ASE Presidential Address: Science education at a time of existential risk

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Abstract Quantitative measures of human wellbeing, such as child mortality, the percentage of people in absolute poverty and the percentage of children who have no education beyond primary level, suggest that, globally, things are getting better for people. But what of existential risks from asteroid impacts, climate change, artificial Intelligence, genetically modified organisms, pandemics, nuclear war and ecosystems collapse? How much of a risk are these to humanity and should school education address such risks?

Background

This article is based on the Presidential Address that I gave at the 2023 ASE Annual Conference in Sheffield. I hope this allows me to start by being personal. I grew up in London in the 1960s and early 1970s. A bookish schoolboy, I did my A-levels early in applied mathematics, pure mathematics, chemistry and physics and went up to university to read physics. Within ten days I realised I wasn't a physicist; it was simply that I had been taught almost all the physics I ever learnt by a superb teacher, Colin Harris, who had inspired me to think that I too could read physics at university. I quickly changed to biology and soon fell in love with it. I stayed on at university and did a PhD on evolutionary biology and population genetics, focusing on red deer, and then did a post-doc.

While doing my PhD and post-doc I had taken advantage of the fact that Cambridge encouraged postgraduate students to supervise undergraduates in small groups of two or three. I soon discovered that I found this very satisfying. As my post-doc drew to a close, I decided, rather at the last minute, to apply to do a PGCE and was fortunate to be accepted. My PGCE year was in 1982–83; I joined the ASE in 1982 and have been a member ever since.

Is the world getting better or worse?

Looking back on it, for the first four decades of my life, I rather unthinkingly presumed that things were getting better for humanity. My parents and their generation had lived through the Second World War and there was clearly a widespread, albeit generally unspoken, presumption that never could anything like that be allowed to happen again. However, since the dawn of the millennium, I have become less optimistic about the future. Even before we get to the existential threats to which I turn below, there are reasons for concern. For example, democracy, which had made huge advances internationally during my childhood and early adulthood (think the fall of the Berlin Wall and the ending of many dictatorships in Europe, South America and elsewhere), feels as though it is increasingly in retreat. And while medicine continues to make great advances, there are gathering storms from such things as antibiotic resistance, mental health issues and problems resulting from the diets that many of us consume.

A number of authors, however, argue that things are getting better for humanity, indeed are better now than they ever have been (e.g. Pinker, 2018; Rosling, 2018). These arguments tend to follow the same form. Numerical data are presented on graphs, where the horizontal axis indicates the date – e.g. from 1800 to 2015 – and the vertical axis indicates some quantitative measure of human wellbeing, such as child mortality, the number (or percentage) of people in absolute poverty, the number (or percentage) of children who have no education beyond primary level, and so on. A good selection of such graphs (e.g. Figure 1) can be viewed on

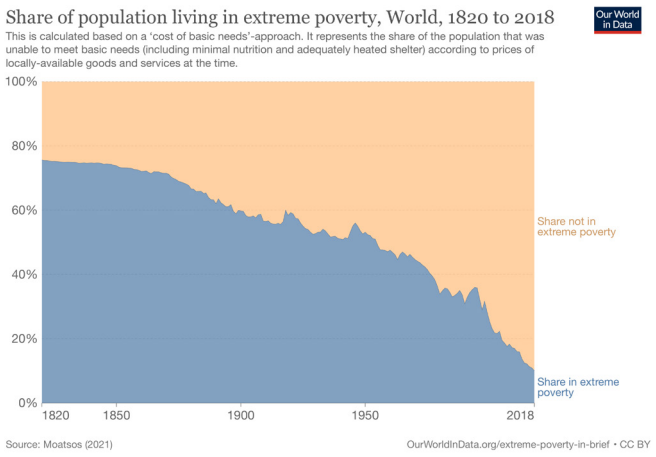

Figure 1 An example of a graph intended to show how things are getting better for humanity (source: *Our World in Data* https://ourworldindata.org)

the *Our World in Data* website (see *Useful links* below), which currently has some 3580 charts. The general message seems to be that we should stop complaining and do something to help those less fortunate than ourselves.

One response to these claims that things are getting better is to point out that there can be something of a disconnect between these apparently objective measures and the frequent subjective experiences of individuals. No one, for example, is against falls in poverty but it is possible for poverty to fall while income or wealth inequalities are rising and the consequences of such inequalities can be surprisingly widespread and negative. In their book, *The Spirit Level: Why More Equal Societies Almost Always Do Better*, Wilkinson and Pickett (2009) argue (graphs, again) that greater inequalities are associated with falls in such measures as physical health, mental health, happiness, trust and social mobility, and with rises in such measures as obesity, drug misuse, under-age pregnancy, violence and crime. Furthermore, these rises and falls are overall, that is, not just among those who are losing out in terms of relative income or wealth. The argument is that societies would do well to reduce inequalities.

Comparable points can be made about most of the other measures that are paraded to show us that things are getting better. Take life expectancy, for example. Over the last century or so, life expectancy has increased greatly across the globe, in part a result of improved sanitation and agriculture, in part a result of improved medicine, and also in part a result of other technological advances (in communications, transport and so on). However, (a) these increases in life expectancy are currently stalling or even reversing in many countries, only partly, but not entirely, as a result of the COVID-19 pandemic, and (b) it is not the case that greater longevity necessarily equates with greater happiness or life satisfaction. Many people do indeed live longer than they would have done in the past but they live longer in poorer health. In many countries we do not deal well with the final phase – which may last many years – of our lives (e.g. Gawande, 2014).

A second response is that these claims that things are improving are fine so far as they go but that we are living at a time when there are far greater threats, often referred to as existential, not only to humanity but often to other species too. It is these threats that are my principal focus.

Existential threats

An existential threat is one that is believed to be capable of preventing continued existence. Perhaps because this tends to suggest apocalyptic fictional literature and films (think the long history from such books as Mary Shelley's *The Last Man* and *Frankenstein* through H. G. Wells' *The Time Machine* and *The War of the Worlds* to more recent offerings such as the films *Bladerunner*, *The Terminator* and *The Matrix* and their sequels, and *Interstellar* and *Snowpiercer*), it can be difficult to take such threats seriously. In any event, it is well known that humans are not very good at understanding and dealing with risk (e.g. Adams, 1995).

Nevertheless, there are a growing number of organisations and academic thinktanks devoted to existential threats, including the University of Cambridge's Centre for the Study of Existential Risk, the University of Oxford's Future of Humanity Institute, Stanford University's Existential Risks Initiative and the Future of Life Institute, a non-profit organization with the mission statement '*Steering transformative technology towards benefitting life and away from extreme large-scale risks*' (see *Useful links* below). In addition, there are the beginnings of serious philosophical examinations of these threats (e.g. MacAskill, 2022) to back up existing work, which is largely scientific and technological.

In no particular order, I now go on to examine seven possible existential threats: asteroid impacts, climate change, artificial intelligence, genetically modified organisms, pandemics, nuclear war, and ecosystems collapse.

Asteroid impacts

Of all the possible existential threats, an asteroid impact might sound the most like science fiction and there is a fictional film genre that starts with *When Worlds Collide* (1951) and *The Day the Sky Exploded* (1958) and goes through to *Don't Look Up* (2021). Except that, as is widely known, it is likely that it was the impact of an asteroid 10–15 km in diameter some 66 million years ago that led to the mass extinction event that ended the Mesozoic Era. It is thought that around 75% of all animal species went extinct as a result, including all non-bird dinosaurs, indeed all animals with a mass greater than about 25 kg (Osterloff, 2020).

There is a growing academic literature on the threats to Earth from asteroid impacts – see Sokolov *et al.* (2020) and also Pultarova (2020), which has the apt title 'Predict, deflect, survive – How to avoid an asteroid apocalypse: asteroid impacts are the only natural disasters that can be predicted but also avoided …'. It is still somewhat unclear both how much a threat such impacts are and to what extent we will be able to prevent them. What is clear is that such impacts happen. In 1908 an asteroid or comet thought to be about 30 m in diameter exploded above ground in Tunguska,

Figure 2 A 1929 photograph showing damage caused by the Tunguska asteroid impact in 1908 (source: https://commons.wikimedia.org/wiki/File:Tunguska_Ereignis.jpg)

Russia (Figure 2). The explosion has been calculated to be about 1000 times more powerful than the explosion of the atomic bomb over Hiroshima. Fortunately, it happened in a remote part of Siberia and no one is thought to have been killed, although 80 million trees were knocked over (The Planetary Society, 2023).

Climate change

Few readers of *School Science Review* will be unaware of the threats posed by climate change, including global warming. I am old enough to remember, when at school, a *New Scientist* article that talked about the possibility of global cooling. There were two reasons why global cooling was thought a possibility in the 1970s, even though it was already known that atmospheric levels of CO_2 and other greenhouse gases were increasing. One reason was simply that we are currently in an interglacial – indeed, on the law of averages, we ought to be entering another Ice Age now. The second was that it was thought possible that the cooling effect of aerosol pollution might outweigh the warming effects of additional greenhouse gases. A survey of the scientific literature found that between 1965 and 1979, 44 scientific articles predicted warming, 20 were neutral and seven predicted cooling (Le Page, 2007). Now we appreciate the extent to which global warming is already happening (Figure 3) and some of the other ways in which climate change is manifesting itself: rising sea levels, increases in ocean acidity, more extreme weather events, and so on.

It is difficult to know how great a risk to humanity global climate change poses. My lifetime has shown negligible evidence that the world's leaders are taking global climate change with any seriousness and I, for one, found COP27 at Sharm el-Sheikh in Egypt in November 2022 to be a somewhat depressing affair. Of course, the Earth has had some pretty extreme climates in the past. Some 600–800 million years ago, in the Neoproterozoic

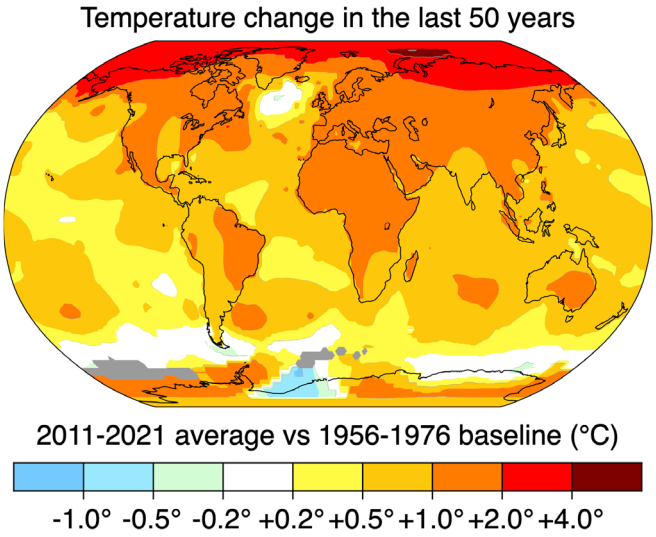

Figure 3 Global warming over the last 50 years (source: https://commons.wikimedia.org/wiki/File:Change_in_Average_Temperature.svg)

era, ice sheets may have extended from the poles all the way to the Equator (Scott and Lindsey, 2020). At the other extreme, some 92 million years ago, champsosaurs (crocodile-like reptiles) lived in the Canadian Arctic, and warm-temperature forests flourished near the South Pole. The biologist in me is therefore confident that life on Earth will survive anthropogenic climate change, albeit with very considerable ecosystem damage and substantially raised extinction rates.

Artificial intelligence

There is a wide diversity of views about the potential for AI, ranging from overenthusiastic pronouncements about how it is going imminently to transform our lives to alarmist predictions about how it is going to cause everything from mass unemployment to the destruction of life as we know it (e.g. Bostrom, 2014). AI is already here; it is already making a huge impact in almost every aspect of manufacturing and there are sensible predictions that it will be used increasingly in a large number of professions, including medicine, law and social care, not to mention education (Reiss, 2021).

Although it may sound like science fiction (*2001*, *Ex Machina*, *The Matrix*), serious concerns have been raised about the possibility of AI posing an existential threat. Indeed, Nick Bostrom (2014), the founding director of the above-mentioned Future of Humanity Institute at Oxford University, believes that of all the existential threats, AI is the one most likely to lead to the extinction of humanity. Bostrom's key concern is what happens when we get to 'the singularity', the time at which we have an AI (a digital computer, networked computers, cultured cortical tissue or whatever) that greatly outperforms the best human minds in practically every field. At that point, AI really

may take over and there is a risk that it might decide that its ends can better be met without humans. Even if things aren't quite as apocalyptic, Bostrom likens the relationship between such superintelligence and humanity to that that currently exists between humans and gorillas, where the continued existence of gorillas depends on whether humans want them to exist or not.

Genetically modified organisms

Concerns about genetically modified organisms (GMOs) may seem rather 20th century now (Reiss and Straughan, 1996). While concerns were raised about the safety of foods made from GMOs, these have not come to pass. Indeed, there is an ongoing argument about whether the greater use of GM crops might improve human health. For instance, so-called 'golden rice' is a variety of rice modified to produce, through genetic engineering, more beta-carotene, a precursor of vitamin A. Rice is a staple crop for about half the world's population, and vitamin A deficiency is thought to cause about 250 000–500 000 children to go blind each year, about half of whom die within 12 months of losing their sight.

Fears that GM crops might run riot have also receded. Such fears should not be dismissed out of hand but crops are not very hardy and it seems likely that the accidental or intended introduction of non-GM plants, such as Japanese knotweed (*Reynoutria japonica*) and water hyacinth (*Pontederia crassipes*), into unfamiliar habitats will continue to cause far greater problems.

Pandemics

Few people know that the infectious disease that has killed the most humans over the last two centuries (records before that time are poor in quality) is tuberculosis (TB), caused by the bacterium *Mycobacterium tuberculosis*. Even today, some one-to one-and-a-half million people die from it each year. The advent of COVID-19 has made most of us more sensitive to the dangers posed by infectious diseases. Long explored in films (e.g. *Contagion*) and novels (e.g. Stephen King's *The Stand*), the risks of pandemics are not to be dismissed. COVID-19 has probably killed about 15–20 million people to date, some 0.25% of the world's population. The 1918–1919 influenza pandemic (Figure 4) probably killed about 50 million people, some 2.5% of the world's population at the time.

Figure 4 Camp Funston, at Fort Riley, Kansas, during the 1918 influenza pandemic (source: https://en.wikipedia.org/wiki/Camp_Funston)

International agencies often place pandemics at the top of their list of threats to humanity, with a new infectious disease arising about every eight months (Mishra *et al*., 2023). Despite this, the same international agencies invariably conclude that the risks from future pandemics remain largely ignored and underfunded. To a biologist it seems difficult to imagine that we won't in the next generation or two experience a pandemic with worse consequences than COVID-19. At the same time, humans have evolved to have an impressive system of defences against infectious organisms – against which our ancestors battled for many millions of years. Contrary to the views of science fiction writers, it seems unlikely, given both our natural immunity and vaccinations, that the large majority of people will die at the hands of an infectious organism. (I am prepared to issue an apology to ASE members in the event of this forecast proving mistaken.)

Nuclear war

Declaration of interest: I have been a member of CND for over 40 years. In 1947 the scientists who had worked to develop the first atomic weapons in the Manhattan Project created the Doomsday Clock. They used the imagery of apocalypse (equated with midnight on the clock) to convey threats to humanity and the Earth, and set the clock at seven minutes to midnight. The decision as to whether to change the time on the clock is made every year by the Bulletin of the Atomic Scientists' Science and Security Board. In January 2023, the Board moved it to 90 seconds to midnight, the closest to midnight that it has ever been.

How much of an existential threat would nuclear war be? In 1982, atmospheric scientists Paul Crutzen and John Birks suggested a nuclear war would produce a smoke cloud so massive that it would cause what became known as a nuclear winter. Climate modelling suggests that the reduced sunlight would lead to a fall in global temperatures by up to 10°C for a decade. The consequences for global food production would be catastrophic. Everything depends, of course, on the scale of the conflict but a recent academic article

predicted that '*more than 2 billion people could die from nuclear war between India and Pakistan, and more than 5 billion could die from a war between the United States and Russia*' (Xia *et al.*, 2022: 586).

A nuclear disaster might be unintended. There is a *Wikipedia* page titled *List of nuclear close calls* (see *Useful links*). It is not recommended for those of a nervous disposition. To give just one example, on 26 September 1983, Lieutenant Colonel Stanislav Petrov was the duty officer at the command centre for the Russian nuclear early-warning system when the system reported that a nuclear missile had been launched from the United States, followed by up to five more. Petrov judged the reports to be a false alarm and disobeyed orders to launch a retaliatory nuclear strike. Had he not done so, it has been estimated that about half the population of the countries of the Soviet Union and NATO might have died. A subsequent investigation confirmed that the Soviet satellite warning system had malfunctioned (these things happen …).

Ecosystems collapse

Finally, we turn to ecosystems collapse. There is a danger that this might happen to farming ecosystems as a result of soil damage or climate change and to natural ecosystems as a result of habitat destruction or climate change. The word 'collapse' is apposite as the point is that the effects of often very long periods of harm are only perceived suddenly. This has happened with commercial fisheries. A classic instance occurred in 1992 when North Atlantic Cod populations fell to 1% of historical levels, primarily as a result of decades of overfishing. In Newfoundland alone, approximately 37 000 fishermen (it was a very gendered profession) and plant workers from over 400 coastal communities lost their livelihoods. Recovery of the fish stock has taken substantially longer than anticipated and it has been estimated that this may not happen until about the year 2100.

To give one more example, permafrost is soil or underwater sediment that continuously remains below 0 °C, and so is frozen. Permafrost is abundant – in the Northern Hemisphere, it is almost the combined size of the United States of America, Canada and China. However, it is melting fast (Figure 5). Once it melts, it can take a very long time to recover, even if the climate becomes cooler; it can get washed away and its very large carbon reserves may become oxidised. One of the worries is that positive feedback is involved: rising temperatures (and human-induced temperature rises are greater where permafrost is found than anywhere else) lead to loss of permafrost, which leads to carbon oxidation, which leads to enhanced CO_2 production, which accelerates global warming.

Figure 5 Thawing permafrost in Herschel Island, Canada, 2013 (source: https://commons.wikimedia.org/wiki/File:Permafrost_in_Herschel_Island_018.jpg)

Existential threats and school science education

There is a danger in simply adding more and more to the school science curriculum but I think there are two arguments as to why existential threats might profitably feature more than they do. One is simply that I suspect that for many students they provide 'engaging' contexts for routine science teaching. Consider asteroid impacts, for instance. Learning about projectiles in physics is not always the most motivating of activities; for some students, examining the consequences of asteroids of different sizes striking the Earth might be interesting. Students will also rapidly appreciate that an understanding of Newtonian mechanics is needed but not sufficient. All of the existential threats considered in this article are examples of what are sometimes called 'wicked problems' – problems that cannot be unambiguously solved and that require contributions from a range of disciplines if they are to be meaningfully addressed.

The second reason for school science courses dealing with existential threats more than they currently do is that for humanity (including politicians) to begin to address these threats we need more people to have a good understanding of them. School science can play an important role in helping people to begin to appreciate both the nature and the extent of these threats for humans and for other species.

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Useful links

Our World in Data: https://ourworldindata.org

University of Cambridge's Centre for the Study of Existential Risk: www.cser.ac.uk

University of Oxford's Future of Humanity Institute: www.fhi.ox.ac.uk

Stanford University's Existential Risks Initiative: https://seri.stanford.edu

Future of Life Institute: https://futureoflife.org

Wikipedia, *List of nuclear close calls*: https://en.wikipedia.org/wiki/List_of_nuclear_close_calls

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