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The role of the mathematics teacher educator in supporting engagement with global issues in the mathematics classroom

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The world is in a period of rapid change. Climate chaos is leading to floods and droughts and exacerbating inequality. A recent global survey indicated a majority of young people are ‘very’ or ‘extremely’ worried about climate change. This paper asks, in such a context, what is the role of mathematics education and, in particular, what can mathematics teacher educators (MTEs) do, in supporting teachers who want to engage in bringing global issues into their teaching? I report on work taking place in one university in the UK where, for the last 6 years, MTEs have been encouraging teachers to address global issues in their classroom. One role which has emerged for a MTE is in supporting the translation of scientific work on climate change into classroom tasks. In the UK, the spaces for such work are being squeezed in an increasingly politicized education system. The lens of critical mathematics education offers a mechanism for reflection on the role of the MTE.

Keywords: Global challenges, climate change, learning to teach mathematics, role of the mathematics teacher educator, critical mathematics education.

Introduction

The effects of climate change, or the climate emergency, are visible across the world. The year 2021 has seen extreme weather in the form of tornadoes, droughts leading to wildfires, rainfall leading to unprecedented flooding and more. Mathematics is deeply implicated in climate change and other global issues, for example, in how events are communicated and how they are modelled. Mathematical models of climate, pollution, virus spread, the economy have real world effects and so mathematics is also implicated in the creation of some of the global challenges facing humanity. For instance, mathematical models of the economy, which place no value on materials before they are extracted, facilitate exploitation of natural resources and the depletion of environments which have historically sustained communities. A report on a survey, about to be published (but trailed in the media) by Caroline Hickman at Bath University, UK, looked at the views of 10,000 16-25-year-olds across 10 countries and found high levels of eco-anxiety: 60% of young people surveyed said they felt ‘very’ or ‘extremely’ worried about climate change. In such contexts, a mathematics education which continues its business as usual, in isolation from the world outside the classroom, seems increasingly jarring. This paper aims to investigate what mathematics teacher educators (MTEs) might do. What role might a MTE take, in working with prospective or in-service teachers, in order to support a re-thinking of the kinds of topics or discussions which take place in mathematics classrooms, to include global issues and challenges such as climate change? My way of approaching such questions is informed by critical mathematics education and I set out this perspective in the next section. I then report on work that has taken place over the last 6 years, at the University of Bristol, in the UK, in which MTEs have been working with teachers to encourage and support tackling global issues in the mathematics classroom.

Critical mathematics education

Critical mathematics education refers to work which brings insights from critical theory into the specific sphere of mathematics education. Andersson and Barwell (2021) offer a summary, that critical mathematics education: “is *driven by urgent, complex questions*; is *inter-disciplinary*; is *politically active and engaged*; is *democratic*; *involves critique*; and is *reflexive and self-aware*” (p.3, italics in original). This characterization says to me that critical mathematics education is particularly appropriate to a consideration of how issues such as climate change might be relevant to the work of a MTE. Global challenges such as the climate emergency, and other ecological disasters are certainly urgent and complex and inter-disciplinary. Addressing such questions as a MTE (in the UK) is a political statement since there is now a mandated curriculum for teacher education which is focused on the techniques and craft of teaching, with no mention, for instance, of our role in preparing citizens for a precarious future. And, as I hope to demonstrate in this paper, the use of critical mathematics education for MTEs can provide a tool for reflexivity.

Andersson and Barwell (2021) identify three broad schools of work within critical mathematics education (acknowledging that such divisions are a simplification): Freirean; Foucauldian; and a Nordic school. They characterize the Freirean school as focused on the use of mathematics for consciousness raising, for “reading the world”, in a way that draws parallels to Freire’s (1970) work on literacy as consciousness raising. Within this tradition there is often an explicit aim to challenge oppression and effect change (Gutstein, 2006). The Foucauldian school investigates the (often invisible) uses of the discourses of mathematics in the “organization of human affairs” (Andersson & Barwell, 2021, p.9), for instance, the way in which middle class assumptions about what constitutes child development can become accepted as what it means to be “normal”, or the way in which differences between girls’ and boys’ relations to mathematics are constructed (Walkerdine, 1988). In the Nordic school, Skovsmose (1994) explores the use of technology in society and argues for the need for students in school to not only be taught to do mathematics but also to critique how mathematics is used and how it gets embedded in technologies which have real social effects, such as algorithms for welfare payment distributions.

Perhaps surprisingly, there has been relatively little work linking critical mathematics education to issues such as climate change, with exceptions such as Renert (2011) and Barwell (2013); although this is a situation that now appears to be changing (e.g., Barwell & Hiis Hauge, 2021; Steffensen et al., 2021). There also appears to be little work bringing critical mathematics education into discussions of the work of mathematics teacher educators. This article brings both of these strands together. I do not adopt one particular school of thought within critical mathematics education but rather use the range of meanings in order to investigate evidence and possibilities for critical mathematics education in the role of a MTE. I use the broad characterization of the three schools of critical mathematics education as a set of ideas, offering opportunities for reflection and critique of the practices of MTEs. I will be reporting on a long-term project which is on-going at the University of Bristol. This is a project that embodies a process of curriculum innovation within our teacher education course and it has not been guided explicitly by ideas of critical mathematics education. In the next section, I offer a description of this project, before reporting on some of its outcomes via a reflection on three professional journal articles.

The Green Apple Project

The name “Green Apple” came from the internal funding scheme which helped kick-start the project in 2015 at the University of Bristol, UK. The funding was to support innovation in our 1-year teacher education course for secondary school, which leads to a Post Graduate Certificate of Education (PGCE). The idea was to support teachers bringing questions of global challenges into their subject teaching, or their work as form tutors (a pastoral role required of teachers in England). Two (or more) “Green Apple representatives” (reps) are recruited from each of the 8 subjects offered on our PGCE course and these reps meet with a group of teacher educators (including MTEs) on three occasions over the year. The reps are responsible for disseminating outcomes from meetings to the rest of their subject group. Meetings introduce reps to ideas (such as the framing of “wicked problems”, or of education for sustainable development) and allow time for discussion between and across subject groups and offer prompts for action between meetings. Classroom resources are shared and previous years’ work is available. Over the last 6 years, the project has introduced and run sessions with all prospective teachers, provoking thought on the role of global challenges in their subject teaching.

In order to present some of the outcomes of the project and to focus on the role of the MTE, I report here on three articles, which have been written by mathematics members of the Green Apple Project, and which have appeared in (or are soon to appear in) the professional journal *Mathematics Teaching*. These are the only publications from the group in a professional journal. In what I report here, I focus on the tasks offered in the articles, and reflect on the role of the MTE in each case, linking to ideas of critical mathematics education.

Sustainable futures, from 2018

Karl Bushnell wrote an article for *Mathematics Teaching* (Bushnell, 2018) based on resources he had developed and trialed for his own classroom. Karl had done his PGCE at the University of Bristol and taken an active role in the Green Apple project. The work he wrote about was conducted when he had taken up a job in a school near Bristol. Karl continued his Master’s in Education (with a specialization in Mathematics Education) at the University of Bristol and developed an approach to offering tasks which paralleled standard exercise questions, with questions that led students to answers which told them something about the global environment. An example is given in Figure 1, which shows the worksheet for students, involving a sequence of tasks leading them to calculate the sea-level rise that would be caused by the Greenland icesheet melting.

In Figure 1, tasks are paired, to have one question, or set of questions, with no context and one question drawing on the same skills but in the context of melting ice sheets. For example, the second task (top right of the sheet) has three prisms and asks students to find their volume. Then the prompt is: “Given that the global water [sic] surface area is 361,132,000 square kilometres, and using your answer to Question (1) [which was to convert 50 metres into kilometres], calculate the volume of water needed to cause a 50m rise in sea levels”. The final question invites students to write down their thoughts having done the calculations, i.e., to reflect on the implications of the predicted change.

The tasks were developed entirely by Bushnell, i.e., without direct MTE involvement. The role of the MTE, in the case of the work written up here, was one of supporting the raising of issues (via the Green Apple work on the PGCE course) and then subsequent support via a flexible Master’s

programme that allowed teachers to follow their own classroom interests. Bushnell was an engaged and passionate individual who took the initiative to continue to develop themes from the Green Apple project after he had left the PGCE course as a qualified teacher.

Melting Ice Sheets

1 Convert the following lengths into kilometres:
 a) 6000 m b) 450 m c) 125 m d) 90000 m
 Suppose that the ice sheets have melted enough to cause a 50 m rise in sea levels.
 Convert 50 m into kilometres.

2 Calculate the volume of each prism:
 a) $3\text{cm} \times 4\text{cm} \times 6\text{cm}$ b) $1\text{m} \times 4\text{cm} \times 2\text{m}$ c) $8\text{cm} \times 7\text{cm} \times 5.5\text{cm}$
 Given that the global surface water area is 361,132,000 square kilometres, and using your answer to Question 1), calculate the volume of water needed to cause a 50 m rise in sea levels.

3 Calculate the distance that a train travels in 20 minutes at 90 mph.
 What is the formula for calculating density?
 Calculate the mass of water needed to cause a 50 m rise in sea levels.

4 a) Calculate the density of a rod of aluminium that has a mass of 575.4 g and a volume of 210 cm^3 .
 b) Calculate the volume of a 770 g block made of brass which has a density of 8.67 g/cm^3 .
 Given that the mass of water is the same as the mass of ice, calculate the volume of ice needed to cause a 50 m rise in sea levels.

5 The cuboid container below is used to store boxes. Each box is a cube with side length 1 m. How many boxes can be stored in the container?
 The volume of an Olympic sized swimming pool is $2.5 \times 10^6 \text{ m}^3$.
 How many pools would be needed to contain all of the melted ice that causes a 50 m rise in sea levels?

Having completed this task, what are your thoughts?

FACTS!

Substance	Density (in kilograms per cubic kilometre)
Fresh Water	1×10^6
Glacier Ice	9×10^5

Our school is approximately 42 m above sea level.

As ice sheet is a mass of glacial land ice extending more than 50,000 square kilometres (20,000 square miles).
 The two ice sheets on Earth today cover most of Greenland and Antarctica.

Figure 1: A sequence of tasks calculating sea-level rise from the Greenland icesheet melting

This task, and the MTE support, do not appear to attempt to offer a critique of the mathematics being used (as in the Foucauldian or Nordic schools). The mathematics is presented as a neutral tool and the assumptions behind the model being used are not discussed, for instance. The MTE did not provoke questions about this neutrality, nor prompt reflection on possible links to social action, or oppressions which are entailed in the causes of sea level rise (e.g., consideration of the almost incalculable human suffering which would ensue). There seems to be an aim to raise consciousness (edging towards a Freirean idea); in the classroom task the aim is to raise consciousness of the consequences of the melting of the Greenland icesheet. And the MTE role appears to have raised consciousness, or awareness, for the teacher, of possibilities for the use of global challenges in mathematics teaching and allowed space for reflection on how this could be done, while also maintaining a focus on the curriculum that needs to be taught in secondary school.

Global challenges, from 2019-20

Across two articles (Brown et al., 2021 Part 1; Brown et al., 2021 Part 2) 9 prospective teachers on the PGCE course (in the 2019-20 cohort), supported by their 3 MTEs, each wrote about one task they had either created or found and then used (or planned to use) with classes they were responsible for in their placement schools. By this time, several years into the Green Apple project, global challenges were involved in one of the mathematics programme's Master's assignments on the PGCE course, and so every prospective teacher had to engage, in at least one lesson, with thinking about how to incorporate an issue such as climate change into their classroom teaching. I relay below 5 of the 9 tasks reported on across the articles. Two tasks began with simply stated challenges to provoke discussion, which then developed into more extended activity.

“How does a country's GDP affect a person's life?” (Part 1, p.9)

“How many trees could fit in this room?” (Part 2, p.9)

The other tasks got students doing some work or calculations that did not necessarily initially relate to a global challenge and then led into a key question. Here are three examples.

Based on data about incomes in England and Romania: “Which country has a bigger pay gap between male and female workers?” (Part 1, p.10)

Based on drawing paths and associated loci (to model a potential Covid transmission distance of 2m): “assess potential transmission points” (Part 1, p.13)

Having worked out the area of the school grounds and, based on aerial photographs of deforestation in Brazil: “find the area that had been cut down, and how many ‘areas of the school’ that this represented” (Part 2, p.11)

Several of these lesson ideas came from the prospective teachers’ engagement in their Master’s studies, where they had to plan a topic (around 5 hours of teaching) which involved at least one global challenge being addressed. For other teachers, these tasks were developed in response to a session given to all prospective teachers on the course, on Green Apple issues. The role of the MTE has shifted here, to one of mandating some exploration of global issues. As MTEs, having seen and been impressed by the work developed by these teachers, my two colleagues and I then proposed some joint writing. As MTEs we helped edit and structure the writing and supported its submission.

As with the previous example, these tasks, and the MTE support for them, appear primarily focused on consciousness raising (Freirean school) without perhaps drawing attention to the uses of mathematics (the Nordic school) and hardly pointing towards more Foucauldian questions around the organisation of society. In other words, the tasks appear focused on raising awareness of issues such as deforestation and the MTE role appears, as before, primarily focused on raising awareness of possibilities within the classroom. The write-ups of the tasks suggest wider implications about society, and links to social activism, were left implicit and that would also be true to say about the MTE support being offered (i.e., consideration of such wider issues was not prompted or provoked).

Climate science, from 2021

In early 2021, I began a collaboration with a scientist (Joseph Darron) from the UK Met Office, after this scientist was given a secondment of a day a week to work at the University of Bristol. Joseph’s research centres around questions of how climate models and statistics are communicated (e.g., to politicians). After a few months of intermittent discussions about making his research into something usable in the classroom, we invited a local partner school to see if they would like to join us. One teacher (Barney Rolph) volunteered and worked on adapting and trialing the tasks that we were developing. Barney had been on the PGCE course at the University of Bristol and been involved in the Green Apple group. The task Barney adapted to use in his classroom was the following (Coles et al., 2022, p.7):

Climate models are used to simulate the climate and predict changes. We will be focusing on models that can be used to predict how much wetter or drier a place might be in the future. There are different models, made by different scientists.

Botswana (in Africa) currently averages around 34mm of rain per month.

Here are 9 projections for the change in rainfall in Botswana (in mm per month) in the coming years:

+17; +13; +6; -2; -2; -6; -6; -6; -14

Your task:

Imagine you are an advisor to farmers in Botswana. You are going to prepare a written summary of this data advising farmers of future risks and changes to the climate. Think about different mathematical techniques that you have learnt that might help analyse and/or present this data.

In the article, Barney offers some of the response of his class to this prompt and further work he went on to do with them using climate data. The MTE role is quite different in this case, compared to the previous two. Here, the MTE acts as a conduit between a climate scientist and a teacher. As the MTE involved, I remember recognizing, in Joseph's presentation of his research, its classroom potential. The questions he was grappling with – to do with what the consequences are of different presentations of data for how they are interpreted – seemed like ones that students in schools could access. I also recognized that the data Joseph was using seemed accessible for quite young students and, in my experience as a teacher, it is not easy to find real data in a form that is suitable for a classroom.

The task here, in contrast to the previous ones, feels more aligned to the Nordic school idea of inviting reflection on the use of mathematics and how complex data might be summarized mathematically. And hence, I also interpret the MTE role in this case as provoking awareness of the use of mathematics. There may be elements of consciousness raising also, in the task and in the work of the MTE, but again little attention to wider societal questions and connections to possibilities for action.

Discussion

Having presented the work of the Green Apple project, as it has manifested in three professional journal articles, and offered a description of the role of the MTE in each case, I now summarise and then reflect further on these outcomes.

My aim in offering the work of the Green Apple project has been to allow reflection on the question: *What role might a MTE take, in working with prospective or in-service teachers, in order to support a re-thinking of the kinds of topics or discussions which take place in mathematics classrooms, to include global issues and challenges such as climate change?*

As alluded to above, I interpret the MTE roles in the first two cases as being most aligned to a Freirean perspective on critical mathematics education, with a focus on consciousness raising. However, having said that, compared to examples offered in Freire (1970), the roles of the MTE in these cases are relatively limited examples of consciousness raising. Nonetheless there is a linking of reflection and action, in the work of the teachers, to implement changes in their classrooms and a hope, on the part of the MTEs, that such work will continue into the future. The final example, of the MTE in the role of conduit or bridge building, edges into more of a Nordic school version of critical mathematics education, in raising questions about the use of mathematics in communicating data about climate change, and the huge uncertainty of current models (despite the certainty that change is happening).

Considering the second example, there seems to be a power in mandating engagement in considering global challenges, as part of a teacher education programme, and supporting further engagement of those who show interest by setting up and coordinating a co-writing opportunity. In the final example, the use of mathematics by politicians, policy-makers and scientists is beginning to be explored in the task, in contrast to the previous two articles.

In all cases, the Foucauldian school of critical mathematics education points to possibilities for the role of a MTE that were not taken. In Bushnell's work, a possible MTE provocation might have been to invite consideration (on the part of the teacher and/or students) of who is in danger from sea-level rise and where do they live? In the case of the 2019-20 writing, similar provocations might have been, who benefits from de-forestation? how fairly spread is a country's GDP? In the climate model scenario, again, we did not address questions of the impacts of drought or flood on different sectors of society. In a UK context it is unlikely such wider questions would be addressed in a mathematics classroom but, in reflecting on MTE roles not taken, these seem like potentially significant provocations for teachers, in forcing a consideration of how global issues link to the organisation of societies and the inequalities which are exposed by global forces such as climate change.

As demonstrated here, the three lenses of critical mathematics education offer a mechanism for recognising what is *not* being done, as a MTE. Questions I might ask myself (e.g., in planning to work with prospective teachers) from each of the different perspectives are:

What are the global challenges that teachers I am working with care about? What tasks and mechanisms (e.g., as part of a teacher education course) can I offer, to support them acting on their interests, in their own classrooms? (a Freirean perspective).

When does mathematics teaching reinforce, or remain silent about, inequalities embedded in the wider organisation of society? Do I call attention to such absences? What might teachers' lived experiences of inequality be and what sensitivities will be needed to explore this (e.g., the space and safety to express reactions and know they have been heard)? (a Foucauldian perspective).

In any context of mathematics teaching (including my own), do I invite reflection on the uses of the mathematics being learnt? Can I link with a professional, who is working on a global challenge, and explore the reality of their use of mathematics? How might I make resources available for teachers in a form that provokes reflection on the uses of mathematics? (Nordic school).

Despite the developments evident over the six-year period of the Green Apple project, I am left with a sense that the resources developed by teachers and the related work of MTEs remains on the margins. The tasks developed seem to represent likely one-offs in the teachers' practices. Similarly, for the MTEs, a mandated "core content" of initial teacher education precludes any sustained focus on global challenges and hence support for such work also has a "one-off" feel.

For both teachers and MTEs there are demands that are hard to ignore (exam success of their students, for the teachers; and, prospective teachers passing a teaching qualification, for the MTEs) both of which, in the UK, pull away from a focus on global challenges. So, although I have provided some answers to my question about what are possible roles of a MTE in supporting such work, I am struck by the limited nature of the roles I have been able to embody, in comparison to the complexity and

depth of the issues facing the planet, and amidst a politicization of educational decisions in the UK that, to take one example, mandates against discussion of “anti-capitalist” perspectives in schools.

One thought that sustains me, however, is that we are developing MTE practices, roles and resources to support a curriculum-in-waiting. COVID has shown how rapidly changes can be made in education systems. Over the six years of the Green Apple project I have sensed prospective teachers increasingly wanting to work on inter-disciplinary and global issues, through the lens of their subject teaching. I suggest that critical mathematics education offers a ready, and perhaps untapped, set of resources to help MTEs think about possibilities for transformation in their roles and practices and, one hope I have is that prospective and in-service teachers will increasingly demand for such change.

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