The mathematical formatting of climate change: critical mathematics education and post-normal science

Richard Barwell
Faculty of Education, University of Ottawa, Canada
richard.barwell@uottawa.ca

Abstract

Climate change is one of the most pressing issues of the 21st Century. Mathematics is involved at every level of understanding climate change, including the description, prediction and communication of climate change. As a highly complex issue, climate change is an example of ‘post-normal’ science – it is urgent, complex and involves a high degree of uncertainty. This kind of science requires the participation of citizens from outside the laboratory much more than traditional ‘normal’ science. This implies a role for mathematics education in educating future citizens to contribute to the kind of dialogue that is needed. In this paper, I argue that critical mathematics education offers a perspective from which to conceptualise how mathematics teaching and learning might undertake this role, drawing in particular on the idea of the ‘formatting power’ of mathematics and the importance of reflective knowing in relation to the mathematics of climate change.

Key words

Climate change, critical mathematics education, post-normal science
Climate change has become one of the most pressing issues of the 21st century. The evidence that human activity is altering our planetary ecosystem is diverse and compelling (see, in particular, IPCC, 2008). For Lovelock (2009), the Earth is a complex living system that should be seen as a living organism, of which humans are just one part. As such, our activity has always affected and been affected by the ecosystem. Human impact has, perhaps, become problematic because we have become so numerous and because we (collectively) consume so much. The planetary ecosystem is so complex, however, that working out what, if anything, we can now do to reverse our impact on the climate is difficult and perhaps impossible. Lovelock (2009) feels we overestimate our power to act: “it is hubris to think that we know how to save the Earth: our planet looks after itself. All that we can do is try to save ourselves” (p. 9).

Despite the weight of scientific evidence and consensus, not everyone is convinced or concerned. Public media often report these disagreements as an on-going scientific debate, leading to much public confusion. Politicians and policy-makers struggle to interpret the science and propose minimal measures based on their acceptability to the general population. The result is widespread uncertainty and disinterest. In this paper, I consider what role mathematics education can play in understanding and even tackling climate change. I argue that critical mathematics education offers a theoretical perspective with which to conceptualise how the teaching and learning of mathematics can engage with the issue of climate change. To do so, I will draw on two sets of ideas: first, the notion of ‘post-normal science’, which highlights the uncertainty that science can entail in response to an issue like climate change (Funtowicz & Ravetz, 1993, 1994); and second, ideas from critical mathematics education (e.g., Skovsmose, 1994). First, however, it may be helpful to say something about the role of mathematics in understanding climate change.

1. Mathematics and climate change

The science of climate change is often complex and technical, despite being based on some fairly basic principles (e.g. the greenhouse effect). It also involves a good deal of mathematics. There are three ways that mathematics is involved: description, prediction and communication. The description of climate change is mostly based on descriptive statistics. Indeed without mathematics, we would have little awareness of climate change as a system-wide phenomenon. The Intergovernmental Panel on Climate Change (IPCC) defines climate change in terms of:

\[
\text{a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. (IPCC, 2008, p. 30)}^1
\]

Climate change is thus described in terms of mathematical notions and procedures such as means and statistical tests. These techniques are applied to a wide variety of data,

---

1 This definition refers to any climate change, whether or not it is “due to natural variability or as a result of human activity” (IPCC, 2008, p. 30). In this paper, for the sake of brevity the term ‘climate change’ refers specifically to the latter.
including air and sea temperature recordings and other standard meteorological readings, as well as records of such things as glacial melting or sea level (both are increasing – see IPCC, 2008, p. 30). It is worth noting, in passing, that much of this mathematics is well within the scope of school mathematics curricula. The prediction of the likely course of climate change in the future is based on more advanced mathematics. Developing predictions about future global, regional or local effects of climate change draws on a range of advanced mathematical methods, including mathematical modelling, differential equations, non-linear systems and stochastic processes (McKenzie, 2007, pp. 22-23).

Several different climate models have been developed to relate greenhouse gas emissions to changes in the Earth’s climate. Various mathematical techniques are used to validate these models (e.g. applying them to historical data). A current mathematical challenge is to develop methods of dealing with differences that arise between models for long-range predictions (McKenzie, 2007, pp. 17-18). Finally, the communication of climate change also entails the use of mathematics and, more particularly, mathematical literacy. Climate change is now explained or discussed in a wide range of non-scientific contexts, including the mass media, official websites, blogs, official publications, reports and so on. Interpreting and, in some cases, participating in the production of these texts entails some level of engagement with the mathematics used to describe and predict climate change. Additionally, a degree of mathematical literacy is also necessary, in relation to the use and interpretation of data, graphs and accounts of the mathematics involved. Newspaper articles, for example, regularly include graphs or other mathematical graphics showing global temperature changes, emissions data and so on. Moreover, I have noticed several examples of public debate, in which mathematical considerations have been significant. Such considerations include arguments about the misrepresentation of data\(^2\), about the status of predictions made on the basis of mathematical climate models and discussion about the concept of a long-term trend (in the light of particularly cold winter weather in the UK, for example\(^3\)). Policy makers, public servants, business and the general public are all, increasingly, consumers of information (and, in some cases, polemic) about climate change. The central role of mathematics in climate science, along with the increasing political and public attention that climate change is attracting, therefore suggests an important role for education in general, and mathematics education in particular. Before I can look more specifically at what that role might be, however, I need a way to understand the interactions between scientists, politicians, public media and the general public in relation to climate change.

2. Climate change as post-normal science

Climate science is not always easy to understand. Several studies have set out to map how well the general public understand the science of climate change and concluded that ignorance and misconceptions are widespread (e.g., Bord, O’Connor & Fisher, 2000; Lorenzoni & Pidgeon, 2006; Stamm, Engels & Pansegrau, 2000). Bulkeley (2000), however, has argued that such an approach is deficit oriented. The underlying assumption of this research is that the general public are passive consumers of scientific information.


\(^3\) For example: http://www.guardian.co.uk/environment/2011/mar/25/global-cooling
With better understanding, better quality information and better education, citizens will be able to contribute more effectively to the development of public policy or ‘do as they are told’. In her research with children and their parents in Australia, however, Bulkeley found that:

public understandings of global environmental risks involve local knowledges, personal values, and scientific information. In these understandings both the social relations surrounding the issue and the physical risks of climate change are important. Despite the scientific uncertainty and claims and counter-claims that have surrounded the issue of climate change, survey respondents and focus group participants continued to place faith in science and education as the most reliable sources of climate change information. (Bulkeley, 2000, p. 329)

This work suggests that the interaction between science, public understanding and public action is much more complex.

Climate change is an example of what Funtowicz and Ravetz (1993) call post-normal science:

To characterize an issue involving risk and the environment, in what we call ‘post-normal’ science, we can think of it as one where facts are uncertain, values in dispute, stakes high and decisions urgent. In such a case, the term ‘problem’, with its connotations of an exercise where a defined methodology is likely to lead to a clear solution, is less appropriate. We would be misled if we retained the image of a process where true scientific facts simply determine the correct policy conclusions. (p. 744)

Unlike ‘traditional’ science, often conducted through controlled experiments and standardised procedures, climate science faces several challenges. First, it is not possible to fully observe and describe the complex ecosystem of which we are a part. The idea of measuring the temperature of a planet, for example, is in many respects meaningless. There is a high degree of uncertainty in our understanding of climate change as a phenomenon (which does not, by the way, undermine the scientific consensus, but rather epistemologically recasts it). Second, despite any uncertainty, the situation is urgent and action is needed. Inaction is highly likely to be catastrophic (some would say it already is – see Lovelock, 2009, for example). But any significant measures designed to tackle climate change will have unpredictable effects, some of which might also be catastrophic, at least for human beings. Finally, however, even where there is consensus that human activity is a major driver of climate change, there is disagreement about whether it matters, or, if it does matter, about what measures should be taken. The uncertainty of climate science occurs as much at the level of policy (what to do) as it does in the pursuit of scientific understanding.

Funtowicz and Ravetz (1993) contrast post-normal science with various forms of more traditional scientific activity. Core science and applied science address fairly narrowly defined problems investigated in reasonably well-controlled conditions. Uncertainty and risks are carefully controlled and managed through standardised, technical methods. This approach to science corresponds roughly to Kuhn’s conception of ‘normal science’. Professional consultancy incorporates the methods of applied science, but more
judgement is used in applying and interpreting the science and the risks and uncertainties are higher. The practice of medicine is a good example of an application of science that involves a good deal of judgement as well as a degree of risk and uncertainty. Your doctor deduces from your description of your symptoms the most likely condition that fits the symptoms and treats you accordingly. But many conditions have similar symptoms and each individual responds slightly differently to both illnesses and their treatment. So the doctor uses her professional judgement. Post-normal science incorporates aspects of applied science and professional consultancy but addresses problems of wider impact, requiring policy responses and involving multiple levels of uncertainty, risk and urgency.

Funtowicz and Ravetz (1993, 1994) highlight several features of post-normal science, of which I shall mention three. First, post-normal science must deal with the contradictions that arise in any system:

we can consider contradictions as being of several sorts. One is of complementarity, where the opposed elements are kept in dynamic balance. Another is of destructive conflict, where the struggle results in the collapse of the system in which they coexist. Finally there is creative tension, in which the resolution is achieved by the qualitative transformation of the system. (Funtowicz and Ravetz, 1994, p. 573)

In the context of climate change, for example, a contradiction arises in our individual desire for material comfort (and its associated consumer lifestyle) and the impossibility that all human beings can achieve this same level of material comfort (Funtowicz and Ravetz, 1994, p. 580). Second, post-normal science features a high degree of irreducible uncertainty. Data, for example, may be inadequate or unobtainable (e.g. high quality data for the Earth’s climate in the past). And the complexity of the systems involved make observation, measurement and intervention difficult. Funtowicz and Ravetz (1993) include mathematical modelling of complex systems as an example of methods that are “untestable” and hence include a degree of uncertainty. Third, Funtowicz and Ravetz highlight the shift from a traditional view of science in which facts are seen as distinct from values. This perspective led to a model of the relationship between science and policy in which science provided the facts and politicians or bureaucrats or individual citizens decided what to do with these facts – the same model that informs some of the research cited above into public ignorance about climate change. In post-normal science, values and facts cannot be separated, in part due to the problem of uncertainty (Funtowicz and Ravetz, 1993, p. 751). Climate models, for example, include uncertainty and any possible action to deal with climate change will have uncertain effects to a greater or lesser extent. Deciding which information to use, which voices to hear and which methods to try depends as much on values as it does on scientific facts.

Based on their analysis Funtowicz and Ravetz (1993) argue that post-normal science must involve engagement with a much wider community of participants. Scientists can no longer simply seek and present facts: the increasing role of contradiction, uncertainty and values mean that dialogue is needed:
When problems lack neat solutions, when environmental and ethical aspects of the issues are prominent, when the phenomena themselves are ambiguous, and when all research techniques are open to methodological criticism, then the debates on quality are not enhanced by the exclusion of all but the specialist researchers and official experts. The extension of the peer community is then not merely an ethical or political act; it can positively enrich the processes of scientific investigation. Knowledge of local conditions may determine which data are strong and relevant, and can also help to define the policy problems. Such local, personal knowledge does not come naturally to the subject-specialism experts whose training and employment predispose them to adopt abstract, generalized conceptions of genuineness of problems and relevance of information. Those whose lives and livelihood depend on the solution of the problems will have a keen awareness of how the general principles are realized in their ‘back yards’. They will also have ‘extended facts’, including anecdotes, informal surveys, and official information published by unofficial means. It may be argued that they lack theoretical knowledge and are biased by self-interest; but it can equally well be argued that the experts lack practical knowledge and have their own unselfconscious forms of bias. (pp. 752-753)

Funtowicz and Ravetz’s arguments for a ‘wider peer community’ and Bulkeley’s findings that science and education are still valued but as part of a wider network of interlocutors suggest an important role for education in contributing to the wider understanding of climate change and its impact. It also underlines, however, that public understanding and individual and collective action draw on a variety of social and institutional practices (Bulkeley, 2000; Lorenzoni, Nicholson-Cole & Whitmarsh, 2007). What, then, does this all mean for mathematicians and mathematics educators? First, as I have outlined already, mathematics plays a central role in describing, predicting and communicating climate change. Mathematics is central to post-normal science. Second, the development of mathematics has made possible the industrial-technological economic system that has led directly (e.g. through the oil industry) and indirectly (e.g. through population growth) to climate change. As d’Ambrosio (2010) says, we have a responsibility, as mathematics educators, “to question the role of mathematics and mathematics education in arriving at the present global predicaments of mankind” (p. 51). In the next section, I discuss some aspects of critical mathematics education as a suitable perspective from which to undertake this questioning.

3. Formatting climate change

Climate science is, as I have discussed, an example of post-normal science. As such, the traditional model of science as providing facts for the rest of society to respond to is no longer tenable. Dialogue, through a wider peer-community for climate science, is needed. Moreover, mathematics is an important part of climate science. In particular, mathematics education needs to respond to this situation. Mathematics education needs to consider the role of learners in these wider peer communities and prepare them to participate as active, critical citizens. The basis for such a mathematics education can be found in critical mathematics education and, in particular, in the work of Skovsmose (e.g. 1984, 1994, 2009).

Skovsmose’s approach is valuable for two reasons. First, it recognises the role of mathematics in creating our world, as alluded to above. Skovsmose (1994) refers to this
as ‘formatting’ (p. 43). I will show how a mathematically formatted society is why post-normal science is necessary. Second, Skovsmose argues that mathematics teaching and learning can include a critical analysis of the role that mathematics plays. A critical mathematics education can offer students some insight into how mathematics is part of their lives and the consequences it can have – including consequences for the Earth’s climate.

In order to explain how mathematics formats or constitutes social reality (although not exclusively) Skovsmose (1994) proposes a distinction between two forms of abstraction. Thinking abstraction refers to:

the mode of thought used to facilitate reasoning, and this type of abstraction is exemplified by mathematical concepts and mathematical modelling. Here we are concerned with explicit mathematics. (p. 51)

In effect, this definition describes the commonly understood meaning of the word ‘abstraction’. Much of ‘applied’ mathematics involves working with thinking abstractions to solve problems, often based on some form of mathematical model. Much of the mathematics of the prediction of climate change involves thinking abstractions, such as, most significantly, models of the climate. Weaver (2008), a climatologist, summarises how they work as follows:

A climate model starts with a set of equations governing the dynamics of the climate system and translates those equations into a model grid that represents the Earth. Each of the subcomponents (ocean, atmosphere, land surface, cryosphere) interacts and exchanges heat, moisture, and momentum. The resulting system is then driven by specified radiative forcings, including energy from the sun and emissions of human produced greenhouse gases (p. 183).

These equations, and the links between them, are not the climate of the Earth; they are abstractions. The ‘resulting system’ is a system of equations, designed to represent the climate but, inevitably, a great simplification.

In contrast to thinking abstractions, Skovsmose proposes realised abstractions:

Thinking abstractions are (though perhaps rather imprecise) ‘images’ of reality, but we also may witness the reverse phenomenon that real structures can be ‘images’ of thinking abstractions, and these we call realised abstractions. They are taken for granted and become reifications of modes of thought. (p. 52)

Examples discussed by Skovsmose include money, taxation (p. 52) and airline booking systems (2001). In each case, a mathematical system or model has become ‘real’: it has become part of the structure of social life and as such, influences what we experience and how we act. Furthermore, in most circumstances, we pay little attention to the mathematics embedded in the abstraction. Is climate change a realised abstraction? Governments around the world are formulating policies and laws in response to the threat of climate change. These measures include attempts to regulate greenhouse gas emissions
or changes in energy policy, as well as mitigation measures, such as the construction of new flood defences\textsuperscript{4}. Such responses are largely in response to the predictions of mathematical models (rather than actual observations of the climate) but have increasingly real effects. It is impossible for an individual to experience climate change on a planetary scale. Our response to climate change is, therefore, changing the structure of our society based on climate models. Climate change is, therefore, becoming a realised abstraction.

For Skovsmose (1994), the process through which thinking abstractions become realised abstractions depends largely on information technology and hence on mathematics. Moreover, the language of mathematics is transferred from one of description in the form of models, to a way of organising human behaviour. A model of airline ticket sales, for example, is ostensibly a description of various factors that influence the sale of tickets – time of day, time of year, route, etc. Skovsmose’s argument, however, is that this description becomes prescriptive. In effect it is a simplifed, mathematised, model of human behaviour, but once established through technology, our behaviour increasingly must conform to the model. We are caught in a mathematical reality:

Mathematics intervenes in reality by creating a ‘second nature’ around us, by giving not only descriptions of phenomena, but also by giving models for changed behaviour. We not only ‘see’ according to mathematics, we also ‘do’ according to mathematics. (p. 55)

This account of how mathematics formats reality underlines the role of mathematics in modern society. It is information technology based on mathematical models and algorithms that makes possible, for example, the creation of global supply chains through which raw materials are shipped around the world (e.g. to China) and made into products that are shipped again across the world before being distributed through national networks of trucks to arrive on the shelves of supermarkets (at an amazingly low price, given this chain of events). One by-product of this kind of activity is high levels of greenhouse gas emissions. The same kind of globalised system could be described for every other sector of modern life – agriculture, mass media, medicine, warfare, etc. Mathematics also formats how we interact with the climate. Through the mathematised, model-based perspective prevalent in climate research, the climate is constructed in particular ways: as, for example, measurable, predictable, technical and controllable by humans, rather like the temperature in a high-tech sensor-controlled greenhouse. This construction of the climate does not include the stories of our ancestors about how the weather has changed or the anguish of people whose way of life has been disrupted by drought or floods or, in the case of Queensland, Australia, both. These kinds of considerations are exactly the kinds of “keen awareness of how the general principles are realized in their ‘back yards’” that Funtowicz and Ravetz (1993, p. 753) argue must be taken into account in the conduct of post-normal science.

\textsuperscript{4} See, for example, the adaptive measures shown in DEFRA (2009)
4. Reflective knowing, post-normal science and climate change

Post-normal science is a way of responding to problems with particular features: high levels of uncertainty, urgency, high stakes and the interrelation of facts and values. Such problems feature contradictions and their solutions need to involve an extended peer community. Normal science with its standardised procedures, ways of defining problems and separation of facts from values is insufficient. Hulme (2009), a climatologist, has argued that as a ‘normal science’ problem, climate change is insoluble. He does not conclude, however, that nothing can be done. Instead he proposes a post-normal science approach in which climate change becomes a focal point for collective dialogue and action involving scientists but also a wide range of other participants:

We will continue to create and tell new stories about climate change and mobilise these stories in support of our projects. Whereas a modernist reading of climate may once have regarded it as merely a physical boundary condition for human action, we now must come to terms with climate change operating as an overlying, but more fluid, imaginative condition of human existence. (p. 364)

It is my contention that critical mathematics education can prepare students to participate the kind of dialogue that Hulme invokes. To consider in more depth how critical mathematics education can do this, I turn again to Skovsmose’s work, this time to his notion of reflective knowing.

Drawing on his examination of the formatting power of mathematics, Skovsmose distinguishes three kinds of knowing that are potentially relevant to mathematics education. Mathematical knowing “refers to the competencies we normally describe as mathematical skills” (p. 100) which constitute the kind of formal mathematics that is embedded in technology. In the case of climate change, mathematical knowing includes the statistical methods involved in describing climate change and the mathematical methods used in predicting climate change: differential equations, non-linear systems theory and so on. It also includes mathematical aspects of the communication of climate change, such as the formal properties of graphs and charts. Technological knowing “refers to the ability to apply mathematics and formal methods in pursuing technological aims” (pp. 100-101). The emphasis here is operating and applying mathematical tools and methods, not for the sake of advancing mathematics but in order to perform some external task. The difference between mathematical and technological knowing is largely analytical and depends on the goal involved. Moreover, technological knowing can be used without an equivalent level of mathematical knowing. For example, airline sales personnel sell tickets by operating their company’s booking system. They do not need to understand the underlying models. Even when the mathematics is understood, in the context of technological knowing it is not necessary to pay attention to it. This is, indeed, part of the power of mathematics. In the case of climate change, technological knowing is relevant in two ways, as suggested above in relation to the formatting power of mathematics. First, climate scientists use technological knowing to conduct much of their work. Most climate scientists are not mathematicians. They use mathematical models and other techniques embedded in software and measuring instruments to understand the climate or some part of it. I recently contacted a glaciologist and mentioned my interest in
how mathematics was used in climate science and his initial response was to say that he
did not do any mathematics. To me, however, his work seemed to be highly
mathematical. On reflection, it seems to me that his knowing was technological rather
than mathematical. He operates software or measurement instruments and interprets the
results but much of this work does not involve mathematical knowing. Second, we all
rely on technological knowing to live in our technological society. Operating a mobile
phone is a form of technological knowing that does not need to connect to the complex
mathematical knowing that makes the phone work. By not connecting the two, however,
the role of mathematics is hidden. Our technological society, however, is responsible for
changing the climate of the planet. *Reflective knowing* “has to do with the evaluation and
general discussion of what is identified as a technological aim and the social and ethical
consequences of pursuing that aim with selected tools” (p. 101). Reflective knowing,
then, is a meta-level of knowing, which goes beyond the narrower formal knowing of
mathematics or the operational knowing of technology. It is necessary to distinguish
reflective knowing from technological or mathematical knowing because the latter are
insufficient in themselves for an awareness of their own social or ethical consequences. It
is through reflective knowing that questions about the role of mathematics in climate
change can be asked. Skovsmose is careful to point out that these three kinds of knowing
are useful conceptual categories. Much mathematics teaching is more geared towards
mathematical knowing, with technological knowing gaining in prevalence through, for
example, modelling-based curricula. In mathematics classroom, however, all three forms
of knowing can be present and are interlinked.

There is some resemblance between Skovsmose’s formulation of three types of knowing
in the context of mathematics education and Funtowicz and Ravetz’s different ways of
doing science. Mathematical knowing and technological knowing are, at a small-scale,
analogous to core science, applied science and professional consultancy. They involve
the use of standardised methods of ways of doing things and a small to moderate degree
of professional judgment. Funtowicz and Ravetz argue that for complex problems like
climate change, a different approach is needed involving dialogue and engagement with a
wider peer community. Reflective knowing, then, is the small-scale analogy of post-
normal science. To do the latter, the former is needed. It is reflective knowing that makes
possible an awareness of the way mathematics formats society and, as such, is a key part
of critical mathematics education. Teaching mathematics from a critical mathematics
education perspective therefore entails teaching for reflective knowing (as well as
mathematical and technological knowing).

Skovsmose (1994) further develops the notion of reflective knowing by proposing three
‘tasks’ or foci. These foci all concern the different language games or registers (I prefer
the latter term, although Skovsmose does not use it) that are involved in using and
applying mathematics. These registers include the use of natural language to discuss a
particular problem, narrower more technical registers associated with the systematisation
of a version of the problem, as well as the formal registers of symbolic representations,
programming languages and so on. The process of moving from a problem to thinking
abstractions to realised abstractions via technology involves moving between these
various registers. For Skovsmose, the foci he proposes for reflection in the context of
mathematics education relate to different aspects of these registers and the shifts between them. First, he discusses how the transition between these different registers makes the role of mathematics invisible (p. 106). In the construction of a mathematical model, for example, decisions are made about what to include and what to leave out. These decisions are, in a sense, forced by the shift from one register to another. The nature of mathematical models, for example, means that some things cannot be included at all: emotions, might be one example. This point is relevant to the description of climate change. Much of the information about climate change consumed by the general public comes from media sources, books and websites. Although I have not empirically verified this hypothesis, my observation of such sources of information suggests that mathematics is rarely mentioned and where it is, the human role in the mathematics is hidden (Barwell & Suurtamm, 2011). So one focus of reflection in mathematics education related to climate change would be the assumptions, decisions and general human presence in the mathematisation of the climate.

A second focus for reflection concerns the effect on uncertainty of shifting between registers. Skovsmose (1994) observes that ambiguity and uncertainty occur unevenly in different registers. When an informal description of a phenomenon in a natural language register is represented as a mathematical model, some of the ambiguity of the informal description is hidden. The symbolic register of mathematics does not eliminate uncertainty but rather diverts attention from it, since the uncertainty lies outside the symbolic register itself. This point is particularly relevant in the context of post-normal science, which is characterised by high levels of uncertainty. Even the measurement of something as basic as temperature involves uncertainty: temperature varies in time and space and it is impossible to measure record temperature at every point in time and space. The act of reading a thermometer and reading the temperature fixes something that is fluid and uncertain. Collating and analysing temperature readings for a whole planet involves many layers of fixing and simplifying – that is, of transitions between registers. The resulting finding that, for example, last year was one of the hottest years on record masks a good deal of uncertainty. The point is not that this uncertainty is bad or that the claim is untrue, but that the situation is complex. Similar issues arise in the communication of climate change across different domains of activity. Weingart, Engels & Pansegrau (2000) analysed scientific, political and mass media discussion of climate change over a 20-year period in Germany. They concluded that there are important disparities in the discourses of climate change in each sphere and hence concomitant differences in the way that climate change is constructed. Climate change discourse in the political sphere, for example, tends to simplify the issues in ways that the Weingart et al. relate to the nature of political decision-making. Uncertainty is downplayed. For Skovsmose, then, “reflections have to get hold of the uncertainties of such transitions; not in order to solve that problem - this cannot be solved – but in order to create an awareness of the nature of the transitions” (p. 111).

Skovsmose’s third focus for reflection concerns the way the terms of debate and discussion are shaped by the presence of mathematics. For me, this point is about the rhetorical force of mathematics. Some ideas or ways of reasoning carry more weight while others are seen as weak or irrelevant. Mathematical reasoning is particularly hard to
argue with (Edwards and Potter, 1992). Skovsmose argues, therefore, that “reflections must address the way a mathematical modelling affects the whole context of problem-solving, seen as a technological enterprise” (pp. 113-114). Again, this point is particularly important in the context of post-normal science. It concerns both the relation of facts and values, as well as the nature of the extended peer community. Part of the rhetorical dimension of mathematical registers, particularly the symbolic register, is that values are not apparent. A mathematical model includes various variables, while excluding others. Where ‘experts’ do this work, they decide which facts and variables are valuable enough to be included in the model. Values relate to interest, however: reflection needs to consider who benefits from particular mathematisations in use versus alternatives that could have been used. Lovelock (2009), for example, claims that “national governments and international agencies are reluctant to fund observation and measurement but ready to fund models [of the climate]. Measurements by scientists are much harder to contest” (p. 8). By extending the peer community, a wider range of values can be considered and included and the presence of values is more evident.

5. Some concluding suggestions

In my concern that mathematics education needs to engage with the issue of climate change, I have drawn together a number of different ideas. I have sketched how mathematics is implicated in the description, prediction and communication of climate change. I have set out how tackling climate change is a case of post-normal science. And I have argued that critical mathematics education is a theoretical approach that can form the basis for the engagement with the issue of climate change that needs to happen in mathematics education. In particular, critical mathematical education makes possible an examination of the formatting role of mathematics in constructions of climate change in different arenas. The encouragement of reflective knowing (as well as mathematical and technological knowing) in relation to climate change offers a reasonably practical focus for teachers at the classroom level. Reflections can examine how mathematics constructs the world in particular ways, how ambiguity and uncertainty are affected and how values and benefits for different groups are constructed through the formatting role of mathematics. In relation to climate change, such reflections can be organised around the four features of post-normal science: facts, values, stakes and decisions. These four features suggest four sets of questions around which critical reflection of the role of mathematics can begin:

- What are the facts? How are these facts produced? Where is uncertainty?
- What is valued and what is devalued?
- What is at stake? Who benefits from particular versions of the facts? Who benefits from emphasising some values and not others?
- What decisions are possible? What decisions are not possible? What action can we take?

As d’Ambrosio (2010) says, as mathematics educators, we have a responsibility to act.
References


