WICKED PROBLEMS IN SCHOOL MATHEMATICS

Lisa Steffensen, Rune Herheim, and Toril Eskeland Rangnes
Western Norway University of Applied Sciences

The paper concerns climate change controversies and teachers' facilitation of pupils' critical mathematics perspectives through wicked problems. The data was collected in a research partnership with three teachers and their tenth grade pupils. A particular focus is directed towards how controversies can influence teachers to make different versions of a quiz, and this is discussed in relation to the teachers' value perspectives. The teachers' choices of questions, numbers, and graphs are connected to their facilitation of action or critical thinking. In the dialogues, the teachers challenged each other's choices, and the controversies and value aspects were made explicit.

INTRODUCTION

During the last decade, a socio-political turn in mathematics education has received a growing interest among researchers and practitioners (Gutiérrez, 2013). This turn links mathematics and mathematics education with complex, socio-political questions and is a core aspect of Critical Mathematics Education (CME). Barwell (2013) argued that socio-political issues like climate change deserve attention by mathematics education, because mathematics is used to describe, predict, and communicate climate change. Climate change is sometimes referred to as a wicked problem, characterised by vague problem-formulations, multiple solutions difficult to define as right or wrong, no central authority, use of multiple time spans, and disagreement on who should bear the costs (Levin, Cashore, Bernstein, & Auld, 2012). Wicked problems often involve controversies that spark disagreement, and for climate change, typical examples are: Does (anthropogenic) climate change exist? If yes, what causes climate change?

In political debates about climate change, biased use of mathematics happen. Some interest-organisations and blogs, for example wattsupwiththat.com, selectively use graphs and mathematical representations to support their arguments. Citizens who regard mathematics as neutral and value-free may then be exposed to a political standpoint without being aware of it. Several researchers (e.g. Atweh, 2012; Ernest, 2009; Mellin-Olsen, 1987; Skovsmose, 1994) challenge the view on mathematics as objective, value-free, and non-political. Skovsmose (2014, p. 116) problematized this view on mathematics and mathematics education by underlining how important it is "to address critically mathematics in all its forms and application". Therefore, mathematics education plays an important role in educating citizens to become able to recognize political use of mathematics, and discussing climate change can serve as a powerful topic to achieve this. In Norway, the Education Act (1998) underlined that "pupils and apprentices shall learn to think critically and act ethically and with environmental awareness". This is a broader environmental perspective, but it is further

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specified in the political guidelines (Ministry of Education and Research, 2016) that pupils should be enabled to critically reflect on climate change, to understand and to believe in, and to acknowledge the responsibility to take actions. The focus on critical reflections and understanding is a common task in schools, while to believe in and take actions represent a more activist perspective. This raises interesting questions in respect to the normative aspect of climate change. For example, can critical reflection conflict with more normative and activist perspective in the curricula? Ho and Seow (2015) explored this conflict, and found that scholars in social studies disagree whether the purpose of teaching climate issues is to develop independent and critical thinking, or to advocate for certain values and environmental change. If mathematics teachers implement climate change in the classroom, then this conflict is an important aspect to consider. Abtahi, Gøtze, Steffensen, Hauge, and Barwell (2017) found in a research survey that mathematics teachers expressed concerns about political and conflicting perspectives in climate change, and how this could affect their neutrality as teachers.

So, there is a profound emphasis in CME on mathematics as political and subjective and not neutral or value-free, and climate change is set forward as a potent topic for giving attention to these aspects in mathematics teaching. Yet, little research has focused on climate change in the mathematics classroom (Barwell, 2013). The focus of this paper is therefore on how controversies and teachers' value perspectives (can) influence teachers' facilitation of pupils´ critical mathematics perspectives.

CONCEPTUAL FRAMWORK – CONTROVERSIES AND VALUES

The field of CME is characterised by addressing social justice, the role of mathematics in society, and the importance of addressing how mathematics is used critically (Skovsmose, 1994). Nicol, Bragg, Radzimki, He, and Yaro (2017) explored different contexts for social justice and mathematics, including environmental ones, and found dialogue as a useful tool to engage with the discomfort and the potential controversies that can take place using such contexts. Atweh (2012) urged mathematics educators and researchers to include controversial topics in the classrooms. A controversial political issue is defined by Hess (2009, p. 37) as "questions of public policy that spark significant disagreement", and as open questions with many different and legitimate answers. In climate change, there are multiple controversies: Is there climate change? If yes, what are the causes (natural or anthropogenic factors)? What are the effects (on oceans, ice, weather, food, health)? What should be done about it (avoid emission or to cope with the impacts)? Who should bear the burden (rich vs poor country/people, polluter vs polluted)? To some of these questions there is a broad consensus by scientists, but in the public sphere and in politics they can be regarded as controversies. Including climate change in their teaching can therefore be challenging for teachers due to for example personal values or parents' opinions. Social context plays a role when deciding if a topic is controversial or not. In Norway, young people express positive attitudes towards reducing oil production. However, as a nation largely depended on the income from oil and gas extraction, this causes much debate and controversies among citizens and politicians. Yasukawa (2007, p. 10) claimed that CME

has the "potential to provide people with the skills and inclination to question how mathematical information and methods are created, presented and used to construct the social and cultural world in which we live". To enable pupils to do this, they must do more than "pure mathematics". A critical mathematics perspective can be connected to mathematical literacy, defined as "the capacity to identify and understand the role that mathematics plays in the world, make well-founded judgments, and use and engage with mathematics in ways that meet the needs of one's life as a constructive, concerned and reflective citizen" (OECD, 2003, p. 24). These competences go beyond calculation and formal methods, and can connect mathematics with topics like climate change.

According to Gray and Bryce (2006), many science teachers avoid political interests and values when teaching certain topics. In mathematics education research, several have argued for a more ethical and value-based teaching (e.g. Atweh, 2012). Values can have a range of perspectives in climate change, such as cultural preference for equitable division of resources, individual interests vs collective ones, and level of altruism. People that hold specific values interpret information accordingly, as shown in beliefs about climate change by democrats and republicans in USA (Corner, Markowitz, & Pidgeon, 2014). Ernest (2009) argued that human values play a significant role in mathematics education, which problems and concepts we include for example, and that any choice is an act of valuation. He elaborated on the values of absolutist mathematics and of the values of social constructivist mathematics, and claimed that a social responsibility of mathematics is needed. In this paper, we see values as a foundation for the perceptions of how we should behave in society, and values can be guidelines for how people view controversies such as climate change. The concept of reflective knowing is relevant when dealing with values and controversies. Skovsmose defined this as "the competence needed to be able to take a justified stand" (1994, pp. 100-101). This competence goes beyond mathematical literacy as defined by OECD, and includes an ethical dimension with norms and values. Reflective knowing can involve evaluation and discussion of potential social consequences of climate change from a mathematical perspective. Skovsmose emphasised, in addition to the ability to evaluate mathematical facts and scientific information, the ability to "receive outputs" and to "provide inputs" to the system (1994, p. 101).

METHOD – A RESEARCH PARTNERSHIP

The data for the overall project was collected through a one-year research partnership with a researcher from teacher education and three mathematics and natural science teachers from lower-secondary school. The research partnership was inspired by action research and a collaborative research agreement based on equity, respect, and dialogue was established. The teachers were invited based on the researcher's knowledge about their engagement with climate change issues, a strategical sampling. The data material consists of video recordings of seven partnership meetings and 42 classroom interactions, audio recordings of interviews with the teachers and the pupils, the pupils' and the teachers' written materials, and observation and field notes.

The teachers explored different ways to facilitate pupil's critical mathematics perspective in iterative loops. They let the pupils collaborate on real-life data from their own excursions and from local community issues, work with specific tasks in the classroom (e.g. calculating average), discuss graphs, make posters, and attend a climate change exhibition. The principal made the exhibition mandatory for the teachers and their pupils. The teachers made a quiz for the pupils to hand out to by-passers on the exhibition, but they chose to make different versions of two of the quiz-questions. This stood out as an opportunity for investigating the teachers' reflections on what seemed as potential controversies and different value perspectives.

The data was transcribed, coded, and categorised, patterns were identified and analysed, all by using NVIVO. The authors analysed emerging findings as a group and controversies and values were singled out. The teachers' quotes were checked with the coded material for consistency of perspectives. In the analysis, the focus is on two of the quiz-questions, on the multiple-choice answers the teachers made (in particular on the use of numbers and graphs), and on the teacher´s utterances in a succeeding discussion about the quiz and CME.

RESULTS AND DISCUSSION

The teachers expressed concerns on the mandatory exhibition, one being to engage pupils in an activity just before their final exams. They therefore chose to make a quiz themselves, and participate with a group of five volunteers from each class. According to the teachers, the intention with the quiz was to get the by-passers on the exhibition to reflect on climate change issues with fact-based questions. The quizzes had five questions, each with four possible answers, one correct and three distractors. Kim made five questions. Max then used three of the same questions but chose to replace two of them. The following two questions are one of Max's own questions and one of Kim's questions that Max chose not to use, both with the correct answers marked:

Max: How much sea ice was it in the Arctic in 2016 compared to a normal level?

a) □ + 10% b) □ equal c) □ -10% d) ☒ -36%

Kim: How much has the Earth's average temperature increased since 1998?

a) ☒ Almost nothing b) □ approx. 1°C c) □ approx. 2°C d) □ approx. 4°C

Both questions concern key topics in climate change: Max's question concerns sea-ice levels in Arctic, and the four alternatives, +10 %, 0 %, -10 % and -36 %, suggest both an increase and a decrease of sea ice. The correct answer, -36 %, is the most extreme choice. Kim's question concerns the global temperature, and the correct answer and the three distractors all suggest a small increase in the average temperature change. The correct answer, almost nothing, is at one end of the scale. Kim had included a graph on the backside of the quiz to justify the correct answer (Figure 1, graph on the left).

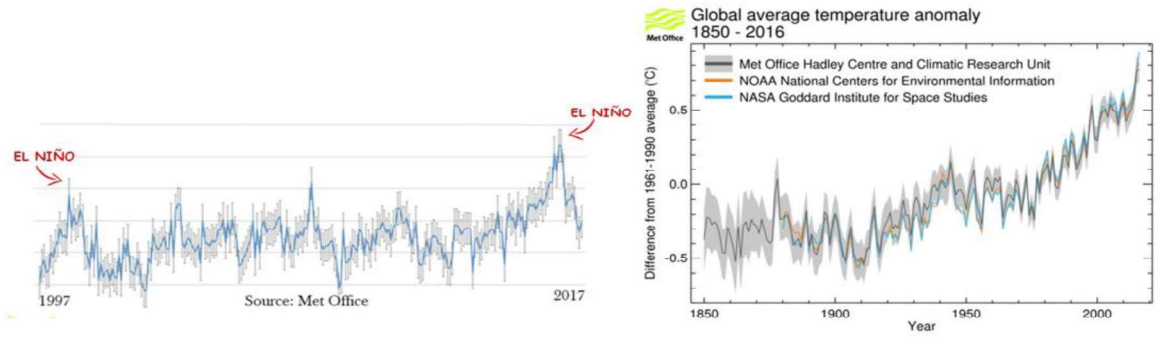

Figure 1: Two graphs showing global temperature. The graph on the left with a 1997-2017 time span, and the graph on the right with 1850-2016 time span.

Controversial aspects and value perspectives: the case of Max

The correct answer stands out from the three alternatives because it is not a round number, a multiple of ten, and by the difference between the alternatives (10 versus 26). Max elaborates on the intention of the question and the alternatives by saying: "so it is a bit to illustrate that it has changed … a lot." By the choice of numbers and by the way the correct answer stands out from the others, Max implicitly brings forward that the temperature has changed a lot. Location can be essential when discussing ice melting, while Artic experience an alarming ice melting, Antarctic is more status quo. When Max and Kim reflect on the sea ice question, the following dialogue takes place:

> Max: … so, maybe it is deliberately cheating when leaving out Antarctic, I admit that …
>
> Kim: Did you try to influence?
>
> Max: Yes, I did.

In the dialogue, Max refers to excluding Antarctic in the question as "cheating", followed by "I admit that". The wording reflects a confession, as if Max has distorted the facts. The utterance can reflect mixed feelings for the choices Max did, and Kim pursue this when asking if Max tried to influence. In the subsequent conversation, Max said that it would be crucial to include ice melting in other areas in a classroom interaction with pupils in order to give a more nuanced picture. The dialogue between the teachers clarifies the value aspect of Max' choice of question, and Max expresses that discussing the topic with others is enriching for own understanding and teaching. The value perspective, the wish to influence, occurs also in other statements by Max: "They should reflect, that is one aspect, but another thing I would like is that they should act … it is important that they make conscious choices about consumption." Max considers mere reflection as insufficient, pupils "should act" as well. This can be interpreted as a teacher's *facilitation of action*. Max's perspective relates to Skovsmose's reflective knowing and output-perspective in which reflective knowing is something more than just reflection. This perspective is also in accordance with how political guidelines promote a normative view by emphasising that pupils should believe in and take actions towards a sustainable development. When asked if and how climate change controversies can affect teaching, Max says: "I think it is important that ... in a

way, they also face this in school … that there are different views on things."

Controversial aspects and value perspectives: the case of Kim

Kim's argument for choosing the distractors for global average temperature, 1°C, 2°C, and 4°C, was to use common figures from media. Like Max, Kim chose to place the correct answer, "almost nothing", at one end of the scale. Although the distractors are commonly used, projections from the Intergovernmental Panel on Climate Change estimate a temperature increase in a range from 0.1°C to 0.3°C per decade (IPCC, 2007). Another reason Kim gave was: "I have tried to make questions that … where they get answers that they do not think is right, in a way. To get them to … oh, that was not what I expected." Exaggerated estimates of temperature change is a typical misconception in climate change (Gowda, Fox, & Magelky, 1997). The emphasis on making questions with unexpected answers to trigger pupils' reflection can be interpreted as Kim's aim to challenge the temperature misconception. Climate change is defined by a change that lasts for an extended period of time, and most scientist do not consider temperature increase as a controversial issue. What may lead to controversies is when someone deliberately uses short or very long time spans (thousands of years), to justify arguments claiming no temperature increase. When the teachers discuss the graph, Max comments Kim's reason for choosing the specific time span, 1998-2017:

> Max: But it was a reason why you chose 1989 and not 1889.
>
> Kim: Yes, yes, this is the last 20 years.

By saying that "it was a reason" why Kim chose 1989 and not 1889, Max challenges Kim's choice, and asking for a reason could uncover Kim's motive for choosing that particular time span. It can be questioned, as Max did, why the graph shows these years, and why Kim chose to use this graph. Giving attention to an overestimated temperature rise can indicate something about Kim's values. This is strengthen by the choice of words used for the correct answer: "almost nothing." Highlighting that the temperature rise is close to nothing can be understood as an attempt to reveal misconceptions and trigger pupils' critical reflection. However, the time span choice can also be understood as an argument against climate change. Kim later presented a graph with a longer time span (Figure 1, graph on the right). Using different graphs indicates that Kim is aware of the potential value-laden perspective of short time spans.

Kim highlighted controversies as important: "I emphasise all the controversies … I try to get the pupils to think. Let them form their opinion. And, I think climate change is an excellent opportunity to do this." Kim takes the position as a facilitator of discussions by getting "the pupils to think" and to "let them form their opinion". This can be interpreted as an emphasis on taking a neutral stand, to not reveal own opinion, and act more like a *facilitator of critical thinking*. Kim emphasises that the pupils should take a stop and reflect on the perceived reality, because the reality may not necessarily be correct. Furthermore, Kim emphasised pupils' ability to be critical with comments such as "they should be critical. A critical mathematics perspective, I hope they learn this. A lot of it".

CONCLUDING COMMENTS

In line with Ernest's (2009) argumentation for human values' influence on mathematics, we find that values and controversies in climate change can influence teachers' facilitation of CME. Max and Kim chose different questions to emphasise particular issues in climate change. While Max highlighted the extensive ice melting, Kim emphasised how small the temperature change was, and both used mathematics to do this. Their different questions and reflections reveal controversies and value aspects. Controversies is perceived as a challenge when teachers consider using climate change in mathematics education. Political guidelines and curricula can put teachers in a challenging and risky situation. Mathematics has traditionally been regarded as a neutral subject with little controversy. This can make it extra challenging to include wicked problems like climate changes in mathematics lessons. The tension between facilitating action versus critical thinking is revealed in the teachers' practise and dialogues. Max emphasises to enable pupils to understand causal relationships that empower reflected choices, by which they can act and create a better future. Kim emphasises to help pupils find their own answers and critically engage in how mathematics is used in argumentation. The teachers see themselves as agents with an important message. Facilitating action can be questioned if it promotes a political agenda with a desire to influence pupils' political standpoints. Facilitating the pupils' critical independent decisions, without revealing own viewpoint, may disclose that choosing certain graphs and numbers is not always neutral. We find that the teachers' question to each other made the controversies and value aspects more explicit. In our opinion, climate change is a major challenge that should be included in mathematics education, both in research and practice. Exploring how teachers find opportunities in the tension between facilitating action and facilitating critical thinking is crucial to address. We consider it as an opportunity, as well as a challenge, to engage pupils in wicked problem within the frames of the school context.

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