Belief *versus* acceptance: Why do people not believe in evolution?

*James D. Williams**

University of Sussex, School of Education, Falmer, Brighton, East Sussex, UK

Despite being an established and accepted scientific theory for 150 years, repeated public polls show that evolution is not believed by large numbers of people. This essay examines why people do not accept evolution and argues that its poor representation in some science textbooks allows misconceptions, established and reinforced in early childhood, to take hold. There is also a lack of up-to-date examples of evidence for evolution in school textbooks. Poor understanding by science graduates and teachers of the nature of science and incorrect definitions by them of key terminology, serve only to undermine efforts to improve public understanding of evolution. This paper has several recommendations, including the introduction of evolution to primary age children and a call to bring evolution back as the central tenet of biology.

Keywords: creationism; evolution; intelligent design creationism; misconceptions; science education

Introduction

Why people do not believe in evolution has no simple answer. With the creationist community promoting intelligent design as a viable scientific alternative to evolution, coupled with calls for the discussion of 'strengths and weaknesses' in evolution in the USA, challenges to evolution have entered a new era.[1] The creationist community is trying to generate a distinction between the old guard that pushed overtly religious creation-science and a new guard that purports to tackle evolution with a wholly scientific approach, intelligent design, while trying to distance itself from any religious motivations.

Part 1 of this essay considers belief in evolution by exploring the nature of beliefs and then misconceptions in science and addresses the issue of whether or not creationism is a worldview, as proposed by Reiss.[2] Part 2 considers evolution education in the UK and how it is presented in commonly used textbooks. Wider problems associated with a confused understanding of key scientific terminology, such as theory, law, hypothesis, etc., are also reported. Finally, recommendations are made for curriculum developers, educators, textbook writers and scientists.

While the UK is used as a source of evidence for the problems in dealing with evolution within the science curriculum, the recommendations and suggested approaches to dealing with creationism in the classroom will have implications for many other countries.

***Correspondence to:** J. D. Williams, University of Sussex, School of Education, Falmer, Brighton, East Sussex BN1 9QQ, UK.
E-mail: james.williams@sussex.ac.uk

Public belief in evolution

Public polls in a range of countries reveal that large numbers of people do not believe in evolution. The evidence suggests that creationism is on the rise, most notably in Turkey, the United Kingdom and Australia.[3,4] Creationism also has a foothold in many other countries, including Russia and Poland.[5–7] A recent conference at the Max Planck Institute for molecular biology at the University of Dortmund brought together a range of academics to discuss the rise of creationism and lack of understanding of evolution,[8] with many delegates reporting similar problems across Europe.

In a review of belief in evolution conducted across 34 countries, languishing at number 33, just above Turkey, as the country with the greatest percentage of its population who believe evolution to be false, was the USA.[9] America has conducted polls over a 30-year period and the percentage of adults that reject evolution has remained relatively stable, between 43 and 47%. In many other countries, regular polls with consistent questions do not exist, making year on year international comparisons very difficult, but occasional polls reveal that significant numbers of people still reject evolution.

A recent UK poll conducted by Theos, a religious think tank that undertakes research and provides commentary on social and political issues, resulted in a major report into attitudes and belief about evolution,[10] it revealed that:

- Only 54% of people know that Charles Darwin wrote *The Origin of Species*.
- Forty-two per cent of people believe that evolution presents some challenges to Christianity but that it is possible to believe in both.

The poll also examined people's opinions on the relationship between human beings and other living things and found that:

- Fourteen per cent of people think that human beings are just another species of animal and have no unique value or significance.
- Forty-three per cent believe that human beings are like other animals but are particularly complex and this complexity gives humans value and significance.
- Forty per cent believe that human beings are uniquely different from other living things and so have a unique value and significance.

Its findings overall are encouraging, though the lack of knowledge about the works of Darwin and that 40% of those polled, see humans as 'unique' will provide creationists with some comfort.

Worryingly, Just 37% of respondents agreed that Darwinian evolution is a theory so well established it is beyond reasonable doubt, with nearly a fifth (19%) believing it has little or no supporting evidence. Also 36% stated that the theory is still waiting to be proved or disproved. To me these statistics indicate that the public understanding of the nature of science, the status of theories and what constitutes scientific evidence may not be well developed.

Weird and implausible beliefs

For some fundamentalist evangelical Christians, belief in evolution represents much of what is wrong in society. Ham,[11,12] for example, claims that evolution is fundamentally evil.

> Many Christians recognize the degeneration that has occurred in society. They see the collapse in Christian ethics and the increase in anti-God philosophies. They are well aware of the increase of lawlessness, homosexuality, pornography, and abortion (and other products of humanistic philosophy), but they are at a loss to know why this is occurring. The reason they are in such a dilemma is that they do not understand the foundational nature of the battle. Creation versus evolution is the bottom line. (p. 100)

In contrast, many scientists who reject creationism, including Wolpert,[13] will emphasise the value-free nature of science, supporting an argument that science does not have a direct impact on ethical considerations.

> . . .science is the best way to understand the world, . . . for any set of observations, there is only one correct explanation. Also, science is value-free, as it explains the world as it is. Ethical issues arise only when science is applied to technology.

Ham represents an extreme version of 6-day creationism, and many Christians, or followers of many other religions, do not reject evolution outright or have Ham's extreme views on the supposed impact of evolution education on society, but we are a long way from establishing the scientific fact of evolution and an understanding of the theory which explains how evolution happens in the minds of the general public.

So why do people reject good science in favour of supernatural pseudoscientific explanations? Mazur[14] suggests that social influences, personality and sincerely held, but irrational, convictions are the key to understanding implausible beliefs. Social influences, *e.g.* belonging to a religion, are more a function of your family's beliefs than original belief of your own. Religious choice, he states is 'an accident of birth or an act of conformity. Once our religious identity is determined we coalesce with co-religionists, we see the world from our religion's viewpoint' (p. 192). Personality, says Mazur, also plays its part. The notion that people who believe implausible things or reject what seems to be common sense or scientifically evidenced ideas must be crazy, deranged, or idiotic and not 'normal' – a viewpoint put forward by Dawkins[15] – should be resisted. These beliefs almost certainly emanate from normal social processes such as religious upbringing or conversion in later life. Personality traits, claims Mazur, may predispose some people towards implausible beliefs but this is not necessarily related to IQ. Smart people who clearly do not have a low IQ will believe in creationism. Their belief is sincere. Mazur relates this back to childhood social attachments as well as attachment to spouses, loved ones, friends and associates.

Shermer's[4] analysis of why people 'resist the truth of evolution' (p.30) and believe creationism over evolution can be grouped under areas: a general resistance to science; a belief that evolution is a threat to specific religious tenets; the fear that evolution degrades our humanity; equating evolution with moral degeneration and a fear that evolution implies we have a fixed human nature. Shermer[16] offers a simple answer to why smart people believe weird things such as creationism, 'Smart people believe weird things because they are skilled at defending beliefs they arrived at for non-smart reasons' (p. 283). Their skill would be a natural product of their education.

Precisely why people do not believe evolution is complex. In my view it begins with the natural, intuitive development of 'creationist' ideas as a very young child. As Duschl explains,[17] this

> . . .reflect(s) the formation of an explicit theory based on their initial essentialist bias – that is, their initial tendency to believe that things have a true underlying nature. Thus a

> belief that species have fixed essences works against the necessary concept of a species as a probabilistic distribution of traits on which natural selection operates. (p. 101)

Once established, this belief is difficult to counter and may be reinforced by friends, family, or social attachments, *e.g.* to evangelical religious communities.

Evolution is also counterintuitive. This is the basis of intelligent design creationism. In 1809 William Paley[18] stated that should we find a pocket watch on a heath we would 'know' there was a watchmaker. Likewise the rock or stone we see alongside the watch needs no maker. How can any complex animal (*e.g.* a human) possibly be the result of natural processes and not be the intentional result of a designer? By adding the inherent bias towards the 'creationist' ideas young children have to the counterintuitive nature of evolution, not believing the scientific answer to evolution and believing in a supernatural, designer-led interpretation of the evidence becomes more likely.

The nature of misconceptions in science

From an educational point of view creationism is a misconception. There is evidence to suggest that young children (aged between 8 and 10) will independently develop a 'creationist'[1] idea about the origins of species, in most cases without direct contact with religious ideas.[19] All learners will have misconceptions, sometimes referred to as alternative conceptions, naive conceptions, or non-scientific conceptions. A misconception is identified by educators when what a person knows and believes does not match what is known to be scientifically correct. The key to good teaching is to understand how these misconceptions arise and then how to challenge them and move the learner towards the currently accepted position.

In an influential paper in science education, Novak[20] described eight principles of learning which, although often debated, are still broadly endorsed by psychologists and educators.

P1. Concepts (scientific and social) are acquired (very) early in life.
P2. Misconceptions are acquired early and are resistant to modification.
P3. Prior knowledge influences new learning.
P4. Information processing capacity is inevitably limited.
P5. Most (scientific) knowledge is stored hierarchically.
P6. Learners are seldom conscious of their cognitive processes.
P7. Epistemological commitments (or cognitive styles) of student thinking influence learning.
P8. Thinking, feeling and acting are integrated.

Misconceptions are difficult things to change in children, let alone adults. The constructivist approach to teaching is predicated on the idea that learners develop understanding from their experiences by generating rules and mental models to make sense of their experiences. Often these will be misconceptions. Teachers therefore need to be cognisant of those personal rules and mental models and, rather than disagree with these constructs and push the 'correct' answer on the learner, provide them with cognitive challenges that contradict their experiences and move them to a more acceptable scientific position. Simply stating that a misconception is wrong does not correct it. Misconceptions are persistent.

Misconceptions can be implanted through formal or informal teaching of incorrect ideas as well as being spontaneously generated. Much work has been done to understand how formal teaching may correct misconceptions.[17] If they are not challenged, the child, or adult, will have the ability to construct their own rational defence for the irrational belief they built or acquired and nurtured (as noted earlier by Shermer). This also links with Mazur's explanation for why their beliefs may be sincere. They link with childhood social attachments. Rejecting an idea provided by your parents or an authority figure may be, in the mind of the holder, a rejection of that individual or institution.

When a misconception is confirmed or reinforced by people who have knowledge, power, authority and who proclaim expertise (*e.g.* the creationist evangelical church minister who has a science qualification), it is built on a strong foundation, with strong social attachments. If it is not challenged early enough, a smart person can, and does, build a scaffold of misinterpreted evidence to shore up the irrational, yet sincere, belief.[21] The public understanding of science is replete with misconceptions – from widely held ideas such as plants obtaining their food from the soil to the misconception that we 'see with our eyes' and that dinosaurs and humans co-existed (a creationist favourite).

Applying Novak's principles to creationist misconceptions helps to define some of the issues teachers have when trying to deal with them in the classroom.

Children develop their own understanding or concept of the origins of species in primary school, often independent of formal teaching, home, or religious influences (P1). It has been shown through research that these conceptions are

[1]In this context 'creationist' does not refer to classical Christian Biblical creationism or any other form of religious creationism, but the notion that something has been 'created' by someone/something, *e.g.* a mythical or fantasy figure. For children in a religious environment, the classical religious creationism offers a solution to the issue of the origin of species or the development and diversity of life. When this definition is used 'creationist' will appear in quotation marks to distinguish it from Biblical creationism.

'creationist' and therefore represent a scientific misconception that is difficult to change (P2). Most children and adults who hold misconceptions are not aware that their ideas are incorrect (P6). When they are told their idea is incorrect, they struggle to overcome this (P2 and 4), often refusing to accept that they are wrong, especially if they have had a misconception for a long time (P2 and 3). People can hold a misconception through a formal examination and provide a correct answer, but still hold the misconception to be 'the truth' (P8). If the misconception is the incorrect notion that 'nature shows evidence of design' or that life must have a 'designer', regardless of whether you name that designer or not, you are laying a firm learning foundation for creationism (P2). The person with the misconception builds upon that foundation and accommodates new knowledge to fit with that misconception (P5). Teaching must utilise a variety of learning styles and adopt a number of approaches and provide cognitive challenges to affect a change in the misconception (P7). Early teaching is essential to challenge intuitively constructed misconceptions.

If young children are additionally indoctrinated with a creationist viewpoint through home education, church 'lessons', or by creationist literature aimed at the primary age group, the easier it is to provide slanted evidence to build on the natural misconception the child adopts. It is also easier to provide an interpretation of scientific evidence which 'fits' the misconception, making it far more likely to be accepted.

With creationists targeting young children with books, *e.g.* 'Dinosaurs by Besign'[22] or 'Dinosaurs of Eden',[23] or comics and posters that refute science and replace accepted geology with tales of a global flood, misconceptions can be implanted very early on. This tactic was reported by the author at the 2009 British Humanist Association international conference in London.[24] Creationists appeal to the interest that children naturally have in dinosaurs and fossils. Using this appeal to reinforce a misconception is nothing short of an intellectual abuse of children through what I call 'insidious creationism', the deliberate, slow, subtly harmful implanting of a scientific untruth. This is not done by the creationist community through ignorance, as those responsible are fully cognisant of the actual scientific standpoint on evolution and its acceptance by the overwhelming majority of scientists.[25] Since evolution as a concept is not formally taught in primary schools in the UK, it makes such challenges to creationist misconceptions harder to mount.

Worldview or misconception?

Is creationism a misconception that can be challenged or a worldview that must be accepted? Reiss[2,26,27] argues that rather than conceiving of creationism as a misconception that sound teaching can change, we should think of it as a worldview. In adopting this stance Reiss[2] concedes that a change from belief in creationism to belief in evolution may not happen.

> Accepting the worldview perspective does not mean that the biology teacher should shrink from presenting the evidence for evolution. However, it does help us appreciate why such teaching may not be as successful as we would hope. (p. 6)

This view may indeed reflect the situation that arises when trying to tackle the teaching of evolution later on in education. In the UK formal teaching about evolution as a theory does not happen until the age of 14 plus.

Aspects of the core scientific concepts that underpin the theory of evolution are taught earlier in the curriculum, *e.g.* variation, adaptation, heredity and habitats, but the idea of a theory of evolution by means of natural selection as a well-evidenced explanation for the development and diversity of life on earth is left too late to prevent early misconceptions taking root.

I disagree with Reiss and his idea of treating creationism as a 'worldview' rather than misconception. Misconceptions arise from worldviews (Fig. 1) and can be challenged. Creationism itself, I would argue, is part of a religious worldview. It is not a worldview in itself. Cobern,[28–31] in a series of articles discussing his worldview theory and the development of a scientific worldview, argues that children in science classes do not have a homogenous worldview. In a class of students from different social classes, ethnic backgrounds, *etc.*, there will be a range of different worldviews. What affects their approach to and acceptance of science can be, and is, affected by their worldview. It is not a failure to understand something; it is more that the students do not believe what is being taught. It is this aspect – belief – that needs to be tackled in science classes and a solution found as to how we may challenge misconceptions (creationism) without having to destroy beliefs or faith (worldviews) in the process. As Cobern[28] states,

> a worldview cannot be reduced to a set of scientific conceptions and alternative conceptions about physical phenomena. . . .worldview is about metaphysical levels antecedent to specific views that a person holds about natural phenomena, whether one calls those views commonsense theories, alternative frameworks, misconceptions, or valid science. A worldview is the set of fundamental non-rational presuppositions on which these conceptions of reality are grounded. (p. 584)

Worldviews may be thought of as schemas, or representations, constructed to make sense of a range of beliefs and observations about the natural world or universe, where supernatural causations for phenomena are not ruled out. It is the way in which a person would see and interpret the world.

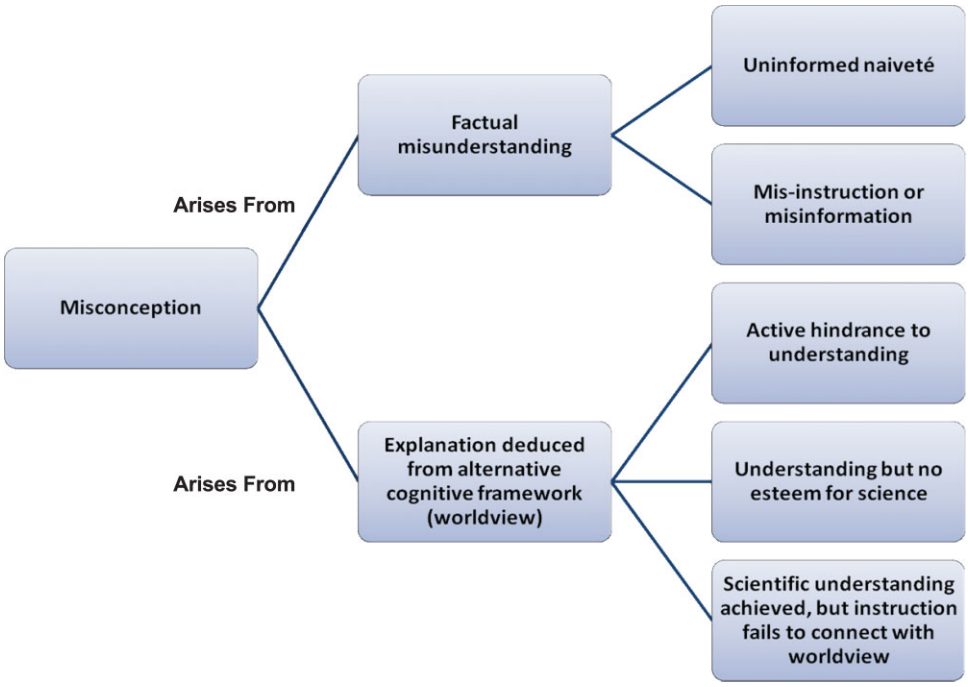

Figure 1. The relationship between misconceptions, scientific understanding and worldviews (adapted from Cobern [28]).

For example, a geocentric worldview would be one in which the earth is seen as the centre of the universe; alternatively, a heliocentric worldview sees the sun as the centre of a particular point in the universe. A religious worldview would be developed not from an individual's own beliefs but from an acceptance of the cultural beliefs of the society to which that person belongs. Cultural history and traditions, therefore, serve to create such worldviews. Christian creationism is one specified view of the origin of life on earth. Many different cultures have different creation stories and mythologies, from the Vedic thinking of the universe coming from an egg to the Aztec's earth mother and the Inuit raven that created the world.

Science education, scientific literacy and evolution in the textbooks

A good science education should have at the heart of its biology curriculum an understanding of evolution. Major health issues such as the rise in hospital infections caused by MRSA and CDiff are linked to evolution, with many teaching courses now referring to the evolution of resistance to antibiotics by bacteria as an example of evolution 'in action'. Having a well-educated, scientifically literate population is an aspiration for many governments. Indeed, it is an aspiration for many scientists. As far back as 1959, Snow[32] saw the failure of communication between the sciences and humanities, the two cultures, as impeding progress and our problem solving abilities. In 2003, Greenfield[33] argued that unless and until we can make science as socially acceptable as sport, or as fun as going to the cinema, we would be unable to harness the power of science to deliver what we really want in life. In a response to this call for greater scientific literacy, Turney[34] cited evidence that despite the growth of popular science books, surveys of the general population's understanding of science in general in the UK are stable and people are indifferent to science.

Here is a paradox. Natural history and science museums enjoy buoyant visitor numbers. Many of the exhibits at the museums will provide evidence for evolution from transitional forms to elaborate displays of human evolution. The recent 'Darwin's Big Idea' exhibition at the Natural History Museum in London, celebrating the 200th anniversary of Darwin's birth and the 150th anniversary of the publication of 'Origin of Species' drew large crowds. Why is evolution not accepted universally and how has intelligent design gained public acceptance?

Forrest and Gross[35] have examined the intelligent design movement – the most recent manifestation of American Biblical creationism – in detail. They expose the 'Wedge Strategy', which outlines the introduction of a supposed scientific alternative to evolution and document its aggressive political and public relations campaign, which focusses on impressing the public at large and the State education boards in America. The most notable feature of the movement's purportedly new scientific paradigm is an abject failure to produce scientific data in support of its claims or even a coherent research programme. Indications from public polls

appear to show that the campaign is appealing to the general public, though the scientific community rejects intelligent design.[25]

The attention given to evolution as a topic in UK science education is scant to say the least. It is poorly presented and uses out of date examples from nature to support evolution theory. But another issue also is evident. The UK science curriculum in general does not give prominence to the study of evolution. As the central tenet of biology, it should be at the heart of the science and biology curriculum, not on the fringes. In the UK, children only start to tackle evolution as a theory and guiding concept between the ages of 14 and 16, yet there is no reason for it to be included so late in our science education. A recent article in a primary science journal[36] called for the teaching of evolution much earlier, stating that Darwin's theory can be used as an example of the process of science, *i.e.* what the UK science education system calls 'How Science Works'. The article goes on to state that it can also be fun for children to learn as it appeals to their natural curiosity and the story behind the theory is a fascinating one for children to learn. Sadly, science has just been demoted from the UK primary curriculum as a core subject. What effect this may have on science education in general is yet to be seen.

When evolution is finally introduced in the last two formal years of education in the UK, the subject is not necessarily well covered and it is not comprehensive. There is a persistent use of old, 'standard' examples from the evolution of the horse, presented as a linear sequence,[37,38] to the peppered moth, where sometimes confusion arises over whether this represents evolution or natural selection. The textbooks, when they do cover evolution and the story of its development as a theory, often contain inaccurate information, from minor errors, *e.g.* stating that Darwin was the Beagle's 'on-board biologist',[39] to an omission of any mention of the co-discoverer, Alfred Russel Wallace.[37]

In yet another science textbook[40] an illustration of a film poster for *Godzilla*, showing a dinosaur-like fire-breathing fictional creature, is captioned 'dinosaurs once ruled the planet'. Not only is this caption misguided, in that the film creation *Godzilla* was neither real nor a dinosaur, but the notion that dinosaurs could breathe fire merely gives credence to creationist claims of dinosaurs being the source of the stories of fire breathing dragons in mythology. Add to this the description of frozen mammoths as 'ice fossils',[38] when a more correct term would be ice mummies and it is no wonder that confusion is evident.

The language of science

More disturbing than errors in the textbooks, which could be corrected, is the apparent lack of understanding that science graduates have of the nature of science and their confused definitions of key terminology such as 'fact', 'theory', 'law', and 'hypothesis'.[41,42] When creationism plays on vernacular meanings of words to discredit science by claiming that evolution is 'not a fact' or 'just a theory', we should expect science to be able to defend its position. Yet some scientists are guilty of being imprecise with their use of terminology, *e.g.* when theory and hypothesis are used interchangeably.[2]

Small-scale research into the issue of science graduates' understanding of scientific terminology reveals that many have confused and incorrect ideas about the nature of science and an inadequate understanding of key scientific terminology. Studying aspects of the history and philosophy of science and how science has developed as a discipline over time would help to alleviate such confusions, but it is evident that this is not the norm for science undergraduates.[41–43]

Another issue is the use of design-orientated language in peer-reviewed, published scientific articles. This use of design language only serves to reinforce the intelligent-design creationist's stance of 'inference to design' for the origin of complex biological structures, rather than the evolution of such structures through natural selection. If scientists use the language of design in their technical papers, or use such language to help translate complex technical science to a wider audience, this can encourage and reinforce misconceptions. For example, in a paper published by the Proceedings of the National Academy of Sciences[44] the following statement was made on the structure and function of the Müller cells in the eye:

> At the same time, the increasing refractive index together with their funnel shape at nearly constant light guiding capability. . . make them ingeniously designed light collectors. (p. 8290)

The author surely did not intend to show evidence of a designer – this is an example of imprecise language in a scientific paper – which is counterproductive. It was seized upon by the creationist community as 'scientific evidence of design'.[45]

In the teaching of science, language plays a central role. As well as explaining scientific terminology, decoding the structure of scientific language and identifying the roots, prefixes and suffixes that characterise scientific narrative, teachers and scientists should reject talk of a 'belief' in evolution. This approach also serves to resolve, in part, the issue of a rejection of evolution due to a clash with an established religious viewpoint. We do not, for example, talk

[2]A recent television programme in the UK on the nature of sleep showed an American scientist describe, first of all, his 'hypothesis' that not eating during transatlantic flights would reduce considerably the impact of jet lag. In another scene, the same scientist referred to his 'theory' about eating and jet lag. Although this was a popular science documentary, the confusion between theory and hypothesis was explicit and will only serve to add to public confusion over the status of such terminology.

about 'belief' in gravity or atoms; we accept them due to the weight of scientific evidence. The same is true for evolution. It is accepted as a scientific fact due to the weight of evidence. Acceptance of something does not preclude belief in God or other forms of religious belief or faith. This approach would not have impact on any 'religious worldview' held by a child or its parent, but it does allow misconceptions to be challenged with evidence.

Conclusion and recommendations

It is clear that creationism, in whatever form, is not going to disappear. To combat any rise in creationism and to ensure that evolution education is at the core of our biology teaching, certain actions must be taken:

1. Policy-makers and curriculum developers must begin to provide for evolution education in primary schools. Creationist misconceptions implanted or naturally occurring in primary age children will be very difficult, if not impossible, to correct at a later date.
2. School science textbook and resource writers must provide better, more up-to-date examples of evolution – from the wealth of evidence that exists in the scientific literature and museum collections.
3. Pre-service and practising teachers must be given the tools to combat creationist arguments as well as a way of dealing with creationist interventions by pupils in science classrooms (*i.e.* discuss acceptance not belief).
4. The community of science educators must come to an agreement on the definitions of key terminology associated with the nature of science and scientific enquiry as used in our school-based science education.
5. Scientists must avoid inappropriate and imprecise language, such as design-related terminology, in the communication of their findings to their peers and the public.

We cannot prevent the publication of creationist books and comics aimed at children, but as a community of scientists and science educators we can prevent creationist ideas being taken on board by our children and students as 'factual'. We can help prevent misconceptions taking hold.

For too long science has been on the back foot reacting to carefully researched creationist arguments that look for areas of science where the evidence is incomplete; not missing, not weak, not unobtainable in time. While science may not have provided all the answers to the development and diversity of life on earth, one thing is certain, creationism, in all its forms, has provided not a single answer. Over the past 100 years it has moved considerably towards accepted evolutionary science, with, for example, their full acceptance of natural selection and the emergence of new species. Evolution has never moved towards creationism.

It is time for science, and biology in particular, to be proactive. The close of Darwin's bicentennial year is a good time to resolve to restore evolution as the central, guiding tenet of biology and re-establish its position at the heart of biological education.

References

1. **Plutynski A.** 2008. Should intelligent design be taught in public school science classrooms? *Sci Educ* DOI: 10.1007/s11191-008-9169-z
2. **Reiss MJ.** 2009. The relationship between evolutionary biology and religion. *Evolution* **63**: 1934–1941.
3. **Williams J.** 2008. Creationist teaching in school science: a UK perspective. *Evol: Educ Outreach* **1**: 87–95.
4. **Shermer M.** 2009. Why Darwin Matters. New York: Henry Holt and Company. p 199.
5. **Koenig R.** 2007. Creationism takes root where Europe, Asia meet. *Science* **315**: 579a.
6. **Levit GS, Hoszfeld U, Olsson L.** 2006. Creationists attack secular education in Russia. *Nature* **444**: 265.
7. **Hameed S.** 2008. Science and religion: bracing for Islamic creationism. *Science* **322**: 1637–1638.
8. **Curry A.** 1999. Scientists clueless *vs.* creationism? Creationist beliefs persist in Europe. *Science* **286**: 1843b.
9. **Miller JD, Scott EC, Okamoto S.** 2006. Science communication: public acceptance of evolution. *Science* **313**: 765–766.
10. **Lawes C.** 2009. Faith and Darwin: Harmony, Conflict or Confusion. London: Theos. p 113.
11. **Ham K.** 1987. The Lie: Evolution. Green Forest: Master Books. p 184.
12. **Ham K.** 2009. Ken Ham – speaker information. *Answers Genesis* Available at: http://www.answersingenesis.org/home/area/about/ham.asp
13. **Wolpert L.** 2005. Life Lessons. London: The Guardian.
14. **Mazur A.** 2008. Implausible Beliefs. London: Transaction Publishers. p 246.
15. **Ross C.** 2008. Dawkins Warns of Human Extinction. Inverness, Scotland: The Inverness Courier.
16. **Shermer M.** 2007. Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time. London: Souvenir Press. p 384.
17. **Duschl RA, Schweingruber HA, Shouse AW.** 2007. Taking Science to School: Learning and Teaching Science in Grades K-8. Washington, DC: National Academies Press.
18. **Paley W.** 1809. Natural Theology: Or, Evidences of the Existence and Attributes of the Deity. London: J. Faulder.
19. **Evans EM.** 2001. Cognitive and contextual factors in the emergence of diverse belief systems: creation *versus* evolution. *Cogn Psychol* **42**: 217–266.
20. **Novak JD.** 1988. Learning science and the science of learning. *Stud Sci Educ* **15**: 77–101.
21. **Tekkaya C.** 2003. Remediating high school students' misconceptions concerning diffusion and osmosis through concept mapping and conceptual change text – research in science & technological education. *Res Sci Technol Educ* **21**: 5–16.
22. **Gish DT.** 1992. Dinosaurs by Design. Green Forest: Master Books/New Leaf.
23. **Ham K.** 2000. Dinosaurs of Eden. Green Forest: Master Books. p 64.
24. **Williams JD.** 2009. Insidious Creationism: The intellectual Abuse of Children Through Creationist Books, Comics and Literature. Darwin, Humanism and Science. London: British Humanist Association.
25. **Leshner A.** 2009. Public Praises Science; Scientists Fault Public: Scientific Achievements Less Prominent Than a Decade Ago. Washington, DC: American Association for the Advancement of Science/The Pew Research Center for The People and The Press.
26. **Reiss M.** 2007. Imagining the world: the significance of religious worldviews for science education. *Sci Educ* **18**: 783–796.

27. **Reiss MJ.** 2008. Should science educators deal with the science/religion issue? *Stud Sci Educ* **44**: 157–186.
28. **Cobern WW.** 1996. Worldview theory and conceptual change in science education. *Sci Educ* **80**: 579–610.
29. **Cobern WW.** 2000. The nature of science and the role of knowledge and belief. *Sci Educ* **9**: 219–246.
30. **Cobern WW.** 2004. Apples and oranges: a rejoinder to Smith and Siegel. *Sci Educ* **13**: 583–589.
31. **Cobern WW, Loving C.** 2008. An essay for educators: epistemological realism really is common sense. *Sci Educ* **17**: 425–447.
32. **Snow CP.** 1993. The Two Cultures. Cambridge: Cambridge University Press. p 183.
33. **Greenfield S.** 2003. A New Kind of Literacy. London: The Guardian.
34. **Turney J.** 2003. How Greenfield Got It Wrong. London: The Guardian.
35. **Forrest B, Gross PR.** 2007. Creationism's Trojan Horse: The Wedge of Intelligent Design. USA: OUP. p 448.
36. **Nicholson C.** 2009. The teaching of evolution in primary schools. *Prim Sci* **107**: 13–15.
37. **Sherry C.** 2005. OCR gateway science B. In Sherry C. ed; OCR Gateway Science. London: Collins. p 267.
38. **Breithaupt J, Fullick A, Fullick P.** 2006. AQA Science. Cheltenham: Nelson Thornes. p 331.
39. **Gadd K.** 2005. AQA GCSE science A + B. In Gadd K. ed; AQA Science. London: Collins. p 312.
40. **Arnold B.** 2005. Edexcel 360 science. In Arnold B. ed; Edexcel GCSE Science. London: Collins. p 295.
41. **Williams JD.** 2007. Do we know how science works? A brief history of the scientific method. *School Sci Rev* **89**: 119–124.
42. **Williams JD.** 2008. Science now and then: discovering how science works. *School Sci Rev* **90**: 45–46.
43. **Williams JD.** 2008. What makes 'science' science? *The Scientist* **22**: 29.
44. **Franze K, Grosche J, Skatchkov SN,** *et al.* 2007. Müller cells are living optical fibers in the vertebrate retina. *Proc Natl Acad Sci USA* **104**: 8287–8292.
45. Anonymous. 2007. New design feature discovered in vertebrate eye. *Truth in Sci* Available at: http://www/truthinscience.org.uk/site/content/view/241/63