ASE Presidential Address: The role of science education at a time of climate crisis and the sixth mass extinction

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Abstract Back in 2011–2013, when the current version of the National Curriculum was being drawn up, the members of the Science Working Party were told by civil servants not to include climate change. One hopes that this would now be unthinkable. What should we be doing in school science, at primary and secondary level, given the increasing importance of anthropogenic climate change and extinctions? Is it enough to help build learners' knowledge and understanding or should we be helping them take action?

Background

This article is based on the Presidential Address that I gave at the 2024 ASE Annual Conference at the University of Northampton. That was the final of my three Presidential lectures and there is a link between them. The first, in 2022, was titled 'Science education: understanding, engagement and social justice' and looked at the aims of school science education. The second, in 2023, was titled 'Science education at a time of existential risk' and looked at whether school science education had a role to play in addressing such existential risks as asteroid impacts, pandemics and nuclear war. My final lecture was titled 'The role of science education at a time of climate crisis and the sixth mass extinction' and this article presents a more fleshed-out version of what I had time to say in that lecture.

Aside from that background, there are two rather more important ones. The first, of course, is that we are in the early stages of what is increasingly being referred to as the Anthropocene, a geological epoch that dates from the commencement of significant human impact on Earth's geology, landscapes, atmosphere and ecosystems. The other background is to do with changes to school science education. Such changes generally happen quite slowly – and I happen to think that this is appropriate for a number of reasons, including the fact that too rapid a change can fail to bring along the majority of teachers (cf. Bapty, 2023). Nevertheless, they do happen and in England, in the rest of the UK and in other countries, the next few years are likely to see increasing questions about how school science should respond to climate change and biodiversity loss. In the UK it seems likely that a general election in 2024, whatever the result, will lead to changes to the science National Curriculum and its associated assessment.

The climate crisis

Whether or not people accept that we have a climate crisis – and there are plenty of people who do not (e.g. Figure 1) – objective data increasingly indicate that the climate is changing, mainly as a result of human activity, and changing more rapidly than it has since humans evolved a few hundred thousand years ago. At present, global warming is occurring about ten times as rapidly as after each of the eight Ice Ages that have occurred over the last 800 000 years (NASA, 2023). Climate change manifests itself in global warming, sea level rises (Figure 2), increasing acidification of the oceans (Figure 3), extreme weather events and some less-expected phenomena. For example, it is increasingly accepted that earthquakes are becoming more frequent as a result of anthropogenic climate change.

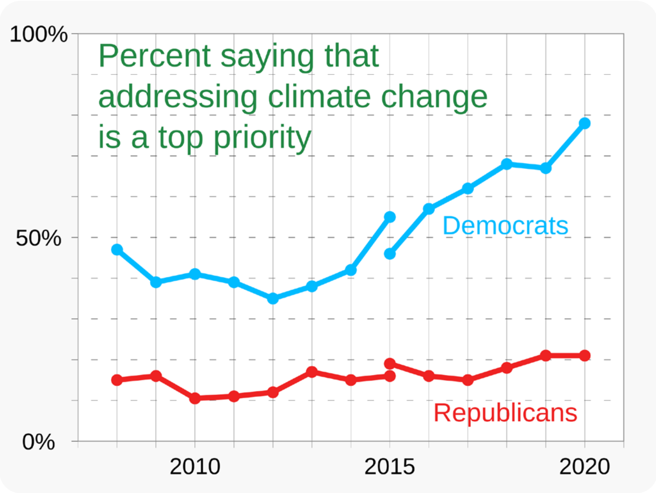

Figure 1 Percentage of US survey respondents with Democratic or Republican membership/leanings saying that addressing climate change is a top priority (2008–2020); question changed from 'global warming' to 'climate change' in 2015; image by RCraig09 licensed under CC BY 4.0

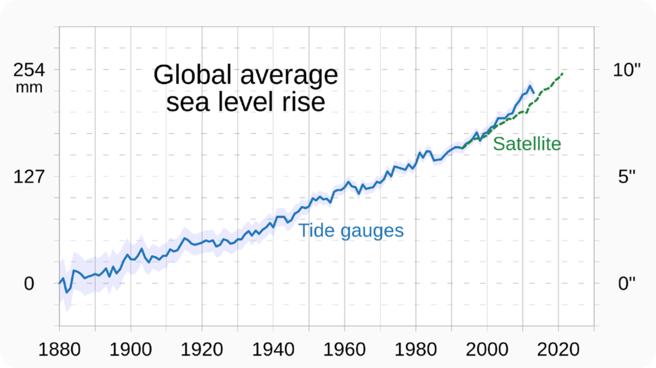

Figure 2 Sea levels are rising as a consequence of global climate change; image by RCraig09 licensed under CC BY 4.0

A rapidly changing climate does not necessarily indicate that there is a crisis but the consequences of climate change are already apparent and getting more severe. It is important to emphasise that not all consequences of climate change are deleterious. For example, a recent major review using data from 2000–2019 concluded that a little over five million human deaths each year are associated with 'non-optimal temperatures', accounting for about 9.5% of all deaths (Zhao *et al*., 2021). About 8.5% of all deaths are cold-related and 1% are heat-related. As a result, global warming might reduce such deaths. However, cold-related deaths are decreasing and heat-related deaths are increasing, so at some point global warming may contribute to a direct rise in temperature-related deaths.

Global warming and other manifestations of climate change have a wide range of deleterious consequences. Disappearing glaciers and increasing droughts result in water shortages. Rising sea levels lead to more flooding and the eventual possible disappearance of some island nations. Changes to rainfall patterns result in both droughts and floods. A range of adverse health consequences result from changes in the distributions of animal vectors of disease. It is possible that anthropogenic climate change will contribute to more wars and political instability over water and food shortages. And so on.

And this is only to summarise the consequences for humanity. The consequences of climate change for other species are far greater. To give just one example, '*Climate change is the greatest global threat to coral reef ecosystems*' (National Ocean Service, 2023). Coral reefs are possibly the most biodiverse ecosystem on Earth; occupying less than 1% of the ocean floor, they support about 25% of all known marine species. Rising temperatures result in coral bleaching (Figure 4) and increase the likelihood of disease outbreaks. Falling pH levels reduce reef calcification rates. In addition, sea level rises increase sedimentation, more frequent and stronger storms directly damage reefs, and changes

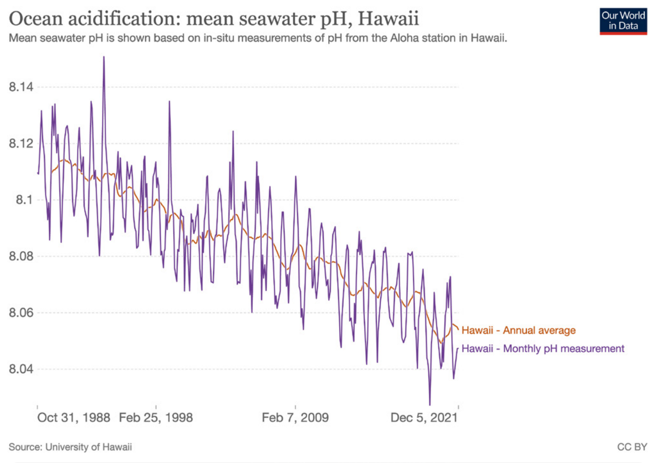

Figure 3 Ocean acidification: mean seawater pH from Hawaii; image by University of Hawaii licensed under CC BY 4.0

to ocean currents can result in decreases in food supply and larval dispersal.

This rather dismal account of the consequences of climate change for biodiversity leads into a consideration of the broader effects of human activity for life on our planet.

The sixth mass extinction

I am an evolutionary biologist by background, and the person to whom I am married was a palaeontologist. I need to acknowledge, therefore, that species extinctions occur naturally and have ever since life evolved. Geologists recognise five so-called 'mass extinctions' (Bond and Grasby, 2017; Ritchie, 2022). These mass extinctions are defined as times when 75% or more of all species are thought to have gone extinct over what is to a geologist a relatively short period (typically less than two million years!).

There may have been one or more mass extinctions during the pre-Cambrian and early Cambrian

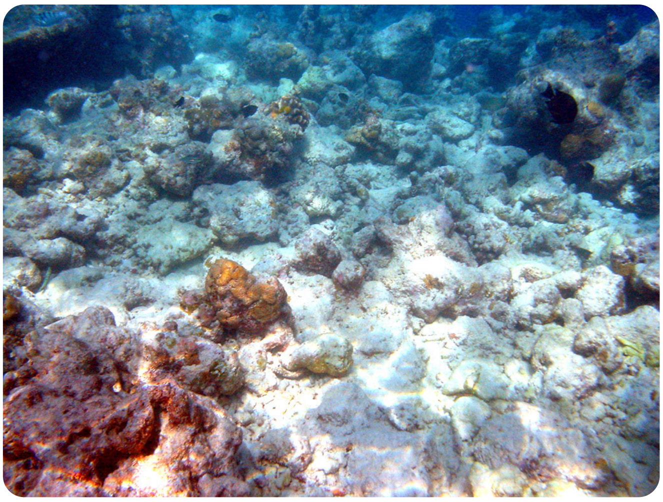

Figure 4 A part of Moofushi's bleached coral reef in the Maldives, damaged by warming sea temperatures; photo by Bruno de Giusti licensed under CC BY 4.0

but there are not enough data to be sure, so the first recognised one took place at the end of the Ordovician (about 443 million years ago). An estimated 86% of all species went extinct, probably as a result of global cooling, reduced sea levels and ocean anoxia. In the Late Devonian (about 360 million years ago), an estimated 75% of all species went extinct as the rapid growth of land plants caused a substantial fall in atmospheric CO_2 concentrations with resulting global cooling. The most extreme mass extinction occurred at the end of the Permian (about 250 million years ago) when fully 96% of all species are thought to have gone extinct. The cause was intense volcanic activity that raised atmospheric CO_2 and H_2S levels, resulting in global warming, ocean acidification and acid rain. At the end of the Triassic (about 200 million years ago), 75% of all species are estimated to have gone extinct as underwater volcanic activity caused global warming and major changes in the oceans. Most famously of all, the Cretaceous ended (about 66 million years ago) with an asteroid impact in present-day Yucatán, Mexico. This caused an estimated 76% of all species to go extinct as rapid cooling killed many species, including all animals with a mass of more than about 25 kg, so all the dinosaurs except for the small ones that gave rise to today's birds.

It is often said that we are living through the sixth mass extinction. We may be soon – but we haven't got to it yet if we accept the standard definition of 75% or more of all species going extinct. Precisely how many species have gone extinct as a result of human activity is unclear and probably varies considerably from taxon to taxon. A major review of mollusc extinctions (molluscs are the second largest animal phylum in terms of known species) concluded that since about 1500 CE, possibly as many as 7.5–13% (150 000–260 000) of all ~two million known species have already gone extinct (Cowie, Bouchet and Fontaine, 2022).

We may not yet be in a sixth mass extinction but a 7.5%–13% loss of mollusc species is a terrifyingly high figure in only 500+ years, and one that is bound to get far worse. Estimates of how today's overall extinction rate for all taxa compares to the background rate are hard to make with any confidence. A highly cited 2015 review concluded: '*Even under our assumptions, which would tend to minimize evidence of an incipient mass extinction, the average rate of vertebrate species loss over the last century is up to 100 times higher than the background rate*' (Ceballos *et al*., 2015: 1). Another study also published in 2015 concluded that current extinction rates for terrestrial plants and animals '*are 1,000 times higher than natural background rates of extinction and future rates are likely to be 10,000 times higher*' (De Vos *et al*., 2015: 452).

Biodiversity loss is about more than global extinction: it includes local wildlife loss and the loss of genetic diversity within species. I have lived in the same Cambridgeshire village for a little over 40 years. When we moved there, I regularly saw or heard cuckoos, swifts, bats and hedgehogs. I have not seen or heard any of these species in the village for years. I remember on my honeymoon a few miles away the number of arable weed species that could still be found. For some reason I seem not to have kept my usual nature diary at that time but none of the more interesting plants that we saw are found there now. These various animal and plant losses have resulted from habitat loss, climate change and the use of more 'effective' agricultural pesticides.

The role of school science education

Given this somewhat dismal litany, what should the role of school science education be? Debates about the aims of school science education are perennial, particularly in the West (Mansfield and Reiss, 2020). Here, I look at five issues: powerful knowledge; the nature of science; interdisciplinarity within science; other subjects; and ethics, values and actions.

Powerful knowledge

The term 'powerful knowledge' is especially associated with the name of Michael Young. Michael is a colleague of mine at UCL Institute of Education and a former secondary chemistry teacher, so it is not surprising we agree about rather a lot of things in education. Nevertheless, we are occasionally positioned as disagreeing fundamentally, since, while I have emphasised the value of considering *human flourishing* as the ultimate aim in education, Michael has emphasised the importance of schools providing *powerful knowledge*. In reality, the two approaches need not be in opposition (Reiss, 2018). Michael's key point can be summed up in his own words: '*the main function of school … is to enable all students to* ***acquire knowledge*** *that takes them* ***beyond their experience***' (Young, 2014: 10), '*experience*' here being understood to include the knowledge that students acquire from their families, peers and other extra-school sources, such as mass media.

Much of school science education is, and in my view should be, precisely about acquiring such powerful knowledge. Many people have a smattering of general knowledge about such fundamental scientific concepts as evolution, acids and electricity. At best, such knowledge is sufficient for the everyday, but it is scientific knowledge that is powerful. This is particularly evident when it comes to arguments against anthropogenic climate change. Many readers of *School Science Review* will have come across such arguments as '*The Earth's* *climate is always changing and this is nothing to do with humans*', '*Computer models which predict the future climate are unreliable and based on a series of assumptions*' and '*It's all to do with the Sun – for example, there is a strong link between increased temperatures on Earth and the number of sunspots on the Sun*'. None of these arguments should be ridiculed but they are all misleading (Royal Society, 2008). One would hope that by the time students had completed their compulsory school education, they would have learnt enough to know why mainstream science rejects such arguments.

The Nature of Science

School science in the UK has had a long history of practical work. In the 1970s and 1980s, this was complemented by an increasing emphasis in some courses on the value of what was then often referred to as the history and philosophy of science. These strands came together in England, Northern Ireland and Wales in the first version of the National Curriculum as Attainment Target 1 'Exploration of science' and Attainment Target 17 'The nature of science'. Joan Solomon, who had been a member of the original National Curriculum science working party chaired by Jeff Thompson and had previously participated in the ASE's 'Science In a Social CONtext' (SISCON) project, responded with her customary enthusiasm by editing a series of excellent booklets on *The Nature of Science* (long out of print but all of which can be downloaded from STEM Learning – see *Useful links*).

As is well known, the nature of science is less well represented in the National Curriculum now than it was back in 1989. Nevertheless, there are good reasons for believing that it would be wise to strengthen it in the next version. There is greater recognition internationally now than there was then on the value of inducting students into the practices of science – something that can be done before children start school (Tunnicliffe and Gkouskou, 2020; National Academies of Sciences, Engineering, and Medicine, 2023) and continued with them throughout their school science career.

Science's fundamental claim for its significance is that it is the way to develop a robust understanding of the material world. The last decade or two have seen something that I had not expected – an increasing number of people in countries with a strong tradition of school education rejecting some of the central findings of science. With colleagues, Jonathan Osborne has argued for the importance of school science tackling issues to do with misinformation (Osborne *et al*., 2022). One of the questions Osborne and his colleagues ask is '*what can be done by scientists and science educators to develop the competency to evaluate scientific information and expertise?*' In answering this and other questions, they draw a number of conclusions, one of which is that:

> *it means that teachers of science must go well beyond the lab activities which 'prove' again that Mendelian genetics, Newtonian mechanics, or the patterns of the periodic table are warranted. What the student needs to know is what justifies a belief in climate change, the efficacy of vaccines, or the drug that their mother takes to reduce blood pressure.* (Osborne *et al*., 2022: 39)

We need an education that helps students understand how scientists practise science, including the role of modelling in hypothesis testing and theory generation. This would help students to understand better whether the future of climate change is likely simply to be a linear progression from the present or entail tipping points, for example to ocean currents, in which there are sudden changes that can only be reversed over very long periods of time.

Interdisciplinarity within science

A really good understanding of climate change and threats to biodiversity requires a good understanding not only of biology, chemistry and physics but of how these scientific disciplines interact. Interdisciplinarity is not greatly helped by the present structure of the National Curriculum in England, Northern Ireland and Wales, which favours separate teaching for the three subjects. In addition, the science National Curriculum has almost nothing, beyond a bit on rocks and soil, that falls within the scientific discipline of earth science(s). Despite a small number of earth science educators consistently and enthusiastically arguing for the place of earth science in the science curriculum (e.g. King, 2001; Balmer, 2021), the low representation of earth science in the National Curriculum means that topics like climate change suffer. I am not calling for earth science to be a fourth science discipline in the school curriculum, given as much curriculum time as the other three sciences, but we do need some ways of ensuring that students can get a rich and balanced science education, one that includes more earth science.

Other subjects

Climate change education is not only the preserve of science. At my own institution, our Centre for Climate Change and Sustainability Education has produced professional development modules for teachers in geography and history (at both primary and secondary level) that can be accessed free online (see *Useful links*). That geography has a role to play in climate change and sustainability education is hardly surprising: it can be argued that physical geography is as much concerned with climate change as is science, while human geography is obviously well placed to consider the influence on humans of climate change and biodiversity loss and to explore how these vary depending on place and inequalities.

Perhaps the place of history in climate change and sustainability education is less obvious. Yet there is a move in history education for the introduction of 'environmental history' (Hawkey, 2023), for history to start far further back in time, not with the invention of writing, some 5000 years ago or even, as the present history National Curriculum does, with the Stone Age (which started about 10 000 to 8000 years ago in Britain) but back to the origin of humans themselves, a quarter of a million years or so ago. That would mean that school history would cover the time of the first anthropogenic extinctions, somewhere between 200 000 and 100 000 years ago, when the first megafaunal (animals with a mass of more than 100 lbs) extinctions occurred. Indeed, by the end of the Pleistocene, some 12 000 years ago, humans had probably caused the extinction of almost two-thirds of the world's megafauna vertebrates '*including short-faced kangaroos, marsupial lions and giant monitor lizards in Australia, and mastodons, ground sloths and glyptodont armadillos in the Americas*' (Turvey and Crees, 2019: R982).

School history is also well placed to deal with more mainstream historical events. Take the so-called 'Little Ice Age' (Figure 5). This lasted from about 1400 to 1850 and a series of Frost Fairs were held on the River Thames, with the first in 1608 and the last in 1814. As is evident from Figure 5, the extent of the cooling was quite modest compared with today's warming. Nevertheless, the consequences were considerable (Wikipedia, 2023). Farms and whole villages in the Swiss Alps were destroyed by encroaching glaciers in the mid-17th century. Agriculture suffered and the rise in Europe of witch hunts and antisemitism has been linked to the need to find people to scapegoat.

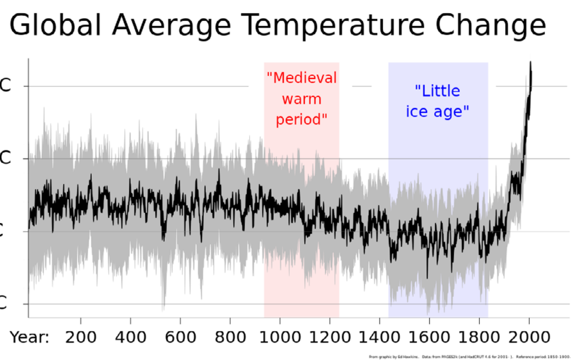

Figure 5 Temperatures in the so-called Little Ice Age; image drawn by RCraig09 from a graphic by Ed Hawkins licensed under CC BY 4.0

Ethics, values and actions

To what extent should science education include consideration of ethics and values and should it ever advocate action? I have long argued that there is much to be said for school science education including ethics and values (Reiss, 1999; McCrory and Reiss, 2023). However, there are also arguments against the inclusion of these in school science (e.g. Donnelly, 2002). For example, many science teachers may feel that they do not have the training in moral philosophy that their colleagues in religious education or philosophy have, or that a careful consideration of such issues would mean that there was less time for them to teach core science. In addition, while many students enjoy discussing ethical issues, not all do. My personal conclusion is that while there is a place for ethics and values in school science, these should not take up a great deal of a science teacher's time.

Finally, should school science education ever advocate action in relation to anthropogenic climate change and biodiversity loss? In the enthusiastic aftermath of COP26 in Glasgow, the Department for Education produced a draft strategy on sustainability and climate change for the education and children's services systems (DfE, 2021). An updated version has recently been published (DfE, 2023). This retains much of the aspirations of the earlier document. For example, it states:

> *Practical opportunities to participate in activities to increase climate resilience, reduce carbon impact and enhance biodiversity will enable children and young people to translate knowledge into positive action to improve their local communities, their country and the planet.*
> (DfE, 2023)

By government standards, this is fairly radical, though it needs to be read in conjunction with government documents about the need for political impartiality in schools (DfE, 2022) where, for example, it states '*It would not be appropriate for a teacher to suggest that pupils join a certain campaigning group or engage in specific political activity, for example, an upcoming protest*' (DfE, 2022). We shall have to wait to see to what extent such aspirations are reflected in changes to the National Curriculum, in examinations overseen by Ofqual and in Ofsted inspections. Nevertheless, there are reasons to be hopeful for the role that school science education can and will play at a time of climate crisis and the sixth mass extinction.

References

Balmer, D. (2021) The value of short Earth science continuing professional development for trainee primary school teachers. *Geoscience Communication*, **4**(1), 33–41.

Bapty, H. (2023) Must introductory genetics start with Mendel? Lessons from two unsuccessful attempts to revise the genetics curriculum. *Science & Education*, **32**(6), 1677–1708.

Bond, D. P. and Grasby, S. E. (2017) On the causes of mass extinctions. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **478**, 3–29.

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M. and Palmer, T. M. (2015) Accelerated modern human-induced species losses: entering the sixth mass extinction. *Science Advances*, **1**(5), e1400253.

Cowie, R. H., Bouchet, P. and Fontaine, B. (2022) The Sixth Mass Extinction: fact, fiction or speculation? *Biological Reviews*, **97**(2), 640–663.

De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R. and Pimm, S. L. (2015) Estimating the normal background rate of species extinction. *Conservation Biology*, **29**(2), 452–462.

DfE (2021) *Sustainability and Climate Change: A draft strategy for the education & children's services systems*. London: Department for Education.

DfE (2022) *What you Need to Know about Political Impartiality in Schools*. https://assets.publishing.service.gov.uk/media/61f137688fa8f5058a4b2f44/6.7731_DfE_Political_Impartiality_Guidance_Pamphlet_WEB__004_.pdf

DfE (2023) *Sustainability and Climate Change: A strategy for the education and children's services systems*. www.gov.uk/government/publications/sustainability-and-climate-change-strategy/sustainability-and-climate-change-a-strategy-for-the-education-and-childrens-services-systems

Donnelly, J. (2002) Instrumentality, hermeneutics and the place of science in the school curriculum. *Science & Education*, **11**(2), 135–153.

Hawkey, K. (2023) *History and the Climate Crisis: Environmental History in the Classroom*. London: UCL Press.

King, C. (2001) The response of teachers to new subject areas in a national science curriculum: the case of the earth science component. *Science Education*, **85**(6), 636–664.

Mansfield, J. and Reiss, M. J. (2020) The place of values in the aims of school science education. In *Values in Science Education*, ed. Corrigan D., Buntting C., Fitzgerald A. and Jones A. pp. 191–209. Cham: Springer.

McCrory, A. and Reiss, M. J. (2023) *The Place of Ethics in Science Education: Implications for Practice*. London: Bloomsbury.

NASA (2023) *How Do We Know Climate Change Is Real?* https://climate.nasa.gov/evidence/

National Academies of Sciences, Engineering, and Medicine (2023) *Rise and Thrive with Science: Teaching PK-5 Science and Engineering*. Washington, DC: The National Academies Press.

National Ocean Service (2023) *How Does Climate Change Affect Coral Reefs?* https://oceanservice.noaa.gov/facts/coralreef-climate.html#:~:text=Climate%20change%20leads%20to%3A,to%20the%20smothering%20of%20coral

Osborne, J., Pimentel, D., Alberts, B., Allchin, D., Barzilai, S., Bergstrom, C., Coffey, J., Donovan, B., Kivinen, K., Kozyreva. A. and Wineburg, S. (2022) *Science Education in an Age of Misinformation*. Stanford, CA: Stanford University.

Reiss, M. J. (1999) Teaching ethics in science. *Studies in Science Education*, **34**(1), 115–140.

Reiss, M. J. (2018) The curriculum arguments of Michael Young and John White. In *Sociology, Curriculum Studies and Professional Knowledge: New perspectives on the work of Michael Young*, ed. Guile, D., Lambert, D. and Reiss, M. J. pp. 121–131. Abingdon: Routledge,

Ritchie, H. (2022) *There have been Five Mass Extinctions in Earth's History*. https://ourworldindata.org/mass-extinctions

Royal Society (2008) *Climate Change Controversies: A Simple Guide*. https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2007/8031.pdf

Tunnicliffe, S. D. and Gkouskou, E. (2020) Science in action in spontaneous preschool play – an essential foundation for future understanding. *Early Child Development and Care*, **190**(1), 54–63.

Turvey, S. T. and Crees, J. J. (2019) Extinction in the Anthropocene. *Current Biology*, **29**(19), R982–R986.

Wikipedia (2023) *Little Ice Age*. https://en.wikipedia.org/wiki/Little_Ice_Age

Young, M. (2014) Knowledge, curriculum and the future school. In *Knowledge and the Future School: Curriculum and Social Justice*. ed. Young, M. and Lambert, D. with Roberts, C. and Roberts, M. pp. 9–40. London: Bloomsbury.

Zhao, Q., Guo, Y., Ye, T., Gasparrini, A., Tong, S., Overcenco, A., … and Li, S. (2021) Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study. *The Lancet Planetary Health*, **5**(7), e415–e425.

Useful links

Nature of Science (STEM Learning): www.stem.org.uk/resources/collection/2903/nature-science

Professional development modules in geography and history: www.ucl.ac.uk/ioe/departments-and-centres/centres/centre-climate-change-and-sustainability-education/teaching-sustainable-futures

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