

The relevance of science in a 'black box' technological world

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ABSTRACT This article questions the need for relatively shallow, widespread, scientific literacy across a broad range of topics if it lacks the conceptual depth, and/or intellectual rigour, to provide any basis for rational, scientifically informed choices. We suggest that *functional*, widespread scientific literacy should only be taught in key stage 3 (age 11–14) and should focus in greater depth on those areas of science relating to human health and some basic chemistry and physics. We also suggest that, in a 'black box' technological world, individuals can be effective users of technology, and the underlying science, without the need for scientific literacy.

What is it reasonable to hope and expect that ordinary citizens will know about science in order to equip them for life in a scientifically and technologically complex culture? (Durant, 1994: 83)

That there is a need for widespread scientific literacy is a belief shared by many. Indeed, Millar (1996: 7) noted there to be '*a broad consensus, both within the education system and beyond, that all children should study science throughout the period of compulsory schooling...*'. Indeed, other than the occasional dissenting voice (e.g. Shamos, 1995; Teitelbaum, 2003) the need for widespread scientific literacy remains a widely held belief within both the scientific and science education communities.

This article will argue that widespread, functional scientific literacy, such as would enable the average individual who ceases to study science at age 16 to make rational, scientifically based choices about a *broad* range of socio-scientific issues, is both unrealistic and unachievable. Indeed, any attempt to develop widespread scientific literacy, without a corresponding development of scientific subject knowledge, leads simply to a form of pseudo-scientific literacy that is all but indistinguishable from personal, non-scientific beliefs.

This does not imply the abandonment of teaching for widespread scientific literacy *per se* but rather a recognition of the need for a much more tightly focused form of scientific literacy. The aim of this would be to enable individuals

to make rational, scientifically based choices in a *narrow* range of socio-scientific issues. These issues would be linked with students' natural interests (since the subject would still be taught at school) and would focus primarily on human biology, along with some aspects of chemistry and physics – the biggest of the '*big ideas*' (Harlen, 2015), all of which could be taught by the end of key stage 3 (age 11–14). With the teaching of tightly focused scientific literacy completed by the age of 14, biology, chemistry and physics would, like history, music, modern foreign languages (MFL) and geography in England, become optional subjects. This would have two primary benefits. First, it would enable the teaching of science to return its focus to science content – a move away from what Sir Richard Sykes, Rector of Imperial College London, stated on BBC News (2006) as being a '*dumbed down syllabus*'. That is, biology, chemistry and physics taught at key stage 4 (age 14–16) would be designed specifically for those students wanting to pursue a science subject post-compulsion, i.e. science for future scientists. Second, it would help to reduce the chronic shortage of science (predominantly physics) teachers (see, for example, Institute of Physics, 2016) as there would be far fewer physics classes in key stage 4, potentially enabling physics specialists to teach in more than one school rather than having to rely on non-physicists to teach the subject.

The aim of this article is not to argue that science education is unimportant, far from it, but rather to question critically, on the basis of available evidence, the need for relatively shallow, widespread scientific literacy across a broad range of topics. While such questioning might prove as unpopular as drawing attention to the fact that the emperor was, in fact, not wearing any clothes, there is a need to move away from opinion-dominated claims – often made by those with specific interests and/or agendas – towards an approach that is far more informed by evidence. We cannot simply keep on repeating the same 'science for all' mantra in the hope that, if we do so frequently enough, we will avoid the need to produce the evidence to show that it is a worthwhile and realisable goal.

One of the aims of this article will be to suggest that a feature of living in a scientifically and technologically advanced society is that we have no real choice other than to rely on experts, as we simply cannot have a sufficient depth of knowledge, across all topics, to be able to make rational, scientifically informed decisions on the basis of our understanding of the relevant evidence – even experts disagree. Indeed, we suggest that one of the main reasons why scientific literacy ought to focus on human biology, along with some aspects of chemistry and physics, and we believe that this could be done effectively by the end of key stage 3, is that there is little need for scientific literacy in terms of an individual's ability to use technology effectively. Indeed, we argue that the reason why technology has been so massively effective in shaping our lives, and the nature of the society in which we live, is the very fact that it can be used *without* the need for any scientific understanding of how or why it works. Essentially, user-friendly technological devices – such as mobile phones, USB sticks, or in-car satellite navigation systems – that function as 'black boxes', enable all members of society to utilise technology and the underlying science, without themselves having to be scientifically literate in order to do so.

Thomas and Durant (1987) provided nine arguments for why people should know something of science and these arguments have been subsequently grouped into five categories by Millar (1996). Our approach will be to take these five arguments and look at the evidence for and against each in turn.

The economic argument

There is no denying that highly qualified scientists are needed to meet the needs of science-based industry in what is a very competitive global market. However, what these industries require of the educational system are not students who leave school with a benchmark GCSE qualification in science at 16 but, rather, highly qualified scientists – and here we are talking about those leaving university with degrees (and ideally research degrees) in science subjects. And, even here, the economic argument overlooks basic free market principles of supply and demand (Shamos, 1995) that would suggest that if practising scientists (as against a science graduate who works in corporate finance) play such a key role in the economic prosperity of the nation then their salaries should rise to attract and retain them as practising scientists. Indeed, despite claiming to need ever more scientists, 74% of those who graduate in the USA with a major degree in science, technology, engineering and maths – the STEM subjects – find employment outside of these areas (Census Bureau Report, 2014), with similar findings being reported (Mellors-Bourne, Connor and Jackson, 2011) among science graduates in the UK.

Furthermore, what is still missing from the economic argument is research evidence that GCSE science provides industry with employees with essential levels of useable scientific knowledge and skills, without which those industries would be unable to function. Certainly, science-based industries would not be able to function without science graduates and postgraduates, but would they also be unable to function if, for example, their HR manager, or their reception clerk, did not have a GCSE in a science subject? While having GCSEs in science can sometimes enhance individual earning potential, this can owe more to the fact that having science GCSEs is given as a requirement for certain careers, such as primary teaching, and, again, research is needed to ascertain the extent to which those working in such careers use their GCSE knowledge and/or skills. Primary teachers still teach history and geography to their pupils without having to have a GCSE in those subjects themselves.

The democratic argument

This argument suggests that science knowledge enables individuals living in a scientific society – although we claim that we essentially live in a 'black box' technological world rather than a scientific one – to engage in debate and decision-making in contexts that involve scientific information. For example, it could be argued that individuals considering whether or not to object to the building of a local wind farm close to their home would benefit from an understanding of the nature of global warming, the payback time to offset the embedded carbon dioxide in the concrete turbine towers (and any access roads), dangers to wildlife, the viability of carbon capture for fossil fuel power station alternatives and the safe storage of nuclear waste – including an understanding of half-life – for nuclear power station alternatives.

However, what this argument fails to consider is the level of scientific conceptual understanding that is required in order to be able to make scientifically rational informed decisions. The fact that even highly qualified scientists can disagree, for example, on the dangers that might be associated with the use of nuclear power raises the question as to what can realistically be expected of students, with very basic scientific GCSE content knowledge, in terms of this and many similar arguments. Indeed, we suggest that a consequence of living in a 'black box' society is that we have to rely on experts and, if we rely on a doctor for a medical diagnosis, or a pilot to fly us around the world, is there any reason not to rely on communication system scientists or nuclear physicists to guide/advise us about the safety of mobile phones or nuclear power stations respectively?

Furthermore, there remains little objective evidence as to the extent to which individuals, even those with a high level of science education, make decisions based on their scientific knowledge. Slovic and Peters (1998) reported that people are more often influenced in their decision-making by their personal beliefs and values. For example, with regard to the construction of wind farms, 'NIMBYism' (an acronym for the phrase 'Not In My Back Yard') and, in particular, the impact on local house prices and vistas, might arguably be a much larger factor in an individual's decision-making process than an understanding of global warming.

The utility argument

This argument suggests that science knowledge – and again there is a lack of research evidence about the level at which this needs to be – is of practical value to individuals living in a society dependent on science. From such a perspective, it is important to teach science in school in order for students to develop the knowledge that will subsequently be utilised in decision-making about science-related issues at an individual level (for example, nutrition, health and safety), thereby enabling them to make rational, scientifically informed choices as consumers (Millar, 2002).

However, consumer choices appear often to be based on a host of factors other than scientific knowledge, and the need for using scientific knowledge in everyday life situations seems to be overly exaggerated. There is no evidence to suggest that physicists, for example, make better consumer choices on how to insulate their houses because they understand the laws of thermodynamics, or have fewer car accidents because they understand mechanics, or eat less food containing high levels of saturated fats because they are educated scientists, than non-scientifically literate people. Indeed, despite science being a core subject in England, we now have an increasing rate of childhood obesity and type 2 diabetes, which shows that the dietary choices made by those children, as well as their parents who also probably had a core science education up to the age of 16, are more likely to be based on taste preferences rather than scientific knowledge.

The social argument

This argument points to the need to maintain a link between science, and scientific research, and the wider non-scientific society. As Millar (1996) argues, the ever-increasing specialisation and remote nature of much scientific knowledge has created a gap between society at large and science, which threatens both. In this respect, it might be argued that a scientifically educated individual – although it is unclear what level of science education would be required – would feel less alienated from science and scientific research, and perhaps more in sympathy with the aims of science. Of course, this leaves unanswered, and unresearched, the question of whether individuals who might be considered as being scientifically

illiterate do in fact actually feel alienated from science, or whether that alienation is, erroneously, attributed to them by scientists who are unable to accept that some people are very content to simply use the products that science provides and rely on experts. Do passengers who fly on jet planes actually feel alienated from science because they lack an understanding of Bernoulli's Principle or Newton's Third Law, or is it the case that they just get on the plane and the question of how hundreds of tons of metal not only stays up in the air, but also moves very rapidly through it, either does not even occur to them or, if it does, the answers are simply of no interest to them?

The cultural argument

If science is, and we strongly believe this to be the case, one of the defining cultural products that characterise our society then part of the role of education is to pass on that cultural heritage to successive generations. However, while we see this as the strongest of the five arguments for the teaching of science to all students, we question whether, and on what basis, science is any more important in terms of cultural heritage than history, music or art, none of which are compulsory subjects in key stage 4. Furthermore, we might reasonably ask to what extent does the teaching of school science inculcate an awareness and appreciation of the contribution made by science to our cultural heritage, and might such an awareness and appreciation be better taught in history?

Conclusion

The reality of the complex society in which we live is such that, whether we like it or not, we

depend on experts and professionals. Most of us are users, rather than designers of technology and/or scientists and, irrespective of our academic achievements (or, just as importantly, lack thereof), we are all able to use our mobile phones, send emails and fly around the world without needing to know, or in many cases having any desire to know, anything about the underlying science that enables such technology to function. Our suggestion is that we need to recognise that, while there is undeniably a need for a level of functional scientific literacy in our society, this should essentially be focused onto those areas of science that relate to human health and some basic chemistry and physics – all of which could be effectively taught by the end of key stage 3. Beyond this point, we argue that there ought to be three, optional, academic subjects – biology, chemistry and physics – that are taught to those who *want* to study these subjects, and a general science that would be an option for those who might require some basic level of science in a future job and/or apprenticeship.

We would end by recognising that this, too, is an opinion-based article. What is needed is some research to examine the extent to which individuals in our society make use of any of the science that they have been taught at school, and the extent to which they are, if at all, scientifically literate after completing 5 years of compulsory secondary science education. Just as importantly, research needs to be undertaken to ascertain whether people do actually feel alienated from science and, if so, to what extent and whether this bothers them.

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