change in mathematics lessons can be viewed as an ethical responsibility of mathematics teachers. These examples lead us to highlight some tensions or challenges arising in the experiences of teachers who have considered including climate change in their teaching of mathematics.

The data come from a questionnaire, designed to gain insight into teachers' reasons for incorporating issues related to the climate change into their mathematics teaching. We were mostly interested to know how the teachers incorporated this topic to promote mathematical learning and vice versa. Among other things, questions were formulated about the teachers' aims, the types of tasks and tools they used (e.g., websites, data, ICT), and their experiences of success and failure in incorporating climate change in their mathematics teaching. We were also interested in how they used data, tables or charts, and what reasons they had for teaching climate change. The questionnaire was prepared in Norwegian and then translated into English, with input from the Canadian team members. It was distributed to mathematics teachers in Norway and in Ontario, Canada (for more details, see Steffensen et al. 2016). Inspired by Barbosa's perspectives of mathematical modelling, the study employed the perspective of climate change as a vehicle to: 1. learn mathematics; 2. learn about climate change; and 3. encourage critical thinking (Steffensen et al. 2016). We investigated the extent

to which teachers' responses could inform research about how teachers connect the topic of climate change to critical perspectives to achieve critical citizenship. In this paper, we looked more closely at teachers' ethical awareness, principles and actions, in relation to the inclusion or exclusion of the issues of climate change in mathematics classrooms. Throughout all the sections of this paper, we incorporate quotes from the participating teachers to highlight the ethical dimensions, perceptions, tensions, and challenges of climate change in the context of mathematics classrooms.

The ethics of climate change

Climate change is considered by many to be the most important present and future political problem facing humanity. That thinking about climate change has an ethical dimension that has long been recognised and is apparent from, for example, current work by UNESCO to draft a Declaration on Ethical Principles in Relation to Climate Change. Possible ethical principles under consideration for the declaration include:

- Safeguarding the interests of present and future generations
- Polluters should pay the price of the damage they cause
- Recognition of the interdependence of life on earth
- The duty to share scientific knowledge. (UNESCO n. d.)

Discussion of the ethical implications of climate change in the research literature are multiple and quite varied in nature. For Gardiner (2008), the discipline of ethics should play a fundamental role in climate change due to the value judgments embedded in decision-making and the many stakeholders involved, including animals and future generations. He discusses three factors that threaten our ability to behave ethically to reduce greenhouse gas emissions. First, local emissions have a global effect, so decisions in one place can have an impact around the world. Second, emissions originate from multiple individuals and institutions, which makes it challenging to respond to climate change. These two factors produce an ethical challenge analogous to the prisoner's dilemma: It is rational that people and nations collectively reduce their greenhouse gas emissions, but on an individual level it is not rational when your contribution alone may not matter much and you do not know whether the others will reduce their own emissions. To this point, Stoll-Kleemann, O'Riordan & Jaeger (2001) add that the complexity, uncertainty and the potentially huge impact climate change could have for individuals can lead to a denial of responsibility and a feeling of powerlessness: It may be better to wait for other people or countries to react, before sacrifices are regarded as worthwhile.

The third challenging factor Gardiner (2008) discusses is institutional inadequacy. He argues that the lack of reliable global enforcement makes an ethical response to climate change difficult. The fact that some people and nations suffer, or will suffer, more from climate change than others, augments the challenge of this factor. Other factors he mentions include scientific uncertainty, economic interests and doubts about whether climate change is even a problem. Gardiner further points to the increased challenge the delayed effect of greenhouse

gas emissions has on all these factors and how most decision-making fails to take future generations into account. Moreover, he claims that moral corruption is seen in many argumentation strategies in the political debate: "distraction, complacency, unreasonable doubt, selective attention, delusion, pandering, false witness and hypocrisy" (Gardiner 2008 p. 36).

While Gardiner (2008) expresses concern about people's "unreasonable doubt" about climate change as a reason for not wanting to limit greenhouse gas emissions, Funtowicz and Strand (2011) have argued that the inherent uncertainty of climate change requires a different approach. They argue that while climate science has provided information to politicians and citizens about the threats of climate change, it cannot possibly dictate how global society should act on this information. That is, they challenge the expectation that science can provide predictions to "lend decisive authority to the mobilisation of collective action" (ibid. p. 999). Funtowicz and Strand propose instead that, as a society, we need to conceive and construct the future we want and then work towards it, rather than work within a paradigm largely based on a process of rational prediction that erases human values.

Raymond's (2006) approach is based on the ethics of the commons. He recognizes the earth's atmosphere as a global common good and discusses various principles for a fair and equitable climate change treaty. What is considered fair and equitable is shown to be greatly controversial because of the environmental and economic stakes. Raymond discusses various ethics-based principles that have been proposed for how greenhouse gas emissions levels should be allocated and distributed between nations. The principle of equal burdens, for instance, implies that nations reduce their emissions relative to their total present emission levels. This is based on the idea that the burden of reducing emissions should be equal. An alternative principle is based equal human rights, allowing an emission level per capita. A version of this approach is to adjust the level in accordance with the nation's subsistence needs or vulnerability to future climate change impacts. Each approach offers a different version of fairness, but is based on somewhat different ethical assumptions. For example, Raymond argues that a per capita approach is based on an unhelpfully uncompromising rhetoric of universal rights. Others might counter that such an argument is convenient for citizens of industrialised countries.

The third perspective we will mention is due to Hourdequin (2010), who draws on a Confucian relational approach. From a Confucian perspective, persons are formed by and through their relationships with others. Hourdequin states that:

> Just as individuals are not atomistic, narrowly self-interested actors, isolated from one another in their decisions and values, actions at the individual level are not divorced from those in the political sphere. A commitment at the personal level may in fact spur greater awareness and more careful consideration of the kinds of political changes that may be most effective (p. 456).

To Hourdequin (2010), the ethical importance and effectiveness of personal choices are that they have "a communicative and social function". That is, individual beliefs and actions gain their ethical and moral values in a social context. Within such a view, we are relational actors, making decisions based on stands intertwined with social and political values. With respect to climate change, Hourdequin (2010) argues that it is a personal ethical moral responsibility to attend to the issue of climate change, but further claims that these responsibilities do not end at the personal level and that one's personal actions ought to be constituted from the broader social and political worlds.

These various perspectives on the ethics of climate change highlight the complexity of this issue. Thinking through the ethical implications of climate change is complex because it involves and affects all human beings (in fact, all living beings) in different ways. Different sets of principles highlight different ethical dimensions, as we seek to demonstrate in the context of mathematics teaching, in the rest of this paper.

Some of the responses of the teachers who participated in our study show that the ethics of climate change is implicitly a concern. After teaming up with her colleagues, for example, one teacher said that she presented "ethics-related topics in class and would regularly present current events to discuss and debate". Her action of incorporating climate change in to her teaching of mathematics is formed by her awareness and considerations of the broader events and ethical debates in society. Many respondents mentioned that an important reason for working with climate change in mathematics lessons was to discuss and critically reflect on such issues. The issue of uncertainty is apparent in several responses to the effect that that climate modelling is too complicated and advanced to bring up in classrooms. Even simple mathematical modelling activities can, however, provide students with experience of the limitations of mathematics models, including their uncertainties and ambiguities. This kind of approach could provide the basis for reflections on the role of mathematics and models in climate change, the controversies relating to climate facts and more ethical discussion of desirable futures, such as, for instance the need for fresh water supplies mentioned by one of the teachers in the study. While there is evidence, then, that mathematics teachers in the study were aware of some of the ethical dimensions of climate change, our focus in this paper is on the ethics of addressing climate change in mathematics classrooms.

Critical mathematics education

In this section, we look to the literature on critical mathematics education (CME) to find perspectives that can support our discussion on whether mathematics education has an ethical responsibility to address climate change, why and how. The extensive work in CME on teaching and learning for critical citizenship is particularly relevant (e.g. Skovsmose 1994, 2011). Ideas on critical citizenship are connected to engaging students in socio-political topics, of which climate change is an example, and/or enabling students to reflect and act on such issues. This value-based stance can be understood as an ethically motivated concern about what the aims of mathematics education should be because developing democratic

capacities or addressing certain issues is considered the right thing to do. Part of the literature is also on the role of mathematics in society and on its contribution to injustice or its role in producing destructive technologies. Also, climate science is associated with uncertainty, and there is disagreement on how this uncertainty should be acted upon. The responsibility of mathematics education to address climate change can, from these perspectives, be based on the idea that students need to learn to take care of the Earth or, more democratically, on the idea that students need to learn about why there are value conflicts related to climate change. In this section we present and discuss the above and related ideas from CME in more depth.

Mathematics education and mathematics teachers possess power and trust through their positions. They have a responsibility towards the common good (d'Ambrosio 2010). One such responsibility that has been addressed is to educate for critical citizenship, which is based on an ethical value stance where critique is seen as essential in a democratic society (see, for example, Ernest 2002; Skovsmose 1992). As a student and as a citizen, one should be able not only to understand and reflect on important social and political aspects of society; one should also be able to critique these aspects. This position implies that mathematics teachers and students should also be engaged in socio-political issues, such as climate change, when teaching and learning mathematics

Skovsmose argues that three types of knowings are necessary to highlight when teaching mathematics in a socio-political context (Skovsmose 1992, 1994). These are, *mathematical, technological and reflective knowing,* which represent competences related to mathematical content knowledge (computing an average of given numbers), the application of mathematics (e.g. modelling average global temperature) and reflective knowledge (reflecting on the role of mathematics in climate change). The latter relates to reflecting on the consequences of how mathematics is both used and applied. Reflective knowing extends from a right-wrong dichotomy in mathematics education to reflections about the wider social context of applied mathematics. Skovsmose connects reflective knowing to what he calls *the formatting power of mathematics* – the power that the application of mathematics has on understanding a topic (1992, 1994).

There is mathematics education literature on climate change that has drawn on Skovsmose's notion of different kinds of knowing mathematics, including reflective knowing, which involves an awareness of how mathematics is implicated in social life, including the disadvantages of a mathematical approach to problem-solving. The intention of addressing climate change in this literature both incorporates learning about the topic of climate change, but also on the way mathematics comes to shape social reality, known as formatting power (Skovsmose 1994). Both intentions are ethics based, since learning about the topic reflects a concern for the future of the Earth and learning about formatting power in relation to climate change reflects a concern for how mathematics can (or cannot) solve the problem. Barwell (2013), for example, examines different kinds of mathematical knowing in relation to climate change and emphasises how mathematics shapes our understanding and experience of climate change. He points to how mathematics is, at a fundamental level, what makes it possible to

observe and think about climate change. Climate change, that is the description that changes in the climate are taking place, relies on the mathematical descriptions of weather over time. The application of mathematics is formatting in the sense that, among other things, it allows us to talk about climate as though it is predictable, which in turn allows us to discuss how our actions might impact future climate.

This mathematical abstraction of climate change involves many unavoidable elements of uncertainty. Hauge and Barwell (2015) looked at how uncertainty is expressed in texts on predictions of temperature change, and Hauge (2016) analysed how pre-service teachers reflect on the many facets of uncertainty in a discussion about predicted temperature change. Insights about characteristics of uncertainty, such as natural variation, limitations of linear regressions or whether uncertainty can be reduced, are valuable in understanding why climate scientists and climate sceptics can disagree on climate "facts". Also, insights about the limitations of what can be expected from scientific and mathematical representations can influence where to find solutions to the problems of climate change, as Funtowicz and Strand (2011) have suggested. Working with uncertainty in mathematics classrooms can be regarded as an ethical responsibility if it facilitates an understanding of different viewpoints and encourages a search for new solutions. Uncertainly was a point that was brought up by some of the teachers in our study, both in terms of conflicting values and also in relation to how to incorporate the topic into their teaching. For example, a participant referring to multiple views about climate change stated: "that are too many 'I believe's in the climate debate. Teachers are no exception and I am one of those. If we get too eager in promoting our views it will easily become unreasonable".

The issue of conflicting values is related to Skovsmose's concept of reflective knowing, which involves understanding the role of mathematics in its social context. According to Skovsmose, reflective knowing is beneficial for critical citizenship and depends on mathematical and technological knowing. The concern for critical citizenship is closely connected to the value of democracy and democratic participation. Aguilar and Zavaleta (2012) address how mathematics education could, amongst other things, serve as a provider of critical mathematical skills useful for democracy and as a source of values and attitudes. They express mathematics for critical citizenship as:

> the mathematical knowledge that allows students to use mathematics to analyze social problems or to address issues relevant in their personal lives. Such critical mathematical skills enable students to identify and judge how mathematics is applied to address socially relevant issues, as well as to reflect on the consequences of their application. (p.7)

In this approach, understanding of societal issues and mathematical competences should be developed together. Skovsmose promoted a mathematics education that enables students to engage in societal issues through "acting in the world structured by mathematics" (Skovsmose 1998, p. 200). Likewise, Gutstein (2006) argues that mathematics education should strive to give students mathematical competences in order to both understand social

issues and to be able to make change (reading and writing the world). Gutstein also analyzes the practical complexities of both facilitating learning about the political role of mathematics in society and supporting academic success in the traditional sense (e.g., passing high stakes tests). Similarly Brantlinger (2013) points to his experiences with implementing a critical mathematics approach, finding that there were some trade-off between learning about a societal issue and learning mathematics. This point is reflected in our survey: one respondent, for example, addressed the following challenge:

> There is no room for climate [change] in mathematics education and I find it uninteresting to oversimplify certain graphs to squeeze them into mathematics. The climate debate takes up enough space as it is.

Climate change is a complex topic, and this respondent expresses a concern about oversimplifying the mathematics or having the issue take up too much space. Another respondent in the study highlighted the potentially strong opinions of the students: "It is a challenge that the students have strong opinion related to certain political issue that sometimes is an obstacle for critical thinking on different sources, especially media coverage." If climate change is as an example of a socio-political issue that CME literature argues should be addressed in mathematics education, the question nevertheless arises as to whether it is too political and controversial to bring into the classroom or even of whether it is a responsibility of mathematics education at all.

In the CME literature, the notion of responsibility is sometimes referred to as *response-ablity* (e.g., Atweh 2012; Atweh & Brady 2009). Atweh and Brady (2009) suggest that mathematics education has an ethical responsibility to "support students' response-ability not only to *read* the world but also to *transform* the world" (p. 274). This emphasis on response-ability could be thought of both as the responsibility for mathematics education to for instance engage in topics like climate change, but also for facilitating student's ability to be responsible. This approach implies introducing real-world problems to students in mathematics classes that matter for them (Atweh & Brady 2009). Working with climate change data, either as a socio-political issue or as climate science, could be an example of reading the world (see Coles et al. 2013, for examples). A desire to transform the world could result from awareness of the social injustice of the effects of climate change, such as the destruction of habitats, food sources and communities. This dialectic relationship between reading and transforming the world could then be the foundation for response-ability with real-world problems.

The answer to the question of whether mathematics education has a responsibility to work with climate change is naturally dependent on one's stance on what mathematics education should be and what purpose it should have. CME can be regarded as a counter reaction to the view that mathematics is neutral and mathematics education should be neutral. For instance, Koestler (2017) criticizes the idea that "'the actual math' exists as a decontextualized entity separate from the social, cultural, and historical context in which it was created and is currently used" (p. 58). Similarly, Skovsmose (1992) claims that the neutrality of mathematics is an illusion, since models are always designed with a purpose and that

assumptions and simplifications need to be made to transform a real world problem into a solvable mathematical problem. Mathematics is used by politicians and bureaucrats to mask biases and claim objectivity (Wagner & Davis 2010, cited in Aguilar & Zavaleta 2012). Indeed, Greer (2008) argues that when mathematics education does not deal with societal issues and controversies, it gives students the impression that mathematics is value-free and non-political. He further argues that this is, in fact, a political statement about the nature of mathematics.

Skovsmose (1992) confronts the belief of classical mathematics education that from focusing only on mathematical and technical knowledge in school, students will automatically be able to reflect on mathematics in society and respond in democratic processes. However, the issue of climate change may be perceived as too complex and controversial by many mathematics educators. This point is illustrated by some of our survey respondents. One teacher found it challenging to find "good updated sources *which are not political*" (our emphasis) when teaching climate change in class. This statement suggests a wish for mathematics education to be neutral, or at least a tension around what materials can safely be presented in class. Another respondent wrote that:

> Education in school about climate change is almost indoctrination. The school invites delegates and enviromental organisations with state funding, and climate threats are being poured on top. Nothing is being put into a historical context for instance the heatwave in the Viking age when Norwegians settled in Greenland and farmed the land or the small ice age. Everything is about the last decades both for those visiting and in the school books.

This respondent is critical of the value stance taken in school in relation to climate change. This teacher's argument is not that education should be neutral, but rather a wish for a balanced education where reflections from several viewpoints are included and "put into a historical context". Another respondent puts it in a slightly different way:

> It is very common that students are unable to manage all the competence aims in mathematics and physics I therefore try to limit myself to the fundamental goals for the subjects and not expand the subject with topics that are not explicitly mentioned. Furthermore, there are too many "I believes" in the climate debate. Teachers are no exception and I am one of those. If we get too eager in promoting our views, it will easily become unreasonable.

The consideration of social and political values in relation to mathematics education and issues of climate change thus provides us with an understanding of the interrelationship between mathematics education and social, political and ecological worlds around us, in a broader sense. The kinds of dilemmas raised by the teachers quoted above, however, are not simply about curriculum content or the political context of schooling; they are also about whys and how(s) of decisions made in the classroom, which we discuss in the next section.

Ethics at interactional level

Skovsmose and Greer (2012) claim that "of profound political importance is the challenge to mathematicians and mathematics educators to accept ethical responsibilities" (p. 4). This position implies that our society depends on mathematics educators who are willing to accept that the teaching and learning of mathematics involves ethical responsibilities. At the individual and interactional level, then, a choice of whether to include (or not) mathematical contexts and activities that are related to climate change, becomes an ethical responsibility for mathematics educators and has implications for social justice (Boylan 2013) and for social injustice, for that matter.

The question of how to understand (ethical) responsibility and response-ability in practice is not, however, easy to answer, and there is obviously not one correct way of dealing with it. Much writing about CME, moreover, is somewhat theoretical, offering valuable critique and developing ideas for classroom practice, but less often investigating the nature of that practice and the tensions that may arise. In the context of contested issues, such as climate change, there is often a myriad of ethical dilemmas at this level of teachers' practices and activities in classrooms.

Boylan (2016) proposes three principle meanings of an ethical dimension of classroom practice: (i) the relational awareness; (ii) the action taken; and (iii) the ethical principles that inform the actions. Teachers' activities implicate students and teachers as political members of society; ethics becomes an inescapable responsibility to the other, rooted in the collective ethical understanding of communities. Hence, any ethical choices that mathematics educators make become more ambivalent and complex (Boylan 2013, 2016). Teachers may face ethical challenges or other practical challenges that made ethical decision-making and ethical actions more difficult. These challenges relate to, for example, the degree of involvement and interest of students in the issue of climate change, the possible discomfort of students, the uncertainty of how to respond, the unclear path of any possible contributions of their actions to the wider society, and finally a more general sense of dealing with the unknown. Other than their own socio-political stances, teachers also face practical obstacles in incorporating issues related to climate change in their mathematics classrooms, such as lack of resources, lack of sources of data related to their immediate community, curriculum mandates (or lack of them), and lack of time. In this section, we highlight some of these tensions of practice, drawing on examples from our survey.

When teachers decide to bring the issue of climate change into the mathematics classroom, one ethical issue is that of *ethical filtration*. Skovsmose (2008) emphasises this concept when discussing the modelling of complex real-life situations. In the modelling process, the modeller makes certain decisions on what to include and exclude. Aspects left out (consciously or not) could be considered as an *ethical filtration*, or an ethical selection. Ethical filtration then involves taking a complex situation, such as climate change and stripping away many of the ethical consideration initially observed in the process of

mathematising the problem into a technically administrable system (Skovsmose 2008). In effect, mathematical and technical knowing are involved, while reflective knowing is not. For example, one teacher explained that "Actual climate models are extremely advanced and much of the criticism relates to weaknesses in the modeling process." He then found it not useful to present a simplistic version of the modeling, as he stated: "I don't think that a simplified presentation of climate modelling within mathematics education is a useful contribution to the students climate competency." Another teacher explained that what the mathematics students know is limited; hence it is harder to reveal the depths and complexity of the issues using the mathematical concepts students know. She explained:

> this is a way too limited foundation to do anything meaningful, since the students know way too little mathematics, It is not possible to make any models beyond the most basic ones, which quickly becomes a matter of fitting polynomials or others[?] to the average temperature. This does not provide enough depth to defend climate models as theme to be brought up.

For both these teachers, students' perceived lack of mathematical and technical knowing appears to be an obstacle for the teachers to work on reflective knowing with their students, amounting to a form of ethical filtration that may be particular to classroom contexts.

Another ethical tension that teachers face in including issues of climate change into the mathematics classrooms relates to the emotional wellbeing of their students. Should the issues of climate change be included if it causes students discomfort? Opinions on this kind of question differ. Ambrose (2004) argues that there is a tendency for teachers to avoid challenging real-life experiences in classrooms as an expression of caring for their students. Bartell (2011), on the other hand, proposes that caring should rather imply exposing students to difficult conversations, while supporting them to do so. The media debate on climate change can be quite harsh or confusing, which supports the idea that carefully bringing the topic into the classroom can be regarded as a form of caring. For example, a respondent explained that he does not include climate change into his earlier grade classed, as it causes fear:

> This is why it is not something to focus on at the earlier grades because it creates fear without the possibility of action, which creates helplessness which defeats, the whole point.

Another teacher explained that "Sometimes, students find the doom and gloom aspect, boring. Others internalize it and find it scary". For both teachers, the tendency is to avoid including climate change in their classrooms, due to an ethical consideration of caring for children.

The global and overwhelming complexity of climate change also creates barriers for ethical consideration of teaching such subject. Lorenzoni, Nicholson-Cole, and Whitmarsh (2007) highlight some of the barriers such as lack of knowledge, externalizing responsibility, and sense of helplessness. When teachers were asked if they experience challenges in teaching climate change, one teacher answered: "That students don't think they can make a difference

on the global situation. That it does not have anything to say whether they recycle or take shorter showers". The challenge this teacher expressed related to the feeling of despair and helplessness in dealing with complexity of climate change. In another example, other teachers explained that climate change "creates fear without the possibility of action which creates helplessness which defeats the whole point" and that discussing issues of climate change is "inappropriate before Grade 7 because it creates fear without them being able to do anything about it. It is self-defeating." From one point of view, one could question whether teachers should expose students to these problems, if there is nothing or little one can do as a person to individually "solve or overcome" the problems. From another perspective, one could say that students already face such questions, and that the real question one should consider as a teacher, is whether the students have to deal with them alone, or in a classroom environment where they can actively engage in dialogue with others.

In this section, we have highlighted some of the ethical principles that informed teacher's actions in certain ways, including the inclusion or exclusion of climate change in their mathematics classrooms. A point we wish to highlight here is that similar ethical principles can lead to different ethical choices. Issues such as ethical filtration, the emotional wellbeing of the students and the overwhelming complexity of the issues of climate change bring up ethical decisions of including and excluding the issues of climate change in their mathematics classrooms. For the above mentioned reasons, some teachers found it more ethical to not include climate change as a social issue in their classrooms, whereas others perceived the inclusion of the issues as more ethical.

Teachers did not always have well-defined beliefs and perception about the issues of climate change. Hence, teachers also expressed a general feeling of being unsure about how to act. For example, when teachers where asked how they could imagine working with climate change if resources were sufficient, one teacher responded: "I would have worked with it in social studies, economics and ethics. What should we do and why? How can we weigh different solutions against each other?" This teacher is concerned with action and the reasons for those actions, and, interestingly, would include the different perspectives of several subject areas, including ethics. It is not only teachers' beliefs and principles that lead them to certain actions, then; teachers also face practical challenges that affect their decision-making. Such decisions are also ethical as they may over-ride the values of the wider community with which they are in relation. These challenges include curriculum constraints, class sizes and time. One teacher mentioned that: "They [issues of climate change] do not have any significance in respect to the curriculum. Sadly we have to prioritize to make it through the curriculum." And another teachers stated the problem of "Big classes with big differences [academic] level, motivation and participation" as challenges she faced which made "Little possibility to use issues of climate change".

As we have illustrated, teachers experience tensions at different levels, when they attempt to open up discussions around the issues of climate change into their mathematics classrooms. Nevertheless, if these openings do not exist for students in the mathematics classroom, the

opportunities for students to develop critical agency seem more difficult to achieve. Atweh (2012) links the ethics of choices and actions to the relationship between mathematics and democratic participation of both teachers and students: teachers' decisions about inclusion or exclusion of climate change in their teaching plays an important role in students' critical awareness of the issues. A focus on ethical responsibility can strengthen teachers' professionalism and allow them to better take into consideration students' social and political lifeworlds (Atweh & Brady 2009). Renert (2011, p. 20), for example, draws on personal experience as a mathematics teacher and researcher, to raise awareness about the ethical importance of including climate change in classrooms. Promoting the need to involve students in such a way so they become aware of the "imminent environmental catastrophes", he suggests that by integrating environmental issues in mathematics classrooms one could enable students to see the world differently, making connections, and "moving to ethical action as a result of increased awareness" (2011, p. 21).

Discussion and conclusions

Ethics is an unavoidable aspect of mathematics education. Since teachers are not isolated from others in their decisions and values, their actions at an individual level are not detached from those in the political and social sphere. Critical mathematics education highlights the importance of bringing socio-political topics into the classroom in order to enable students to use mathematics to understand and reflect on the topic, as well as to appreciate the mathematical dimensions of such issues. This argument goes further than engaging students with such topics for the sake of inspiring mathematics learning. This stance can be understood as mathematics education having an ethical responsibility to teach mathematics in a way that empowers students to be able to act on injustice. An important value underlying this approach is that an ethically just democracy needs critical citizens as agents of change. Climate change is one such socio-political issue where injustice can be connected to impacts on individuals, peoples and generations, and the environment. Mathematics education can contribute to understanding these impacts of climate change.

Critical mathematics education also underlines the formatting power of mathematics, implying that the way mathematics shapes society and our lives can be questioned. From this point of view, mathematics education has an ethical responsibility to enable students to take up such questions. This could include reflecting on uncertainty associated with climate science, the role of this uncertainty and more generally, the role of mathematics based knowledge in finding solutions to the problem and how it influences (re)actions, both positive and negative. Critical mathematics education promotes an understanding of mathematics that is about more than computation and the narrow application of mathematics: rather, it promotes reflection on how mathematics is applied in society. If climate change is the most urgent of global problems, it can be argued that mathematics education has an ethical responsibility to facilitate learning about this multi-faceted problem through mathematics, but also to reflect on the role of mathematics in climate change. In this respect, climate change can be seen as a complex real-life situation, where teachers can make transparent the

formatting power of mathematics, and where students are allowed and encouraged to critique (with) mathematics. It can also be seen as an opportunity for teachers to let ethical considerations be an integrated part of mathematics education, and not detached from problem solving.

While the perspective of critical mathematics education implies a clear imperative for addressing climate change in mathematics classrooms, our discussion of ethics at the level of classroom processes suggests that this imperative may not be so easy to put into practice. An attempt to engage with and to mathematize the issues of climate change can conceal different ethical tensions. Our examples highlight some of the political and value-laden practices and challenges facing mathematics educators at the level of individual actions.

Teachers make complex and ethical choices, in relation to including (or not) climate change as part of their mathematics teaching. On the one hand, these choices are made in the light of teachers' own broader social and political value stances, ethical beliefs and the recognition of the ethical importance of incorporating climate change into their teaching of mathematics. On the other hand, teachers' choice and actions, at a classroom level, are on the basis of their relationships to their students and to other social groups. Hence, teachers' awareness of the potential ethical significance of climate change does not necessarily lead to the act of including climate change in their mathematics classroom. So for teachers, ethics include sensitivity to their relationships with their students and their needs. Boylan (2016) sees the ethical responsibilities of the teachers not as an isolated matters but in relation to their relational awareness of not only the ethical significance of climate change but also of the needs of others with whom teachers in relation. Hence, the action teachers take are part of an ethical relational web with others (students, the curriculum, community, etc.), and for which teachers are responsible. The ethical principles on which teachers base their own ethical philosophy are not always that easy to achieve. The uncertainty, value conflicts, controversies in the media and finally the complexity of the mathematical and scientific background of the issue of climate change make it particularly challenging for teachers to form their own individual beliefs around this issue of climate change.

We acknowledge and respect the ethical challenges teachers face in their attempts to include issues of climate change into their classrooms. We argue that these challenges need to be faced and addressed not only by the community of mathematics educators but by other social educational actors, such as ministries of education and curriculum authors. Our rationale for such a position is based on two essentials. Firstly, the climate change is one of the most (if not the most) urgent issues of the Earth today. Secondly, students of today are the decision makers of tomorrow. The social forces that are in play in the issues of climate change, are multiple and potentially powerful. Our students potentially have the power to effect change, both on an individual and a societal level. We, mathematics educators, also have the power to effect change: taking an ethically responsible stance towards engaging students in critical citizenship. By enabling students to critique mathematics and to critique with mathematics in the classroom, and by integrating moral and ethical questions in a non-normative way,

mathematics educators can help students evolve as critical citizens to reflect on the different challenges of climate change and to become active participants of democratic societies.

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