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# Science Education for Citizenship and a Sustainable Future

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In this article Jerry Wellington argues very strongly in favour of the role of science in citizenship education. He emphasizes the need for knowledge, skills and action and suggests areas and ways in which pupils can be engaged in the struggle for a sustainable future where interdependence and interconnectedness mesh well with notions of equity and justice.

**Introduction**

My main argument here is that science has a unique role to play in the Citizenship curriculum. Citizenship is far too important to be left solely to the Humanities staff or assigned to PSHE/PSE slots in the timetable. Without a strong contribution from science, the citizenship curriculum is incomplete. One of the main aims of Citizenship Education in its current 2002 form, is to produce 'informed and critical citizens' who can 'act responsibly'. My emphasis here is on the responsibilities *of pupils* as future citizens that stem from the key ideas of science. My reading of the DfES documents on Citizenship is that we should focus on three key strands: *knowledge*, as part of the goal of producing informed citizens; *skills*, of enquiry and communication; and *action*, so that pupils are encouraged to act responsibly. I will call this the KSA framework (knowledge, skills and action). Science has a unique role to play in each strand of this framework. Put concretely, virtually any lesson plan for a science teacher can contain elements of the KSA framework. Finally, by way of introduction, I intend here to take a *futures education* perspective. The basic premise of this approach is that 'the school curriculum should encourage pupils to think more critically and creatively about the future' (Hicks, 2001: 231). I follow Hicks's view that 'effective citizenship education' should take this stance (Hicks, 2001: 238).

The questions I would like to pose, although I do not have space to answer them fully, are these: if we are really serious about science education for citizenship what will we have to teach people?; what should we 'inform' them about?; what can be learnt from science that will make people better citizens in the future, in terms of their knowledge, skills and action?; and, more generally, how should we educate people for a sustainable future?

I need to pause briefly because I have just used a hotly debated word: *sustainable.* I am going to offer a working definition so that we can move on.

SUSTAINABLE ACTIVITY: activity and development that meets the needs of the present without compromising the ability of future generations to meet their own needs. A sustainable society is one that satisfies its own needs without diminishing the prospects of future generations. (See Allen and Thomas (1992); and Capra (1997) for a full discussion.)

**Knowledge: Some Key Ideas for Citizenship and a Sustainable Future**

My main message here is this: in science education, we have dwelt for too long on the detail. Let us go for the big issues and key ideas, the ones that really matter for citizenship and sustainability. My plan is to go through SEVEN of these and then show how they relate to citizenship, education for sustainability, the individual responsibilities that we all need to consider and act upon, and the legislation that needs to come with them. I have chosen seven key ideas – it could be argued that there are more but I doubt if there are many:

*1. Energy supplies are finite and not always renewable ('once we use it we lose it'). Energy is degraded when energy sources are used (we can't get it back)*

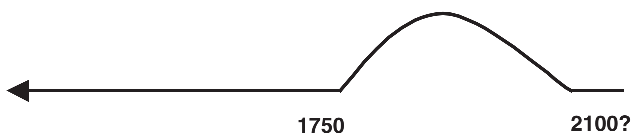


*Figure 1. Fossil Fuel Use: A Tiny Blip on the Human Timeline. To provide an idea of scale, the arrow on the left on this graph would extend back for about five kilometres*

Fossil fuels are marvellous things – they are highly compressed, concentrated sources of energy and they have enabled people to achieve remarkable feats. Each litre of petrol and lump of coal is effectively thousands of years of sunlight compressed into a small volume. Fossil fuels are precious commodities. They were formed two or three hundred million years ago. At the present rate we seem destined to use them up in a period of about 400 years.

When fuels are used, their energy is 'spread out' or dissipated – the fuel is degraded. Once used, the energy ends up as waste heat in the Earth's atmosphere. It cannot be retrieved or recaptured and put back. This is ROUGHLY the second law of thermodynamics and it relates to the idea of entropy or disorder. The path of time takes us towards degraded fuels and greater disorder.

*2. Resources are finite and not always renewable or replenishable (same again: 'once we use it we lose it')*

This is a simple one and we all hear or read about it frequently. The world's resources – animals, plants and materials – are being used up at a tremendous rate. Once used, like fossil fuels, they cannot be recaptured or retrieved. Some resources can be recycled. In a very few cases, resources are reused over and over again (like milk bottles). But in most cases, resources and materials are used once and simply thrown away or discarded. For example, in the UK alone, nearly two million cars are discarded every year. Fridges and freezers suffer the same fate – about 1.5 million of them are being thrown away every year, and no one is quite sure what to do with them. The figure for mobile phones is even higher. Last year, nearly twenty-five million phones were discarded in Britain. It is estimated that as many as ninety million of them are sitting in people's sideboards and cupboards. They contain heavy metals such as cadmium and, again, nobody knows quite what to do with them. A similar crisis exists with obsolete computers. At present, most discarded computers from the USA are sent to India, Pakistan and China to be stripped. The valuable parts are kept and recycled but many of the remnants are dumped in fields and rivers and these remnants contain poisonous materials such as the heavy metals lead and mercury, which leach into the water and soil.

*3. Energy and resource usage is unevenly distributed around the world. Some countries, and the people in them, are greedy. This greed is not only unfair, it is also unsustainable*

We only have to look at United Nations figures for global energy use to see this graphically.

To pupils, we can convey the message from the figures in this chart in concrete terms. For example, they show

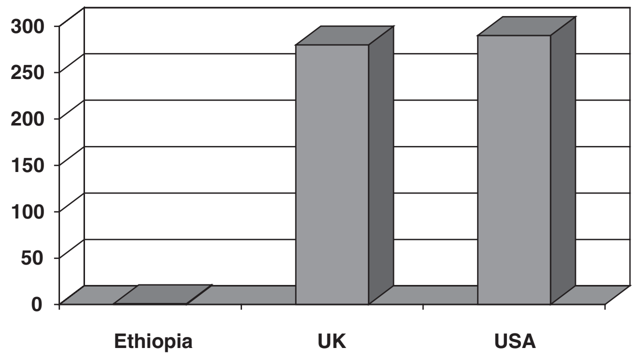


*Figure 2. Energy Usage in Different Countries (units: megajoules per person p.a.)*

that the average British citizen uses as much of the world's resources in two and a half days as an Ethiopian uses in one year. The average North American achieves this in just one and a half days. Put it another way, the average North American has the same impact on the planet as 280 Ethiopians or 47 people in India – or, closer to home, four people in Spain. There is a simple but valuable concept called our 'ecological footprint' (Wackernagel, 1996). It is a measure of the impact we each make on the environment as a result of our lifestyle. At present, as you can see from this graph, people in the UK leave large ecological footprints.

Looking at this graph, it will be no surprise that the USA is by far the world's biggest producer of greenhouse gases and is responsible, on its own, for about a quarter of the world's emissions. This is certain to continue in the near future as long as the USA refuses to cut back its carbon emissions in going against the Kyoto agreement.

More recent figures from the UN, in May 2002, show that one fifth of the world's population is responsible for 90 per cent of the world's consumption.

*4. Fossil fuel use has pollution and health effects*

I said above that fossil fuels are amazing entities. But like most good things, they have major drawbacks. One litre of petrol will fuel an average car for about nine miles, a large four-wheel drive for about five miles. Burning this fuel in a car engine produces the main greenhouse gas, carbon dioxide, as well as many other gases, some of which are poisonous. How much carbon dioxide will this produce? This petrol has a mass of about three-quarters of a kilogram. How many kilograms of *carbon dioxide* results from our journey: will it be about the same as, less than, or more than three-quarters of a kilogram?

Most school pupils, according to a recent study (Myers, 2002), think that it will be a lot less, mainly because it is a gas and gases do not really 'weigh anything'. In fact, some fairly simple chemistry indicates that this litre of fossil fuel produces 2.4 kg of carbon dioxide (over three times the original mass of the petrol), a major greenhouse gas, partly responsible for global warming and its effects.

The waste products of fossil fuels also contain poisons. Lead has largely gone from car exhausts in this country, but there is no such thing as 'green petrol'. There is increasing evidence that exhaust fumes are a major contributor to asthma in children (and adults) who live near main roads. This is one of the nasty ironies of the short fossil fuel age. Basically, we are all dependent on something that is poisoning some of us and changing the nature of the planet for all of us.

*5. Genetics: increasingly, current research into genetics is showing that the differences between humans in terms of their genes are small. In other words, there is far more variation* within *so-called 'races' than there is from one race to another*

Several conclusions follow from current research into genetics. School pupils and indeed all citizens need to know about them:

- The concept of 'race' is certainly questionable and in the eyes of some scientists, no longer tenable.
- The *interaction* between our genes and our environment is far more important than just the genes that we are all born with.
- No concept of genetic superiority is acceptable, whether it be based on the idea of race or the old ideas of 'breeding', class and people's station in life. There can be no support from science for the idea of an 'upper class' or caste, or any form of aristocracy.
- It also follows that there can be no *scientific* support for the concept of a 'royal family', i.e. people should be citizens, not subjects.

*6. The nature of science and scientific knowledge has changed: some scientific knowledge is certain and reliable; but a lot of the work of current scientists is more tentative, speculative and uncertain, e.g. on BSE, GM foods, and many of the other issues of the twenty-first century. Science has its limitations*

It follows that most of the knowledge that citizens will have to deal with in this century will be uncertain knowledge. The old ideas of cause and effect (X causes Y) and scientific proof (we can demonstrate that 'X causes Y') are no longer tenable in real situations. There will be few scientific certainties in the future. We now need to deal with probabilities and the idea of risk. People need to be aware that most of our decision-making is, and should be, based on an assessment of risk and probability. An appreciation of the nature and the size of risk needs to become a key part of education for citizenship. For example, current data show that in the year 2000, citizens in the UK were seventy times more likely to be killed when travelling in a car than when travelling on a train. Yet for some reason there is a national outcry when rail accidents occur but we seem to accept road deaths (currently about nine people every day in Britain, on average) as just a fact of life.

*7. And finally, most importantly, the overarching idea: interconnectedness*

Some people have called this the web of life, karma, or 'you reap what you sow'. The idea is central to modern physics but can actually be traced back over a thousand years to the Anglo-Saxon concept of 'Wyrd'. They believed that the world is connected by a vast, all-reaching system of links or fibres, like a three-dimensional spider's web.

This interconnectedness occurs in both space and time: what we do *now* affects people in the future. What we do *here*, affects people *there*, on a global scale.

This interconnectedness hit the news in a fairly graphic way when the problem of acid rain was first publicized on television screens and in newspapers. Burning coal and other fossil fuels in UK power stations produces carbon and sulphur dioxide which, blown for miles by the prevailing wind, turned raindrops in Scandinavia acidic. This acid rain fell on forests and lakes, killing trees and poisoning fish. A similar event occurred later (in 1986) when the nuclear reactor in Chernobyl near Kiev overheated and discharged huge amounts of radioactivity. The fall out from Chernobyl affected the grass in Cumbria and North Wales, several thousand miles away, and the lambs grazing on that grass became radioactive.

The idea of a web was later expressed when 'Chaos theory' (Gleick, 1993) became well known through the saying: 'A butterfly flapping its wings in Australia may lead to a storm in Europe'. A slight exaggeration perhaps but attention grabbing. To put Chaos theory simply, I would say that small changes in one part of a system can have unforeseeable, unpredictable yet massive effects in another part.

Current thinking is that the world as a whole must be treated as a system, with interconnections and links. This idea is part of the Gaia hypothesis, named after Gaia, the Greek goddess of the Earth. This suggests that we should view the world as a kind of living, self-regulating organism. Thus Planet Earth can be viewed as rather like a human. Humans are self-regulating – if we get too hot we sweat or become red and flushed, and cool down. If we get too cold we shiver, the hairs on our body stick out to trap a layer of insulating air, and we warm up. The Earth regulates itself in a similar way through a number of cycles: the rock cycle, the nitrogen cycle, the carbon cycle, and so on. For example, human and natural activity has been producing carbon dioxide for millions of years. Some of this carbon dioxide is absorbed by forests and converted to oxygen, which is essential to human life and activity, which in turn creates more carbon dioxide, which is reabsorbed, and so on in one endless cycle. But these cycles or feedback loops are fragile. If this, or any other cycle, is damaged or broken – perhaps by excessive carbon dioxide from fossil fuels or by destroying large chunks of rain forest that absorb it – the cycle can be broken beyond repair. It is rather like stretching a spring. Normally it will bounce back but if it is stretched beyond its elastic limit it becomes permanently damaged. In global terms, the balance is disturbed and then Chaos theory comes into play. Anything can happen, and apparently already is, if some of the newspaper cuttings about global warming are to be believed.

One of the consequences of this 'new view of reality' (Capra, 1997) is that the only viable solutions are those that are sustainable. New technology may help to provide solutions. For example, the Americans seem to be planning to keep up their high level of carbon dioxide emissions whilst simultaneously spending money on ways of absorbing it – one brilliant idea is that they might plant a lot of trees. But this would be a bit like turning the bath taps on harder whilst keeping the plughole open. The long-term solution cannot be a technological or technical one. A sustainable solution requires changes in human behaviour, and this in turn requires education: to alter individual actions and to pave the way for legislation to regulate people's collective actions.

## Actions: The Implications of these Seven Ideas for our Responsibilities as Citizens and Our Individual Actions

Unfortunately, I do not have sufficient space here to draw out all the implications of these ideas, and how they might be put into practice. So this section has to be brief and selective, largely by way of giving a few examples and anecdotes. So, what individual actions can people take? First, every individual can make a difference. All these tiny differences add up to large numbers of megawatts or mega joules. Here are a few specific examples of the actions that individuals, in homes, schools, the workplace and travelling to the workplace can do.

*1. Switching off appliances:* a few simple things to begin with, most of which are fairly obvious: switching off lights in rooms that are not being used at home or in the workplace provided it is safe to do so; when boiling a kettle, by using no more water than we need, as long as we cover the heating element; by regulating the temperature in buildings, where this is possible, so that it is comfortable, rather than opening windows or stripping to your T-shirt; turning off computer monitors rather than using screen savers, when the computer is not in use. (Screen savers do not actually save any energy.) A computer monitor left on overnight wastes enough energy to print 800 A4 pages; a photocopier left on overnight wastes enough energy to make 5,300 copies; leaving the light on overnight in a large office wastes enough energy to heat the water for 1,000 cups of coffee (and that would keep the average academic in caffeine for at least a week!). Individuals in an organization such as a school, college or University can collectively make a vast difference.

*2. Saving resources and materials:* how many people use a polystyrene cup to drink tea or coffee from just once, and then throw it in the bin, along with the plastic spoon? This is hugely wasteful, especially as polystyrene is derived from fossil fuel (oil).

Recycling of materials such as bottles, plastic and waste paper can make a difference if the majority do it. But actually, it would be far more energy efficient to reuse bottles, as some countries insist on, rather than throw them in a bottle bank. I suppose at least bottle banks make us feel a little better – a bit of guilt relief for the middle classes, cynics would say. But we do need to invest as much effort into *reuse* as we do into recycling.

Generally speaking, we need to ask a simple question of everything we do, either individually, or collectively. Is it sustainable? As individuals, we need to examine our own ecological footprint on the planet in terms of what we eat, how we live and how we travel. To take a specific example, we need to increase awareness of the overwhelming case from science for *public transport* as a way of moving people around, especially in cities. Car use by single drivers is grossly inefficient and ten times more 'energy greedy' than a bus, and 400 times less efficient than the train. The current mode and extent of car use is not sustainable.

So far I have argued that individuals, once aware of the issues and the value of small actions, can make a huge difference – a difference that is measurable in megawatts, gigajoules or quite simply power stations or barrels of oil. But there is a limit to what individual actions can achieve. Legislation and something called 'mutually agreed coercion' is needed. But these can only become part of social and political life as a result of education and people's awareness. This is a central part of citizenship education.

## Skills, Attitudes and Awareness

What skills and values should we try to develop in citizenship education in the science classroom?

First, healthy scepticism (but not cynicism). When George Bush says we cannot reduce carbon dioxide emissions without losing jobs and causing a recession, we should ask WHY? When members of the pro-car lobby say that we cannot introduce pollution/congestion charges, we need to ask WHY NOT? Next, critical reading, watching and listening: we need to develop careful, critical readers and viewers of articles, television programmes, news items and sometimes the advertisements that go with them, in all the media. Judgement which is critical, but not dismissive or scathing, needs to be nurtured and encouraged.

Citizenship education through science can also develop:

- the ability to make informed personal judgements based on the best evidence – not just: 'that's my opinion and I'm sticking to it';
- thinking skills, including being able 'to think for ourselves' and to assess risk and probability, for example;
- the skill of searching for and finding data, information and viewpoints, not least through the use of ICT;
- for this so-called information age, we also need the skill of questioning and evaluating where information comes from, who put it there and how it is presented – for example, media reports in the papers or on television and material on the Internet;
- the ability to discuss and debate controversial issues and to listen to other people with tolerance and respect;
- the skill of communicating information, views and opinions in a measured, balanced way;
- finally, we all need the ability to think carefully about the consequences of all our own actions and our 'ecological footprints', right down to the simple ones such as: if we pour excessive bleach down a toilet, where does it go and what happens to it?

Pupils, and indeed all citizens, need to be aware of and reflect on their own consumption and to act upon it. We need to look at our current lifestyles. There is an increasing view that the *quality* of life does not simply go on increasing steadily according to the *quantity* of energy that we consume. The connection is actually a more complex one, something like the graph shown in Figure 3.

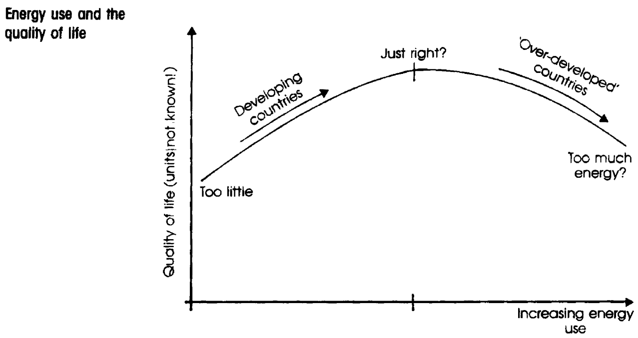


*Figure 3. Energy Use, Consumption and Quality of Life (Wellington, 1992)*

This is a view that could be discussed and considered as part of a science lesson with an eye on citizenship.

**Implementing Citizenship within Science Education**

I do not have the space to describe in detail how these ideas can be put into practice in schools, but there are good grounds for optimism here. All seven of the key ideas are already out there, in the National Curriculum for Science, though some more implicitly than others. Citizenship does need to be included in initial teacher training and continuing professional development (CPD) for teachers, but this need not be a major undertaking. Science teachers can include a citizenship dimension at KS3 and 4 without a huge change in their skills and knowledge. (Though it may require, for some, a change in attitude.) A good supply of material has been published, starting in the 1980s (Wellington, 1986) followed by a steady supply since then, which gives guidance and advice on handling science in society debates, on dealing with controversial issues and on the teaching/learning strategies required.

**To Sum Up . . .**

Some people may blame science for our present situation, but science will not go away. When we envision the future, and ask what we want from it, that is, our *preferred* future, knowledge of the big ideas of science must play a part. Without it, our vision of the future cannot be either complete or realistic.

In reflecting on the future, there are good grounds for pessimism. A UN report in June 2002 stated that one third of the world's fish stocks are depleted, half of the world's rivers are heavily polluted, one fifth of the world's animals in coastal regions (where most human beings live) are faced with extinction, and disasters related to global warming are up by one third in the last ten years. But there are some reasons to be cheerful. One of the main environmental success stories is the recovery of the ozone layer. As a result of increased knowledge and individual actions, in not buying or using products containing CFCs, coupled with legislation against them, the depletion of the ozone layer has slowed down sharply. The UN forecast is that it is slowly repairing itself and could be back to normal by 2032. A long time, I know, but it shows that education can make a difference to our future.

In his own century, David Hume (1888) may have been able to separate facts from values (as he put it, an 'ought' cannot follow from an 'is'). But current thinking, scientific ideas, and school science education can and should have an influence on ethics and morals, that is, how we ought to act and behave. The ethic that seemed to prevail in the 1980s was based on snappy slogans such as 'Look after number one' or 'There is no such thing as society'. Given current views of reality, this is no longer acceptable or sustainable. Conveying the key ideas of *interdependence and interconnectedness* should, in my view, be the main aim of education for the twenty-first century. With this in mind, the central moral principle has to be the old biblical ethic of: *do unto others, as you would have them do unto you.* (This echoes a strong point made in Holden's article.) This just about covers everything to do with a sustainable future that will be based on globalization.

In summary, citizenship education should be a key element in the science classroom and it should focus on sustainability. If we do not aim for this goal, then what *is* education for? And how will we leave the UK and the rest of the planet for the next generation?

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