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EDITORIAL

Socio-scientific issues in school science: a theoretical suggestion

Ralph Levinson

University College London (UCL), Institute of Education, London, UK.
Contact: r.levinson@ucl.ac.uk

Recent editorials of this journal have focused on issues close to my heart: the misappropriation of knowledge in supporting racist ideologies, the role of activism through science education, the political control of scientific knowledge. Throughout my career as a school science teacher to working as an academic in higher education, the problems of enhancing social justice through science education continue to challenge.

Educationalists and teachers have, rightly, pressed for a more socially and politically relevant curriculum. Two technoscientific issues dominate national and international governance in an unprecedented way. Both are exemplars of pursuing solutions that must be multidisciplinary, but in examining these solutions, educators must be careful to avoid epistemological traps. Manifestos for a more socially and environmentally conscious curriculum must identify the kind of learning at stake. We have a responsibility to support the epistemic and pedagogical means for transforming science curricula into practise.

The first issue is the threat of climate change, which governments believe they can do little about because the imperatives of economic growth and comfortable middle-class lifestyles are at odds with decommissioning fossil-fuelled power stations. One technofix is the use of green technologies (while there have been recent advances in nuclear fusion, scalability and applications remain a long way off). A prevalent approach is to demonstrate that wind, solar and geothermal technologies can reduce reliance on fossil fuels. That is a scientifically appealing solution, but to ignore the social, ethical, and political implications is to compound the environmental challenges we face.

The second global issue is the pandemic. Covid-19 was unsparing in the ways it hit poor and rich alike – except of course the rich had resources of health and wealth which helped protect them against its worst excesses. But, as Brazilian educators are only too aware, conspiracy theory and denialism (why am I thinking of a recent President of Brazil?) – the guardians of post-truth – have hampered vaccine production and uptake. As the Amazon is exploited, burned for its natural resources, and indigenous peoples are displaced, the previous President laughs at the protests – claiming that global warming is a hoax. Equally, covid-19 was simply a small germ like the flu. Get over it, people!

Cassiani, Selles and Ostermann (2022) make an excellent case for how scientists have endorsed racist philosophies based on distorted evidence, how colonialist assumptions have been built into the study of science, that the and how the uncertainties inherent in scientific evidence have been used to belittle arguments warning about global warming. They make an important point about the misunderstanding of uncertainty in generating conspiracy theories:

> […] the scientific method is about doubting its certainties. In this sense, denialists arrogate to themselves the right to doubt scientific knowledge as well, though without going through the same processes regarding the empirical testing of laboratories and educational facilities. (CASSIANI; SELLES; OSTERMAN, 2022, p. 7).

They identify a crucial problem in scientific production. That denialists exploit the very strength of theory construction, the invitation of doubt, to show that science does not have straightforward answers, that it has no deep epistemological justification. How, then, are teachers to deal with this superficial scepticism?

Much of my research over the last thirty years has been on socio-scientific issues, SSIs. There have been a number of distinct rationales for justifying these in science curricula. One is that lay people need to be more scientifically literate. If they know more about science there would be more sensible discussions about the use of genetically modified crops, the production of medicines, aerospace programmes and so forth. A scientifically educated public would be more rational. This is predominantly a deficit view approach (LEVINSON, 2010) which places well-adhered to scientific principles at the core of content. Perhaps – but many conspiracy theorists and denialists have been through higher education. Enhancing scientific literacy was a prevalent position with science brokers in the 1990s, less so now.

In 1993, a small book was published by a relatively obscure press. It was called *Inarticulate science* (LAYTON *et al*., 1993) and was a series of case studies of lay people addressing problems of a scientific-medical-technological nature such as parents of Down Syndrome children wanting to understand how best to nurture their young, people in the locality of a chemical factory taking action about the toxicity of fumes, and sheep farmers wanting to know what precautions to take about fallout from the Chernobyl power station. The studies explained that scientific expertise did not translate easily into public problem-solving. What the authors concluded is that context matters, formal and local knowledge need to be in dialogue with each other. Roth *et al.* (2004) came to similar conclusion in a study of a community's struggle for safe drinking water.

One way forward is to create forums for citizens to discuss technological issues with scientists. But these are not enough. Such forums have been around for many years. The challenge is which voices get heard, and how that translates into social action (LEVINSON, 2010). It is a problem of power relations. Young people need to understand what knowledge and skills they need to influence policy (JOHNSON; MORRIS, 2010). Knowledge and understanding of scientific principles do little without the know-how of forming alliances, campaigning, explaining your ideas coherently.

In terms of traditional school science education there is the issue of discipline boundedness (HIRST; PETERS, 2011). Science explores the workings of mute Nature; it is an empirical subject aimed at developing theories about the natural world. It cannot shed light on social affairs except in an oblique way. How individuals or society ought to act is not a question science can answer. As one history teacher explained in a research study 'How can knowing the chemical structure of Zyklon B help us understand the moral horror of the Holocaust?' (LEVINSON, 2001).

Understanding gravity, blood circulation, gaseous diffusion have nothing in common with socio-political phenomena. Gravity acts the same way in communitarian or individualist societies, blood supplies nutrients and oxygen to cells regardless of whether citizens are governed by socialist or neoliberal governments, and gases diffuse according to certain laws in both colonial and post-colonial societies. Science is reductionist whether we like it or not (DONNELLY, 2002). To say we should socialise science, in these terms, is meaningless.

So, here is the challenge: How can school science be constructed to promote social justice in a way which is consistent with understanding basic scientific principles such as atomic theory, forces, natural selection?

The problems

In relation to the question of Global Warming let me illustrate what we're up against. I mentioned earlier the hope for alternative technologies involved in energy supply. Take the case of wind turbines. The scientific principle behind wind turbines is that rotary motion of steel blades provided by the wind turns a generator which supplies electricity. The blades are fixed to massive towers that sit on the sea bed, and their rotation are assisted by very complex arrangements of gearing and engines. The scientific principles are relatively straightforward. Surely, encouraging economies to manufacture wind turbines would reduce our dependence on fossil fuels and assist in the movement to reduce global warming.

Wind turbines which operate off the east coast of the United Kingdom are mainly manufactured in Vietnam, where labour costs undercut those in the UK, and then shipped to the east coast of England by huge vessels pumping tonnes of fuel into the sea on their journeys. The growth of wind farms in the UK indicates a green future looks possible, but at what social and political expense? James Meek (MEEK, 2021) reports on the Vietnamese city, which now produces these turbines, and the massive natural devastation and social upheaval in setting up the manufacturing base. It is a textbook lesson in the chimeric process of neoliberal economics.

Another case in point is conservation in relation to biodiversity. For many years, illegal trade in rare species has been a nightmare for conservationists and those committed to biodiversity. Perhaps the most notorious case is the killing of elephants by poachers for trade in ivory in certain parts of the world where it is a precious commodity. An understanding of food webs and interactions of species makes the case for the protection of many species of wildlife. But, as Duffy (2022) points out, trade in rare living commodities is linked to many different illegal activities such as money laundering, gang warfare, fraud, and drug smuggling. There have also been reports that poaching has been used to finance terrorist activities such as those of al-Shabaab in Somalia. As a result, the practise of species conservation and attempts to stop illegal wildlife trafficking is transformed into security and surveillance issues in which the objective becomes the threat posed by humans rather than the protection of wildlife. In a secondary sense, it can also justify the presence of troops from Europe and the US inside Third World countries deepening colonialist attitudes and power structures.

Finally, the global production of semi-conductor microchips has transformed communication systems enabling – putatively – a greater responsivity from government to the governed. Even in very disadvantaged communities cell phones and tablets are prevalent. Surely the scientific advances made in solid state physics have helped transform the nature of society?

But the metals needed for high-density capacitors in cell phones – tantalum and niobium – are relatively rare. An important source of coltan, the mineral containing these semi-conductors, is in the mines of the Democratic Republic of Congo. Here coltan is extracted under slave labour conditions (SUTHERLAND, 2011). It seems that in schools social issues focus predominantly on the consumption of technoscience, while its production is invisible. This is one aspect to be addressed.

There is no simple green solution. How can a change be labelled just if the production of advanced technologies benefits one sector of the population while exploiting another? What is more, green solutions themselves may degrade the environment even more than the old technologies (LEVINSON, 2022).

There are two purposes in raising these examples. The first is to demonstrate the complexities of solutions to technoscientific injustices that are also socio-political in nature. Solutions that might seem just on the surface might have deeply unjust consequences. The second purpose is that solving problems of injustice goes way beyond disciplinary boundaries. A possible objection is that a transdisciplinary curriculum will dilute science; these are the kinds of objections advanced, for example, by Young (2009), who argues that the socialisation of science is disempowering and deepens class distinctions. However, I want to argue that transdisciplinary approaches to a problem can actually enhance and deepen understanding of scientific concepts.

A possible solution

I do not want to appear as a nay-sayer, someone who believes that the project of transforming the science curriculum from one evaluating facts and processes to one encouraging political agency with social justice at its core is impossible in predominantly neoliberal economies. On the contrary, this is an eminently achievable aim.

But tradition and history have to be grappled with. The scientific project, as presented to schools, has in it embedded the heroism of modernity, the (usually) white, male scientist unravelling the mysteries of mute Nature. And such ideas dominate the unwitting consciousness. As the physicist Carlo Rovelli writes about our understanding of time,

> If… the existence of this Newtonian concept of time which is independent of things seems to you simple and natural, it's because you encountered it at school. Because it has gradually become the way we all think about time. It has filtered through school textbooks throughout the world and ended up becoming our common way of understanding time. We have turned it into our common sense. But the existence of a time that is uniform, independent of things and of their movement which today seems so natural to us is not an ancient intuition that is natural to humanity itself. It's an idea of Newton's. (ROVELLI, 2019, p. 60-61).

Those who question the triumphalist march of modern science point to commonsensical ideas that have dominated the way we think about Nature, the dualisms of conscious Mind and inanimate Matter, the Sciences and the Humanities, fact and non-fact. So how can both a curriculum and pedagogy be transformed to reflect this *weltanschauung*?

In a discussion of thinking about the Covid-19 virus, Sharma (2020) has provided an alternative to the substantivist perspective. What drives a pandemic are relations of heterogenous entities with affordances that allow for a series of interactions. To understand the origins and spread of Covid-19, we must consider assemblages of global markets, trade of non-human beings in conditions that allow transmission of viruses between non-humans and humans, the media that supports and glorifies such interactions, global policies and infrastructures which promote or detract from health remediation, and the discourses surrounding these interactions. In other words, Covid-19 is a much broader assemblage of interacting and changing entities that influence the pandemic's progression rather than a simple case of virus transmission between bodies.

Assemblages are a useful way to think about the pandemic. It suggests that understanding of pandemics and climate change are much more than the application of science and technology. In advancing a possible pedagogic solution, I want to draw on the metatheory of critical realism (BHASKAR; HARTWIG, 2016; COLLIER, 1994). I have written about Critical Realism and its relation to the science curriculum elsewhere (LEVINSON, 2018), but I want to focus on one specific aspect, that of emergence.

Humans and objects constitute a school: humans such as pupils, teachers, and ancillary staff; objects such as classrooms and textbooks. But a school as an entity is more than its constituent parts, the social and pedagogical relations that exist in a school are not reducible to the component individuals and objects that make it up. Nonetheless the components are capable of being organised in such a way to form a larger whole; in other words, there are affordances about the people and objects that come to make up the school. Conversely, the school as an entity influences the interactions of its pupils and teachers. The school is an emergent entity from its component parts – more than the sum of its components, but in turn influencing their interactions.

An example related to social justice in thinking about science, is consciousness. Consciousness broadly refers to the awareness of an individual, their perceptions and discernment of the world influenced by aspects such as culture and society. These are social and psychological constructs. Consciousness is not possible without the architecture of a brain and a nervous system (biological concepts). Yet consciousness cannot be explained solely in biological terms, it is not possible to have consciousness without the biology, but the explanation goes well beyond this. In addition, the nerve impulses that allow brain function to occur follow physicochemical principles, e.g., the flow of ions along a concentration gradient through a nerve pathway. The biological account of the brain and nervous system cannot only be understood by reference to physicochemical principles. Consciousness can, of course, be studied without any understanding of biology, physics and chemistry, but for a deeper level of social justice, the scientific principles are crucial.

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Learning science utilises consciousness in many different ways: awareness of the relevance of the concepts, the subtleties of pedagogy, the discourse that is entailed in questioning and understanding. Nevertheless, if an individual does not have the conditions in which to think and study, sustenance that provides the nutrients for a fully functioning nervous system, nor the space and leisure to direct consciousness towards its objectives, then learning cannot take place. At a very simple – and possibly simplistic – level, if people do not have enough to eat, they cannot learn. So, to teach science, or indeed any other subject, demands certain basic conditions which stem from effective collective political organisation in distributing basic commodities such as food, shelter, space, and so forth. To address any important social question involves bringing together different disciplines.

There are diverse accounts and theories of emergence (PRATTEN, 2013). But here I simply want to demonstrate interconnectedness.

How might this reflect a science curriculum?

The example I am going to take is from the manufacture of aluminium (LEVINSON, 2009), partly because I first became aware of the nature of this topic when I was travelling near Rio de Janeiro about twenty odd years ago and became aware of workers collecting around rubbish tips. These were the *catadores de lixo*, and my Brazilian friends explained the importance of these impoverished people to clearing streets and recycling of aluminium cans in Brazil. Their activities have also led to improving educational and work opportunities of the *catadores*, but this is too complex a topic to discuss fully in this space.

One aspect I want to bring to light, and a topic often addressed in the school science curriculum, is the manufacture of aluminium. The big manufacturers make claims that they use hydroelectric power to provide the energy that drives the smelters in the electrolysis of aluminium. The electrolysis is basically a chemical reduction process of aluminium ions to generate pure aluminium metal – but the focus of my argument is hydroelectric power. Hydroelectric power is a good example to demonstrate the application of potential energy and kinetic energy, the rotation of a turbine supplying electricity. The process itself does not need to use fossil fuels hence manufacturers claim it is 'clean energy'. See, for example, https://www.hydro.com/en-US/aluminum/about-aluminum/renewable-power-and-aluminum/.

A reductionist approach focusing only on the scientific principles would simply underpin the manufacturers' claims. However, expanding the inquiry a little would reveal more questions. Geography, for example. Hydroelectric power stations are typically constructed in areas of outstanding natural beauty. Mountains give height and fast-flowing rivers supply the water to fall and drive the turbines. Much heat is produced by this process, which raises the temperature of the water. Now because fish are poikilotherms, raising the temperature of the water would cause them distress, if not death, and would affect the ecology of all the species dependent on the river. In other words, the use of hydro-electricity comes at considerable environmental cost, and suggests that the word ‘clean’ stands up to critical questioning.

My reason in choosing this example is that it deepens understanding of the science. The question *Is hydro-electricity clean?* draws on an understanding of physics but also biology, and indeed chemistry in thinking about the diffusion of oxygen and carbon dioxide in water. To address a question concerned with sustainability it not only draws on basic scientific principles but geography and economics as well.

Socio-political inquiry

As a start, inquiring into events is a way of bringing different disciplines together to address socio-political questions. I have outlined a couple of examples how this might be done. Thinking about wind turbines, scientific questions might be: What conditions do they need to work? Where would they best be placed? What are they made of? How are they manufactured? How are they transported? Why are they manufactured in Vietnam and not near the site of their use? These will certainly raise other questions in turn.

The issue of biodiversity assumes knowledge of species inter-connections – why and how particular species are valued. If we start with a socio-political question, it becomes clear that different types of knowledge are related to each other in trying to address the question. Using visual models, such as concept maps or causal loop models can support initial exploration of these areas through complex systems thinking (HIPKINS, 2021).

At this point, I would not advocate for wholesale change, but rather for more cautious gradual change, so that both teachers and students become aware of the advantages of such an approach. In an article in an edited book (LEVINSON, 2018), I referred to a teacher who used innovative methods but needed to ensure his students were on board. Through judicious mixing of old and new methods, he took them along with him. By dissemination, advocacy and sympathetic mentoring these approaches can develop. But more work and research are needed.

I want to conclude by referring back to the problem of denialism and conspiracy theory. Cassiani, Selles and Ostermann (2022) discussed how denialists profit from uncertainty in science. That is indeed the line of attack denialists use. Climate change is a scientific prediction and is full of statistical prediction. Why should we trust science more than any other form of knowledge? It is a problem that disturbed Bruno Latour (LATOUR, 2004), to clarify what stood as facts and to augment his environmentalist position. Latour and Woolgar's Laboratory Life (1979) interrogated how scientific research becomes facts, but Latour also recognised that unscrupulous and reactionary agents could use such thinking for oppressive purposes. Recent research I have carried out with colleagues in Cyprus and the UK (HADJICOSTI *et al.*, 2022) indicates that induction into scientific research enhances interest and scepticism of school students and a deepening appreciation of complexity. A realisation, I would argue, that is encouraging.

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