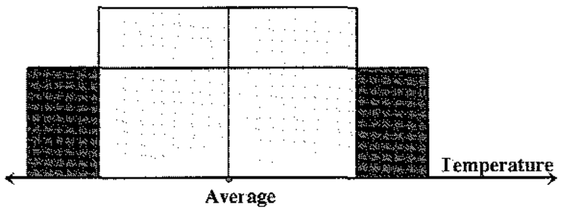

Figure 2. Simplified representation superimposing increased variability in in temperatures

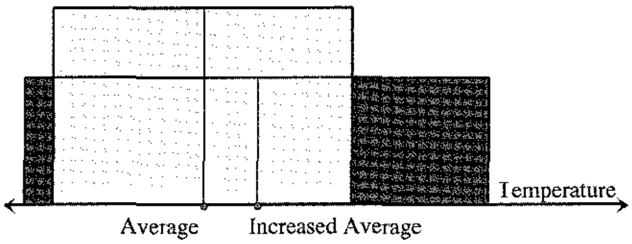

Figure 3 Simplified representation superimposing increased variability in temperature plus increased average temperature to generate more events at both extremes, but many more extreme heat events

(including qualitative visual reasoning) would be a big shift in the current curriculum. Many mathematics undergraduates (and future teachers) still think of formulae as the primary representation of functions, as I know from recent classes Representation via formulae worked for Euler, but it will not work for us with these problems

Here is a very simple example of "visual modeling" of the frequency of extreme events in the climate (the statistics of weather) The representations shown in Figures 1-3 are designed to support reasoning about how global warming could generate many more extreme hot events *but also* some more extreme cold events, with modest increases in mean temperature [2] Figure 1 is a very simplified visual representation of the variety of temperatures over a year. The second image (Figure 2) superimposes what the weather distribution would look like if the model gives a wider variation of weather, with the same average temperature.

The third diagram (Figure 3) superimposes a new distribution, with the wider variation plus an increased average temperature. What may seem as contrary evidence (more extreme cold events) becomes part of a larger visual comparison that can be further adapted to investigate patterns with more complex distributions. Similar changes in distribution can be explored for other extremes such as in rainfall (*i.e.*, drought and flood). Using visual representations as the initial model makes the discussion "reasonable" (one about which we can reason).

Reliance on modeling, with its corresponding uncertainty, is a factor in debates about the regulation of DDT, acid rain, tobacco smoke and secondary smoke, depletion of the ozone layer, and now CO_2 loads and climate change. In the recent book *Merchants of Doubt,* the authors, Naomi Oreskes and Erik M. Conway (2010), describe several decades over which key people have worked to prevent any form of regulation on all of these issues, in part by questioning the science (and mathematics) of predictions based on modeling and by contesting any decisions made under these stochastic characteristics (uncertainty).

The development of the capacity to assess information emerging from modeling, with a described range of uncertainty, and to still make decisions within this context is a task that cannot happen without effective mathematics education Developing this capacity is also essential in a culture that often interprets "likely" as a synonym for "do I want it to happen"! I look forward to richer examples and more pointed discussion within the mathematics education community.

Notes

[1] AAKKOZZLL: chance, statistics and a new paradigm: www.aakkozzll.com Note the pronunciation of the site name is 'acausal'.
[2] These images are simplified and adapted from Weaver (2008, p 8).

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Now it concerns us! A reaction to Sustainable Mathematics Education

UWE GELLERT

The third millennium has come with a remarkably increased awareness of ecological dynamics triggered by the way we live on earth. Sustainability appears as a new key concept for thinking and acting Do we need a Sustainable Mathematics Education? If so, what could Sustainable Mathematics Education look like? I will briefly comment on the not-so-altruistic nature of the sudden concern for sustainability before arguing that the political and sociological dimensions of the relationship between mathematics, technology and society are fundamental to an "ethic of mathematics for life" (Renert, 2011, p. 25).

The catastrophic side effects of industrial production and increasing consumption have always been part and parcel of economic growth during the last century. The catastrophes have been more visible when abrupt, *e.g.* the disasters of Bhopal or Chernobyl of Fukushima, although the pollution caused continuously by major and minor raw material plants in Latin America, Africa and Asia may have caused even more damage to individuals and the environment This destruction of life and lifeforms has not directly affected all those who have profited most from the outsourcing of the side effects: the joyfully consuming North American and European middle class But now, the maintenance of the consumer lifestyle is no longer guaranteed. The awareness of the finite nature and instability of fossil fuel supply and of the possible effects of overpopulation is like a Sword of Damocles hanging over us Damocles learnt his lesson well and decided to willingly do without the luxuries - and without the threats that go with those luxuries What lesson do we need to learn? And how can mathematics education contribute to that lesson?

One aim of Critical Mathematics Education is the deconstruction of the formatting power of mathematics (Skovsmose, 1994). For at least 5000 years, mathematics, technology (including social technologies) and society have been closely connected in the regulation of our social, political, economic and ecological existence The power of mathematics has been described through the notion of an increasingly mathematised society: as our social and technological reality is based on mathematics, mathematics seems to be the best (and only?) means to improve or repair the social and technological conditions of that reality (Gellert & Jablonka, 2007; Keitel, Kotzmann & Skovsmose, 1993) New social, technical, economic or ecological problems consequently call for new mathematics to improve our perception, control and regulation of the problematic situation. However, thinking of mathematics only as a powerful tool for solving economic problems is a truncated conception of mathematics-in-society For example, the International Mathematical Union has declared 2013 as The Year of Mathematics of Planet Earth And the International Commission on Mathematical Instruction has commented: "We need to remain aware that effective Mathematics and Mathematics Education are necessary in order to protect our planet, our lives, and our futures " Accordingly:

> high-school teachers need to demonstrate that there is mathematical modeling and algorithms behind water resource management and hydrological forecasting; behind energy generation, preservation and allocation; behind weather prediction, fluid dynamics, forecasting extreme events (tsunamis, hurricanes, earthquakes) and risk management; behind analysing complex systems (like transportation and finance); behind understanding epidemic spread and virus infections; and behind ecological conservation. (ICMI News 16, February 2011)

That sounds great, though such statements run the risk of overlooking the fact that most of the technologies that contribute to excessive use of natural resources, pollution and the like are mathematics-based, as is military technology. As Jablonka (2003) argues:

> Mathematics and science are the core of those disciplines that originally were considered as a basis for social advance which is linked to liberation from moral constraints. [...] As long as mathematics is not conceived as intrinsically linked to destructive technological developments, the problem is viewed only as one of control over the fields to which it is applied. (p. 87)

The mathematics of exploitation was rather simple in former times when the value of the life of a drudge was disregarded by those extracting huge quantities of, for example, silver on behalf of the colonial powers The mathematics of exploitation has become increasingly complex. What are included as factors in the mathematical models nevertheless remains an issue of power. In search of a mathematics education as a democratic forum, Keitel, Kotzmann & Skovsmose (1993) call for reflective thinking that includes questions such as: "What are the general implications of pursuing [a problem] by formal means? How does the use of algorithms influence our perception of (a part of) reality? [...] What is the general role of mathematics in our society?" (p. 272) These questions seem to be at the very core of any mathematics curriculum critical to modernist conceptions of growth.

To calculate the ecological advantage of a vegetarian over a carnivore diet might in fact increase ecological awareness Such a sustainable mathematics education looks like the ecological equivalent to "radical maths" with its social justice focus (Frankenstein 1989) If the call for a sustainable mathematics education includes a critical questioning of the relationship between mathematics, technology and society, and if it does not reduce mathematics to a remedy and an answer, then this mathematics education has the potential to break with many myths about mathematics and to reconcile the mathematics educator's task with the desire to act in an ecologically sustainable way

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