Report from the Sustainability Working Group: Developing a Research Agenda

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The Sustainability Working Group is being convened to discuss how to integrate sustainability issues with the teaching and learning of mathematics. The aim of the group is to share perspectives on a range of research questions, and to develop collaborative research on sustainability in mathematics education. The group is open to all. In this article, I explore some potential issues for a research agenda.

Keywords: sustainability, climate change, mathematics, teaching, learning, teacher education, curriculum, critical mathematics education, practice, systems, social justice.

Introduction

The first meeting of the Sustainability Working Group (SWG) was not a great success: only I attended. However, several members of BSRLM have expressed interest in research on sustainability in the context of mathematics education, a significant number of teachers and students are working with mathematics on sustainability topics in schools, and there is a nascent literature developing. So SWG will meet again at the BSRLM conference in June 2012.

The discussion issue for the first meeting was developing a research agenda for sustainability in mathematics education. I outline in this report ways in which I think sustainability is a research issue for the mathematics education community. I am conscious that this reflects my personal priorities. I am at an early stage in my career as a researcher, and so unaware of many historical themes and current trends in research. I look forward to learning about these, and other people's ideas and understandings about research perspectives and priorities, either at the next working group session or in personal correspondence (nichola.clarke@nottingham.ac.uk).

Sustainability issues and learning mathematics

Learning about sustainability can be considered an issue for whole school action (e.g. when a school organises paper recycling, or discusses and implements measures for reducing water consumption), as a subject in its own right (e.g. a non-curriculum day to learn about sustainability issues) or as an issue to be taught in existing subject lessons. In whatever context students learn about sustainability, mathematics seems an embedded part of the activities: quantifying, measuring, modelling. On the one hand, students might use their existing mathematics knowledge, skills, and practices to learn about sustainability issues. On the other hand, sustainability issues might be a context through which students learn mathematics. In learning about issues such as water pollution, energy efficiency, and urbanisation, there may be a breakdown of traditional subject boundaries (e.g. between science and mathematics, economics and mathematics, or geography and mathematics). Some questions that the SWG might consider are thus:

(1) What mathematics do students need to understand and be able to use if they are to engage in powerful learning about sustainability?

(2) How can students best learn the mathematics they require to understand sustainability issues?

(3) What values and principles inform our choices of the mathematics involved in teaching about sustainability?

The science and mathematics of climate change is not simple. Although basic principles such as the greenhouse effect can be explained in lay terms, communicating in more depth requires some mathematical, scientific and statistical sophistication. This raises a question about accessibility:

(4) Which parts of the mathematics and science of sustainability and climate change are accessible to students, at what stages of learning?

Sustainability topics

There has been some development of resources for teaching about sustainability and developing understanding of mathematics in mathematics lessons. For example, resources for cross-curricular teaching of mathematics and science have been developed in COMPASS, an EU funded Comenius project (2011). COMPASS resources include teaching units on car pollution, biodiversity, solar energy, water shortages, and the impact of severe weather. They are intended to engage students in cross-curricular inquiry and modelling. Charities and NGO projects also provide some teaching resources. For example, Bowland Mathematics (2008) has a case study on water availability, and the World Wildlife Fund (WWF/Allfrey, 2001) has some resources on oil spills.

The mathematical and pedagogical quality of existing resources varies, though. Some internet resources I have found did not seem to have much potential for mathematics learning. For example, there were some tasks that involved repeated use of the four basic operations on very large numbers extracted from "real" data.

Production of high quality resources for learning about sustainability involving mathematically challenging tasks is thus a possible context for a design research initiative:

(5) To design high quality materials for use in teaching sustainability in mathematics lessons.

(6) To evaluate materials for learning about sustainability in mathematics lessons.

Critical mathematics education

Climate change and the human impact on climate change are not controversial topics in the scientific community (Barwell 2010, 193). However, this level of agreement is not reflected in public discussions of climate change and sustainability. One purpose of educating students to understand the causes and consequences of climate issues is to provide a basis for participation in democratic debate about political and personal action.

Brown and Barwell (2011) problematise the idea that mathematical models *tell* us what is happening. The subjective stance does not emerge only when consumers of information use what they have learned about mathematical and scientific facts. Mathematical models, journal articles, and grey literature disseminating research are also perspectival, having been created by people within some discourse community.

Thus Barwell (2010) argues that a central role of mathematics education is to enable students to engage with the information presented critically, "supporting future citizens to be critical about their consumption (or production) of the media". Taking a critical mathematics education perspective (Skovsmose 1994), he argues that students need to learn not only to understand given information about sustainability, but enough mathematics and science to engage critically with debates about social choices and change. This is a problematic issue for democracy, with consequences for mathematics education.

> (7) What mathematical understanding is required to enable students to participate in democratic decision making?

It thus seems possible that we will need to change the focus of the mathematics curriculum to develop students' practices of evaluation and interpretation.

Reflecting on Barwell's use of critical mathematics education as a lens raises another question:

> (8) What methodologies and theoretical perspectives might usefully inform research, teaching and learning about sustainability in mathematics education?

Agentive problem solving

So far, I have discussed learning content knowledge about sustainability, and developing some mathematical practices such as representation and justification, in the critical use of knowledge in decision-making. Responding to the consequences of climate change may require a deeper change in mathematics learning. From knowledge of climate change, we know that environmental and social change is coming, but we do not know the nature of the changes that will occur (Brandt 2009; Clarke 2012). We are thus educating young people to meet uncertain future demands.

> (9) How can we best equip students to deal with uncertain and evolving social, economic and environmental conditions?

It may be that to educate young people to meet uncertainty, we should prepare them to be flexible and creative problem solvers. In mathematics education, we might broaden the curriculum focus from content and skill to include more on application of mathematics, evaluation, collaborative problem solving, modelling, representation and communication. These skills will equip young people with abilities to choose and develop mathematical and other tools to work on novel contexts.

Prioritising problem solving is not necessarily about enabling some students to engage in high-level technical activities. Scientific and mathematical models do not determine how we should act in the face of environmental change. Varying and nevertheless rational human choices will depend on our individual, social, cultural, locally contextualised desires and values, and on our abilities to use available tools and technologies (Brandt 2009; Clarke 2012).

However, becoming a problem solver may require more than a change of content. Lave (1988) argues that knowledge is produced in situations, and so is to be thought of not as a representation in an individual mind, but a set of culturally developed practices into which students learn to participate. Knowing is thus dependent on the social relationships, cultural locality, and the language resources available. Perhaps problem solving behaviour, and creative engagement with novelty, is something to be mentored and apprenticed into, rather than knowledge to be transmitted.

This would not be a trivial change. Rodd (2002, 2) points out that in many classrooms, mathematics is experienced as a body of already established, abstract knowledge about which there is no debate, and which belongs to experts. Learning mathematics is thus only a process of acquiring that existing knowledge of rules and procedures. Enabling problem solving in a broad sense would seem to involve changing social relationships and pedagogy. How we know, and how we come to knowing are inseparable from what we know: practices in learning profoundly influence what is learned.

Sustainability in mathematics education as a professional development issue

The different forms of potential curriculum change identified above raise questions about teacher learning in ITE and CPD contexts. From conversations with colleagues, I am aware of developing individual and team activities to help beginning teachers teach about sustainability in mathematics lessons in ITE in various university contexts. I am not aware of co-ordinated work in this area, though. I am not aware of any current sustainability in mathematics CPD. Teacher learning is thus another potential area of enquiry.

(10) How do [teachers] learn and teach about climate change issues?

(11) What initiatives are being/have been developed to integrate sustainability issues into (university centred elements of) Initial Teacher Education programmes? How can teacher educators best learn from each other?

(12) What ways of engaging teachers with sustainability issues best help them develop their practice in teaching about sustainability and in working sustainably?

An example of learning about how to better understand and support teacher learning on sustainability issues was seen in the COMPASS project. Wake (2011) and his colleagues noticed difficulties teachers experienced as they worked with cross-curricular materials. A new construct, ‘bridging concept’, was developed. This is a tool for thinking about concepts that occur in mathematics and science curricula but with different meanings. For example, the concept of *flow* is discussed as a measure in mathematics, and as a model to explain phenomena in science. The professional development issue for designers was how to enable teachers to work together on flow, given these differences in understanding.

Social perspectives on teacher education

Some professional development initiatives take a *top down* approach to teacher learning. Teachers are provided with knowledge and asked to implement externally identified changes in practice. (Consider, for example, the delivery of teacher learning on the National Numeracy Strategy.)

From a critical mathematics education perspective, professional development is recast as a co-operative endeavour. Agentive teacher learning involves reviewing research methods, and conducting research in collaboration with trainees and school participants, rather than *on* them. For example, the LIMA toolkit for professional development involves teachers in generating and sharing knowledge and practices appropriate to their own needs whilst taking into account developing understandings in research.

This raises a new sustainability issue: stewardship of resources.

(13) What are the differences in impact on teacher practices between "top-down" and collaborative, "bottom-up" models of professional development?

(14) Is "bottom up" teacher learning more sustainable?

Positioning teachers as active participants in research practices also links with the issue of students as active problem solvers. I suggested that given climate change, students might need to learn to become agentive problem solvers. Creating a milieu in which teachers are active learners about their own practices seems to chime well with students participating in active problem solving. If students are to be agentive and flexible problem solvers, they need not only to be *taught* that content, they need to experience adults as creative agents, and participate in problem solving behaviour.

These ideas are very underdeveloped. I link two separate contexts: teachers as active agents in developing classroom practices, and students solving mathematical problems. Moreover, the idea of students as active problem solvers involves an abstraction from particular practices that does not sit easily with Lave's ideas of socially developed and contextually embedded behaviours.

Sustainability and systemic change

Renert (2011) mentions how current educational systems perpetuate an unsustainable industrial modernist model of growth. Noyes (in press) argues that the time scales of various levels of system change (e.g. national government policy, examination board, school) are different. As a result, the implementation of initiatives cannot become established before new initiatives are introduced. This precludes valid evaluation of new initiatives.

Current English systems for developing and implementing curricula (and associated teacher learning) seem to be driven by party politics: each time the government changes, there seem to be new initiatives, driven by a different set of values. The system appears unsustainable: it involves poor stewardship of the energies and abilities of human participants and of the physical resources available. Part of the research agenda for mathematics educators working on sustainability might thus be to explore more sustainable systems in mathematics education.

(15) What models of curriculum and teacher development are available from other national contexts?

(16) What would a system for the sustainable development of mathematics education look like?

To make systems in mathematics educational more sustainable, we might, for example, consider models for incorporating diversity of values (Sandel 1998, MacIntyre 1984, Sen 2009), so as to enable evolutionary change with higher levels of mathematics educator participation.

Conclusions

It might be asked why BSRLM members should consider sustainability, given all the other intractable issues mathematics education research faces. This is a good question. I feel that sustainability is the defining issue of our age. Change is coming, for better or worse, as a result of converging problems of water, soil, population and biodiversity depletion (Wilson 2002). I hope that the Sustainability Working Group will be a medium for professional conversations about sustainability and mathematics teaching and learning, in classroom, professional development, and systemic contexts. I would like to work on this as part of a community of enquirers, to meet the challenges that we, and previous generations, have set for future generations. To paraphrase Jimmy Carter (1980):

> The choice, the choice between the two futures, could not be more clear. If we succumb to a dream world then we'll wake up to a nightmare. But if we start with reality and fight to make our dreams a reality, then [we could] have a good life, a life of meaning and purpose in a [world] that's strong and secure.

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