Working Group Reports

Report from the Sustainability in Mathematics Education Working Group: Task design

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The Sustainability in Mathematics Education Working Group discusses research on how to integrate learning about climate change and sustainable living with the learning of mathematics. In the third group meeting, participants from Denmark, Greece and the UK focused on the design of cross-curricular tasks for the simultaneous learning of mathematics and sustainability issues. We drew on examples of task design experiences from Greece and the UK.

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

Introduction

In this third meeting of the Sustainability Working Group, we explored some of the particular features of designing tasks for learning mathematics whilst also learning about climate change and sustainable living. We considered some of the ways in which producing cross-curricular tasks might raise particular issues for a task designer. We took advantage of the three national contexts represented in the meeting (Denmark, Greece, UK) to consider the ways in which local context can inform what and how students learn about sustainable living, climate change, and mathematics. Our discussions in this session stemmed from elaboration of two examples of tasks designed for learning about sustainability issues whilst learning the mathematics outlined below. The initial foci for discussion were drawn from the research agenda set in the first working group (Clarke 2012):

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

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

The Euro-Axio-Polis Game

Chionidou-Moskofolou, Moskofolou, Liarakou and Stefos (2011) have designed a game with fourth year education students engaged in initial teacher education practice at the University of the Aegean. The game is called Euro-Axio-Polis. This is a board game aimed at 6th grade students, in which pupils make spending decisions in small groups, stimulating whole-class discussion about mathematical calculation techniques and the effect of repeated percentage changes, but also stimulating argument about difficult social choices. Designed with education students, this project also helps beginning teachers embed teaching about sustainability in their practices.

The mathematical content of the task includes calculating percentage changes, using interest rates, repeated percentage change, and manipulation of large numbers in a money context. The mathematical practices in which students engage include attending to others' actions, turn taking, understanding others' calculations, and justifying and explaining their own calculations. The sustainability context of the game is making difficult economic choices given scarce resources, and choosing between actions with different ecological and economic impacts. The pupils are learning about the types of choices faced in their political context, and become aware that social choices are based not just in economic constraints, but are based in values.

Clarke's *virtual water* tasks

Clarke (working with a science teacher and environmentalist, Michael Sparks) is developing a sequence of tasks on the measure of *virtual water*. This is a concept developed by Allan (2011) to make sense of the amount of embedded water used in production of goods and services. Clarke works with schools engaged in sustainable living projects to help them embed sustainability in classroom curricula. The sustainability focus of these whole-school actions is food security and urban growing. Clarke also works to promote mathematical learning about sustainability in out-of-school contexts.

Clarke claims that if students are to learn how to live sustainable lives in response to constraints imposed by climate change, they need good understanding of scaling relationships (Wake 2011). Scaling is especially import because students need to notice that small personal changes they as individuals might choose to make, if adopted by large numbers of people, could have large impact. Scalings work (potentially) across time, from individual at a time to cumulative individual action, and also from individual to group actions. Students need also to gain a sense of the relative effect of the different scalable actions they might engage with. Sustainability contexts thus afford important learning opportunities on proportional reasoning.

The tasks on virtual water also afford learning about measures and quantification. Often, the measures used in work on sustainability are complex, involving averages, and combinations of averages. These defined measures need to be explicated as part of students' learning. Clarke uses the context of virtual water to develop students' understanding of devising and critiquing measures.

The virtual water context also affords work on sustainability: understanding the effects of scalable actions on the amount of actual and embedded water used, and the way water is imported and exported in virtual form. This helps students to make sense of the impact of choices they make about water use. Students also learn to engage in sustainable practices, by identifying resource use and considering alternative choices of action, based on their use of their measures and their own personal values.

Clarke linked her work to some research questions raised in the report of the first working group (Clarke 2012):

> What mathematics do students need to understand and be able to use if they are to understand everyday life choices about sustainable living?
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> How can students best learn the mathematics they require to understand everyday choices linked to sustainability issues?

> What values and principles inform our choices of what mathematics to teach and how to teach it to students, to help them learn about living sustainably?
>
> Which parts of the mathematics and science of sustainability and climate change are accessible to students, at what stages of learning?

She argues that much of the science and mathematics of climate change is complicated: basic principles such as the greenhouse effect can be explained using school mathematics and science, but communicating in more depth requires greater mathematical and scientific sophistication. However, if the reality of climate change is accepted (and this is the current scientific consensus) there are different choices to be made between actions. The mathematics about those choices can appear simultaneously too simple (scaling) and too complex (large and very small numbers; complex measures) for use in schools. Nevertheless, students need to be taught to engage with this type of value-laden estimation task, and to use and critique such measures as a central part of learning to live sustainable lives.

Discussion

We spent some time discussing the role of values in the tasks presented to students. In both Chionidou-Moskofolou et al.'s game and in Clarke and Sparks's scaling tasks, students are presented with choices between possible actions. Their mathematical work shows different resources use consequences of choices, with different economic and social impacts. In neither case did the authors intend that the choice on offer was false, and students were to be constrained to a particular form of (environmentally preferable) action. The designers were trying to avoid 'moral' overtones in those choices, by giving real options linked to different viable sets of values, raising awareness of resource use rather than condemning one set of choices.

The task designers were thus not intending that students learned the 'correct' choice to make. Rather, part of what students are being offered is the opportunity to engage in public discussion of a plurality of values that inform different choices, and the practice of justifying choices and values to others. What blurs the issue is the need to offer particular alternative forms of action in the tasks: those choices are clearly informed by the designers' own values and their intentions to produce constructive argument.

The group agreed on the importance of developing negotiation and argumentation skills, given the complexity of many of the environmental choices to be considered. For example, although a food might have relatively low virtual water content, its embedded energy costs might be high. Making judgments about incommensurable resources requires consideration of values, not just mathematics (Brown and Barwell 2011 discussed in Clarke 2012).

The group discussion also explored the different educational contexts within which tasks were being offered. Partanen described the Danish schools context, in which there is a requirement that students address green issues in school learning. Parrish and Clarke described the shifting educational and political contexts of the UK, and differences between school subjects. This raised research questions: Why do some teachers choose to teach about sustainability in the context of mathematics lessons? Why do others choose not to? What impact do national and school policies have on teacher choices?

Chionidou-Moskofoglou and Moskofoglou developed discussion of local context. They outlined the relevance of the Euro-Axio-Polis Game to the Greek national context. The game engages students in thinking about large-scale economic decisions. These might be argued to lack realism since all the numbers are initially rounded to the nearest hundred thousand Euros, the percentages are neat integer values, and school children do not really make these types of economic choices. However, Chionidou-Moskofoglou et al.'s research findings show that students were nevertheless highly engaged with the game and many argued passionately, perhaps as if the decisions were real for them (Chionidou-Moskofoglou et al. 2011). The hard economic decisions being made in Greek politics have impact on students' lives, through cuts, unemployment, and national debt. This perhaps makes national economic decision-making a "live question" (Peirce 1877) for Greek children.

Similarly, Clarke described how children in Lancashire and Hong Kong schools who are engaged in growing projects raised questions about planting arrangements, water use and crop yields. Those students are raising what for them are "live questions". Since those students raise issues there is no need to make assumptions or guess what (all) young people want, in an attempt to design a task that is relevant or real, because the crop production work of the group of students provides them with relevant mathematics in a truly shared context. That context works for those students, but would not necessarily work for others; the same is true for economic decision making in the Greek students' context. We thus began to develop a sense of the importance of localism in task design for teaching about mathematics and sustainability, perhaps reminiscent of Lave's discussion of the difference between abstraction and generality (Lave 1988). However, this also raises the problem of which mathematics can be made a "live question" for which students.

Conclusions

Exploring issues drawing on three different national contexts allowed us to share experiences of working on sustainability in mathematics lessons. We opened up possibilities for tasks, task designing, and research on the efficacy of tasks, and considered working together to explore topics and share the load of designing tasks, identifying potential difficulties for teachers. We considered the value of large-scale contexts and how to attend to the importance of different locally-live issues whilst drawing on (abstract) mathematics. We agreed to continue our discussion online, and a literature review was suggested as a topic for the next working group meeting in the UK.

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