Conceptual frameworks, metaphysical commitments and worldviews: the challenge of reflecting the relationships between science and religion in science education

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Abstract

One issue for science educators who are concerned that science teaching should be inclusive, and so should be accessible to all students, is the perception of science as in some sense essentially contrary to religion, and inherently atheistic. This is a view that has been strongly presented in public by some scientists, and - despite not representing the views of the scientific community - it is a perspective that seems to have been accepted by many school children in some national contexts. If students who have a personal faith, or at least identify strongly with faith communities, consider that science is essentially opposed to religion, then they are likely to feel excluded, compromised, disadvantaged or indeed alienated from science and science classes. School age learners are known to generally have limited understanding of the nature of science, and may not appreciate the distinction between the extra-scientific claims made about science by some of its practitioners, and the 'scientific values' that are adopted as shared commitments by the scientific community as a whole. This chapter offers an analysis of this issue, and argues (i) that a pluralist science education should be informed by the distinction between the metaphysical commitments (some shared, some not) that scientists bring to their work, and the conceptual frameworks and knowledge claims that are constructed and critiqued through scientific discourse itself; and (ii) that inclusive science education must explicitly represent the diversity of views within the scientific community on whether, and if so how, science and religion are related.

Key words: science & religion; worldviews; metaphysical commitments; scientific values; extra-scientific considerations

Introduction

Learning is mediated by social interactions, and education involves the induction of learners into facets of culture that are represented, explicitly or implicitly, in curriculum. Yet for many young people growing-up in technologically advanced, multicultural societies, learning occurs in a range of contexts and is mediated by diverse groups of others: the home and its extended family and social community; playtime peer groups; indirectly through interaction with the media-rich environment (newspapers and magazines, television programmes, the internet etc); *as well as* in the formal learning context of the school class. Indeed, whilst a school may have an 'ethos', and represent certain values and norms (which may match those of the home to differing degrees), it also offers mediated access to those elite features of culture: the academic disciplines – *each* having their own norms and privileged ways of behaving, thinking, communicating and so forth. Science is one such way of knowing and acting in the world, and Alsop and Bowen (2009, p. 53) have argued that in science education "an overwhelming emphasis (in research and practice) is put on induction and initiation into a subculture and its associated epistemology - the language, culture and tradition of science".

Entering the science classroom has been compared to making a 'border crossing' for students (Aikenhead, 1996), as the world of science (as represented in school science) may seem quite foreign to many pupils. School science is a form of mediation into a particular way of using language (Lemke, 1990); a specific set of customs for how one should think and come to knowledge. The privileged concerns, the ways of doing things, and especially the ways of communicating, may be quite at odds with the learner's life outside the science classroom (Solomon, 1992). Regardless of whether this is something welcomed by, or alienating to, students; it certainly adds to the 'learning demand' (Leach & Scott, 2002) of the subject. It has been argued that many of the common 'alternative' (i.e., contrary to scientific thinking) conceptions exhibited by science learners can be considered as the application of life-world knowledge (Schutz & Luckman, 1973) that functions effectively in everyday social exchanges, but is inadmissible as part of formal scientific discourse (Claxton, 1993; Solomon, 1993; Taber, 2009). Students may find that something that works well in a more familiar language community seems to be judged as inadequate in the particular context of the science lesson.

The present chapter considers one particular aspect of cultural mediation of learning in the science classroom: that of the relationship between science and religion. This issue has attracted much public attention because of the question of teaching scientific theories of origins (the 'big bang'; and in particular evolution by natural selection) to those for whom such ideas are perceived as contradicting their own faith commitments (Antolin & Herbers, 2001; Poole, 2008). In some contexts, such as the U.K., it is sometimes perceived as a 'minority' (i.e. fundamentalist) issue, as the main-stream Christian churches have long been happy to accommodate scientific theories. In such a context, suggestions that teachers need to engage in dialogue with pupils on such issues (Reiss, 2008) - despite being supported by research evidence (Verhey, 2005) - have been criticised (Vallely, 2008), for example as a 'slippery slope' towards relativism.

However, such simplistic responses ignore the complexity of the issue in practice. Many pupils from faith backgrounds (not just those who identify with 'fundamentalist' groups) hold to worldviews that encompasses the supernatural as an *integral* part of their world in which they live. Science does not inherently exclude the existence of a supernatural realm (although *some* scientists, including some high–profile science 'media stars' do vehemently claim otherwise), but does in a sense require it to be put aside when doing scientific work. Moreover, there are a range of positions that can be taken about such matters as: the extent of the magisterium of science; the absolute nature of scientific laws; the potential of science to offer explanations; the ability of human minds to understand the nature of the world; and so forth. These are largely metaphysical matters: they are not (and cannot be) determined by empirical work in science; but underpin the very values that inform the enactment of science itself.

School science offers a representation of the nature of science (Millar, 1989), and science teachers portray messages about such matters (intentionally or otherwise). However, in many educational contexts, teachers are often not well informed about the nature of science, and in particular its philosophical underpinnings (Hodson, 2009). The preparation of science teachers often offers them limited support for developing an appreciation of the range of respectable scholarly positions about the relationship of science and religion, and the range of views about the nature and limits of science that in part underpin such positions. That is, teachers may not appreciate how the culturally constituted set of ‘scientific values’ which are shared commitments within the community of science, and into which scientific training inducts new community members (Kuhn, 1996), can obscure a diversity of underpinning ontological, epistemological and axiological frameworks informing different individual scientists’ work. Teachers are therefore often not well placed to mediate a balanced view about such issues through their own interactions with pupils in the classroom.

Consequently, there is much potential for the image of science offered to pupils to be scientistic: one of an all-encompassing, and exhaustive approach to understanding the world. Often, the view communicated in school science (i.e., the message as perceived by many students, regardless of whether intended) is that the natural world is all there is, and that it can in principle be fully understood by science (Francis, Gibson, & Fulljames, 1990; Fulljames, Gibson, & Francis, 1991; Hansson & Redfors, 2007; Taber, Billingsley, Riga, & Newdick, 2011a, 2011b). Such a world is very much at odds with the one inhabited by many scientists of faith (Berry, 2009); and certainly is an alien world for many school pupils.

The tradition in Western science (with its tendencies towards an analytical and reductionist approach) to precede as though the existence and potential role of God in nature is irrelevant to answering scientific questions, if not explicitly explained to students, may well give the impression that because *science* (as a socio-cultural activity) does not need to adopt the hypothesis of the divine, *scientists themselves* (as individuals sharing membership of various social groups with their identities as scientists) eschew such an idea. This is likely to be especially the case for learners who have been brought up in a faith tradition that considers God to be immanent in all things, and which teaches that the believer should put God at the core of their entire life. A theist who considers God to work through nature might well take the methodological stance that she or he is likely to come to a better understanding of God’s work by proceeding in scientific work *as though* God is irrelevant: but this may not be inherently obvious to school students. Indeed, if ones whole life is ground in a belief that God works through and maintains all aspects of nature, then this may operate as a taken-for-granted commitment that no more needs to be made explicit in accounts of scientific work than the taken-for-granted assumption that the scientist breathed air, or stopped for meal breaks, during scientific work. Yet the potential for alienating many pupils from science (and so advanced scientific study and scientific careers) is clear.

The present chapter sets out a discussion of this major problem in science education, by considering some of the range of metaphysical commitments that inform different understandings of the nature of science (in particular, in its relationship to religions), and considering how these can contribute to making pupils' 'border crossings' (Aikenhead, 1996) into science more or less problematic. Such an analysis is needed as the first step to supporting teacher education in the issue, something that is essential if we wish to ensure that the image of science mediated by teaching is not more alien to many young people than it needs to be.

Cultural border-crossing in science education

To understand how young people respond to school science, we have to acknowledge its cultural dimension, in the sense that school science offers certain norms (e.g. ways of talking, and so legitimised ways of thinking) that may seem strange to students such that they experience science lessons as somewhat 'alien' or 'other'.

For some scientists, science may be an important *part of* culture, yet also considered cross-cultural in the sense of science being seen as 'universal'. After all, natural science is intended to be about the way the world is *independently* of human contingencies (Bhaskar, 1975/2008). Yet science has been subjected to various critiques that consider that *the practice of science* has reflected norms of particular social or cultural groups rather more than others: for example feminist critiques suggesting that science has traditionally reflected ways of thinking predominantly associated with what it is to be masculine (Bentley & Watts, 1987). Similarly, it has been argued that it is far from clear that science today can be considered pan-cultural and 'universal' (Harding, 1994).

Science as culture

Indeed the notion that any person can completely rise above their socio-cultural context (or even fully recognise its influence) is questionable: it is important not to under-estimate the significance of culture on each one of us. Indeed Geertz has gone as far as to suggest that,

> "Whatever else modem anthropology asserts - and it seems to have asserted almost everything at one time or another - it is firm in the conviction that [people] unmodified by the customs of particular places do not in fact exist, have never existed, and most important, could not in the very nature of the case exist"
>
> (Geertz, 1973/2000, p. 35)

Science is practised by people from specific cultural contexts, who are products of those contexts. As such, they will bring with them particular ways of thinking and understanding the world, and particular value systems, at least parts of which will have in effect become 'second nature' (or perhaps, in view of Geertz's comment, just, 'their nature') during their upbringing, and so will in effect be invisible, and therefore influence them in an insidious way.

Kuhn's (1996) famous work on the structure of scientific 'revolutions', acknowledged this. Whilst some saw his essay as the justification for taking a relativistic view of science, a weaker version of the thesis (more akin to Kuhn's own position), would be that scientists are never going to be able to completely immune to biases deriving from extra-scientific background issues. This is, in effect, little more than acknowledging that any person's current thinking is inevitably contingent upon, and so influenced by the cognitive resources available (what might variously be described as ideas, knowledge, beliefs, expectations, habits of mind etc.) This is recognised in science education in how learners very commonly come to alternative understandings of many scientific ideas because their existing ideas provide the interpretative frameworks for making sense of science teaching (Taber, 2009).

Indeed, research in student learning in science not only finds some very common alternative conceptions which appear to develop in a range of educational contexts (and so may reflect 'genetically directed' aspects of how the human cognitive apparatus tends to process information about its environment), but also some differences between populations in different educational contexts (e.g., Brewer, 2008): suggesting that different cultural backgrounds channel students' understanding of scientific ideas in different directions.

Much the same will happen with scientists themselves. Professional scientists may be in a better position to recognise and overcome sources of 'bias', and science itself is set up to do just this, but if science is dominated by some cultural groups (e.g. mostly men, or mostly those educated in a European/North American tradition, etc) then there are likely to be consequences.

Worldviews

One notion which has come to be increasingly used in considering such issues is that of a person's 'worldview', that is, a set of "assumptions held by individuals and cultures about the physical and social universe…[including] the purpose or meaning of life" (Koltko-Rivera, 2006, pp. 309-310). These assumptions may be held implicitly, but concern fundamental commitments,

> "Thus, 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."
>
> (Cobern, 1994, p. 6, italics added)

When Cobern refers to such assumptions as 'non rational', this is not intended in a pejorative sense, but rather reflects their nature as starting points for coming to make sense of the world. Whilst metaphysics *as a topic of discussion* in its own right might be seen as the business of philosophers, fundamental intellectual commitments in terms of how we understand the nature of the word we experience are essential to sense-making for all of us (see figure n.1).

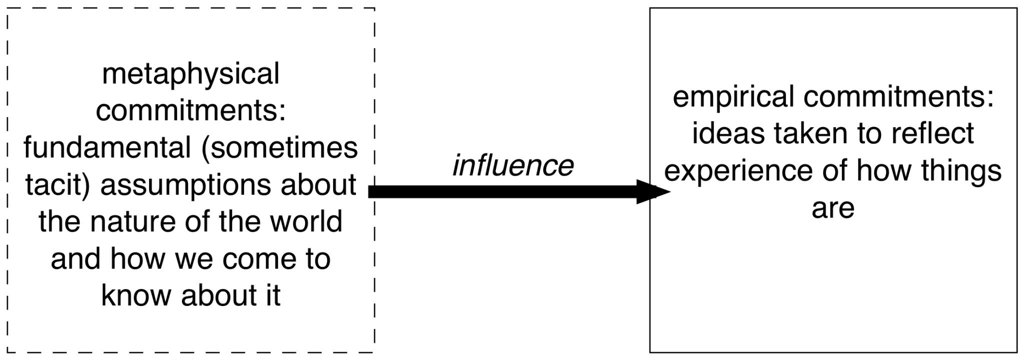

Figure n.1: The ideas we have about the ways things are, that we consider to be based upon our experience in the world, are influenced by background assumptions that we may not always be explicitly aware of

Arguably, there have to be some such commitments as starting points for making sense of the world that in themselves are not open to logical demonstration. The modern ('Western') scientific tradition has been built upon the two foundations of empirical evidence and rational thought, but the claims relating to these grounds have been subject to ongoing discussion by philosophers (Losee, 1993). It is worth pausing to consider how one would try to persuade another individual of any scientific claim if they did not accept (a) that evidence from experience had any relevance to the true nature of the world and/or (b) that logic could be relied upon as the basis for sound thinking. Perhaps it seems unlikely that anyone should take such a stand, but if we accept the possibility for argument's sake, then finding grounds for accepting these starting points, *without actually drawing upon them to make the case*, might seem a rather forlorn project. Without an alternative foundation, the whole of science (and much else) could be considered somewhat tautologous.

An individual's worldview may in particular include religious beliefs that are basic assumptions about the nature of the world in which we live. Hodson comments that "because a worldview includes fundamental beliefs about causality and about humanity's place in the world, it is fairly easy to see how it could be incompatible with the fundamental metaphysical underpinnings of science" (2009, p. 120). Thagard (2008, pp. 385-386) offers an example from considering the history of medicine, where "popular concepts of life, mind, and disease are tightly intertwined: God created both life and mind, and can be called on to alleviate disease [and so] conceptual change can require not just rejection of a single theory in biology, psychology, and medicine, but rather replacement of a theological world-view by a scientific, mechanist one." However, this need not always be the case of course. For example, Newton considered that the world was created by God, and that activity in the world was primarily due to God's will. So although Newton investigated the nature of what we would now call physical forces, he understood those forces in terms of his own theological beliefs (Tamny, 1979).

Worldview as a part of culture

The notion of worldviews was adopted in anthropology to describe "the cognitive, existential aspects" of a culture, where a people's "world-view is their picture of the way things, in sheer actuality are, their concept of nature, of self, of society. It contains their most comprehensive ideas of order" (Geertz, 1957, pp. 421-422). As Matthews (2009, p. 707) points out, one aspect of worldview concerns ontology, "ideas of what entities exist in the world—matter? spirits? minds? Angels?" So for example the Yupiaq people of Alaska view the world as being composed of five elements: earth, air, fire, water, and spirit" (Kawagley, Norris-Tull, & Norris-Tull, 1998, p. 138) positioning spirit alongside (what would be considered in the scientific tradition) 'material' elements in a way that would seem quite incongruous from a modern scientific perspective.

Hewitt (2000, p. 111) notes that "worldviews do not arise spontaneously" but are "shaped in part by the cultural imprint of socialization". He describes how Australian aboriginal peoples' worldview have developed over many generations in a difficult environment where "survival depends on cooperation and coexistence with the forces of nature rather than expecting to manipulate and control them" (p.112), a view rather at odds with technical-scientific-industrial mentality dominating much of 'Western' culture. Similarly, in working with Kickapoo students in Alaska, Allen and Crawley (1998, p. 126) reported how the young people generally expressed "a harmonious relationship with nature, recognizing kinship without seeking control". From the perspective of students from this culture it was not appropriate for animals to be kept caged in school laboratories, and used in investigations. Part of the Kickapoo worldview was to consider (non-human) animals as 'brothers' to people (whereas from some other worldviews the more limited degree of kinship suggested by scientific models of common descent are considered unacceptable).

Worldview encompasses epistemological as well as ontological commitments, and the separation of formal canons of knowledge (e.g. science) as marked apart from what is learned through everyday experience (and indeed the institutions of formal schooling where such knowledge is often decontextualised from its application) make little sense within the worldviews of many indigenous peoples. So for the Yupiaq, for example, "their science is interspersed with art, storytelling, hunting, and craftsmanship" (Kawagley et al., 1998, p. 137) and "Western methods of teaching science often run counter to the students' own cultural experiences" (p.141).

School science as a representation of the culture of science

By contrast, a simplistic view of school subjects in Western education might see the curriculum in terms of partitioned portions of content knowledge to be 'delivered' by different subject teachers. There has long been a notion of curriculum as providing access to those aspects of a society's culture that are judged to be of importance and value to the young. From such a perspective science is a 'form of knowledge', that is, a "complex way of understanding experience which [humanity] has achieved" (Hirst, 1974, p. 38), and science lessons are not just about being told some science, but acquiring something more profound: "the development of creative imagination, judgment, thinking, communicative skills etc., in ways that are peculiar to [that form of knowledge, so here science] as a way of understanding experience". So part of the role of science education in a 'liberal' curriculum might be to provide access to a scientific way of thinking, or a scientific attitude or perspective.

This might be seen to encompass, *inter alia*, thinking for oneself; questioning and not accepting the views of authority without supporting grounds; being sceptical and so forth: reflecting the famous motto of the London Royal Society to 'take no one's word for it'. Such an attitude might seem to be at odds with other values that could be encouraged in some cultural contexts: such as respecting elders, knowing and having to earn one's place, and having faith in 'the Word'.

This might increasingly be the case as the nature of science education itself has shifted. There is increasingly a view that science for citizenship in the modern world encompasses a kind of scientific 'literacy' that goes beyond learning a corpus of presented examples of the products of science, to appreciating the processes of science (Millar & Osborne, 1998). Learning about the nature of science is seen as more than learning about a bowdlerized notion of 'the' scientific method (Taber, 2008). Increasingly, science classes have come to be seen as about enculturation into the practices and norms of science themselves (e.g., Roth & Bowen, 1995). When science is seen in this way, it is increasingly clear that success in school science is likely in part to depend upon how readily a learner can recognise and adapt to the culture being represented in science lessons: something that will surely be influenced by the extent to which that culture fits or challenges her or his own worldview.

Border crossing into school science

The metaphor of border-crossing has therefore been used to describe the process of entering into the culture of the science classroom. Aikenhead and Jegede (1999, p. 269) note that whilst barriers to border-crossing may be most severe among students from developing countries who find "that school science is like a foreign culture to them" due to "fundamental differences between the culture of Western science and their indigenous cultures"; nonetheless "many students in industrialized countries share this feeling of foreignness as well".

Difficulties for science education are to be expected among "students whose worldviews conflict with mainstream schooling and Eurocentric science" (Brandt & Kosko, 2009, p. 398). So Carambo reports a study carried out in an urban setting in the US that explored "students' development of secondary discursive practices of the scientific community" through a project where youngsters designed and built toy-model racing cars. It was intended that "the analysis and redesign processes would create a field where students' primary discourse would reflect practices associated with scientific discourse" which would provide a 'border crossing' (p.477). However, although students were engaged by the premise of building and racing their model cars, they did not adopt the hoped-for scientific approach to analysing the performance of different models as a means to look to improve their designs. Or as Carambo concluded, “students failed to adopt secondary discursive practices as they refused to engage in the analysis and redesign of their model cars” (p. 477).

Carambo’s study suggests that the mentality of science may be at odds with the thinking of many young people, *even* in an area where there would seem to be little sense of conflicting with fundamental personal values of the type that may be related to strong cultural beliefs. Religion may offer very strong commitments that are adopted into an individual’s Worldview at a young age, often with strong support from family and the most respected members of the community. This potentially offers a basis for very significant barriers to science learning if science is perceived as in conflict with the learner’s own worldview.

‘Science and religion’ is an issue for science educators

This potential for students’ worldviews to appear to clash with a scientific perspective on religious grounds has been recognised, for example by Martin-Hansen:

> “When we consider the way we teach science or how the general populous thinks science is conducted, not only are there very naïve views of nature of science concepts, but also different worldviews are coming into conflict. Science teachers are asked to help students understand the way science works, but some teachers as well as many of our students hold rigid theistic worldviews that threaten their understanding of science concepts.”
>
> (Martin-Hansen, 2008, p. 318)

Clearly different religions have different tenets, and so inform worldviews in different ways, in turn leading to different degrees and points of potential contact with scientific principles and ideas. Interestingly, for example, developments in some areas of Twentieth Century physics saw some scientists and commentators seeking to make sense of areas such as quantum theory (where mechanistic notions of causality and ‘common-sense’ thinking about how the world is structured seemed at odds with scientific evidence) by drawing upon religious and philosophical ideas from Eastern cultures (Capra, 1983). The present chapter will focus in particular on examples relating to Christianity and Islam, where there has been recent concern about the potential for student worldviews to lead to conflict with science teaching, especially about evolution (Hameed, 2008; Long, 2011; Reiss, 2009).

Perspectives on 'Origins'

Martin-Hansen (2008, p. 318) gives the example of "when a student says that they believe the earth is 6000 years old [which] is usually due to a conflict between a theistic worldview and a naturalistic worldview". Issues of origins may often be the contexts for explicit perceived conflicts in science classes, as for example in the perspective adopted in the comments of student Brent, reported by Roth and Alexander,

> "When I hear you and other people talk about how the Earth was created, by referring to the theories of Big Bang and evolution, I say, well that is wrong. I believe that you are wrong and I am right—I am right because God has taught me so; and you are wrong because God did not bring you up that way, you are misinterpreting what the world actually is."
>
> (Roth & Alexander, 1997, p. 142)

Where a student takes such a strong stance as Brent ("you are wrong and I am right"), there seems little scope for common ground between teachers and learner, to allow any kind of dispassionate exploration of ideas. Indeed, the very notion that one *should* seek to explore such matters in a dispassionate manner might itself be seen as an alien cultural norm within some communities.

The themes of the beginnings of 'the world' (a notion that itself may be incongruous from different perspectives, i.e. a vast universe including this planet among a myriad of others; or humanity's earthly home in its almost incidental or supporting cosmic environment), and the origins of human beings, are well recognised to be problematic topics in science lessons for some learners due to apparent clashes with their own worldviews. It does not help that evolution is counter-intuitive, and that understanding natural selection as a 'simple' and yet powerful concept, first requires the coordination of a number of different key principles (Taber, 2009, pp. 287-288).

These principles, once understood can be integrated into a coherent conceptual framework that allows one to make sense of a great deal of data about the natural world, and which with regular use can come to provide the taken-for-granted basis for interpreting new information about life and living things. Such conceptual frameworks can be very powerful in channeling thinking. Science educators have noted how learners' alternative conceptual frameworks can hold a strong influence on their learning (Duit, 1991), but scientists' conceptual frameworks can be just as influential in biasing perception and thinking. This may explain how a popular science book by an influential evolutionary biologist proclaims on its dust jacket that that "no one doubts that Darwin's theory of evolution by natural selection is correct" (Eldredge, 1995). Brent certainly doubted Darwin's theory is correct, and he is by no means alone.

Hokayem & BouJaoude (2008, pp. 407-408) report the comments of a University student in the Lebanon who begins by asserting he agrees with, and even finds obvious, one tenet of evolution: but then immediately goes on to reject evolution as the origin of species: "survival of the fittest, I accept 100%, and I don't think its such an achievement when Mr. Darwin discovered it, but transitions between monkeys and humans and others between reptiles and birds, that is not very credible". The student supports this position with various arguments, such as:

- "[natural selection as the origin of species] has nothing to do with science, there's no research or something they work in the lab…[rather] its like an artist created a picture"
- "If organisms did not exist today in essentially the same way they existed in the past, it doesn't mean they evolved from each other, God created them like that…there's no evidence to say they came from each other, but [just] after each other"
- "They haven't scanned the whole earth to see if what they're talking about is true, it's fragmented, they find one thing they make up a theory on it, they find something else, they change their theory…they're basing it on their imagination

> nothing else…they need to show me transitional species that are really found, not just they found a human being with a bigger jaw, it's normal for the jaw to be bigger because he used to eat other kind of food, if this is what they mean by evolution then fine but not the evolution from monkeys to human, this is another idea"

I have drawn upon Hokayem & BouJaoude's original published data in some detail here, because I find something very interesting about this student's position. This student's arguments remind me of scientists interviewed for a sociological study reported by Gilbert and Mulkay (1984), where they found their scientist interviewees operated with two interpretive repertoires when asked about differences of opinion within science. Put simply, scientists tended to present their own view through an *empiricist* repertoire that suggests it is a neutral view based upon what the evidence shows. However, the different views of some of their colleagues would be explained through a *contingent* repertoire that emphasised subjective aspects of how other scientists' views were influenced by factors outside the true interpretation of clear empirical evidence. (This brief outline cannot do justice to the work reported in Gilbert & Mulkay, 1984, to whom the reader is referred for a fuller account.)

Hokayem & BouJaoude's informant here seems to present his views in a similar way, in the sense of suggesting that scientific knowledge needs to be empirically grounded ("there's no research or something they work in the lab"; "there's no evidence to say they came from each other"; "They haven't scanned the whole earth to see if what they're talking about is true"; "they need to show me transitional species that are really found") and that the scientists supporting the views he does *not* accept are basing their view on non-empirical contingent, and so subjective, factors ("has nothing to do with science …[rather] its like an artist created a picture"; "they find one thing they make up a theory on it, they find something else, they change their theory…they're basing it on their imagination nothing else"). Presumably this reflects a widespread aspect of human thinking, whether scientist, student or science teacher: my views are rational and well-grounded; whilst yours are arbitrary and contingent on chance factors. Perhaps such a bias in human cognition (Nickerson, 1998) has had value for survival during the evolution of our species, but it does not help us come to see the merits of a disparate viewpoint.

Science proceeds through the iterative interaction between evidence and imagination (Taber, 2011). Sensory data only becomes perception by being interpreted through an existing cognitive apparatus, and those perceptions only become evidence within the context of some existing conceptual framework: i.e., data is always 'theory-laden' (Kuhn, 1996). Imagination is always involved in devising a theoretical scheme within which evidence is interpreted and coordinated – in setting up hypotheses, and devising tests for them - but *in retrospect* natural science formally focuses on the context of justification, not the context of discovery (Medawar, 1963/1990). That is, the modern scientific literature is based in the empirical repertoire which is used to argue how we know, not the contingent repertoire which can tell us who had the idea, and whether it derived from a serendipitous accident in the lab, a chance conversation at a conference, a dream, or a flash of inspiration 'popping into' consciousness whilst bathing. So although both imagination and evidence have essential roles to play in the processes of science (Taber, 2011), we can understand why it may be rhetorically convenient to emphasise how *our* views are based on evidence, whereas *their* different views derive from their imagination.

Is there a scientific worldview?

If individuals are considered to have a set of assumptions about the world making up a 'Worldview' which can sometimes conflict with the science presented in the classroom, then this leads to the question of whether science itself reflects a worldview which would suggest that full admission to the scientific community is only possible to individuals who adopt that worldview. The answer offered here is a clear 'no': that what we might term the scientific perspective, or the scientific attitude does involve some features that could be considered constituent of a worldview, but is not a fully encompassing worldview in its own right: "religions and science answer different questions about the world. Whether there is a purpose to the universe or a purpose for human existence are not questions for science" (National Academy of Sciences Working Group on Teaching Evolution, 1998, p. 58).

That is, the nature of science, as currently understood, is informed by a common set of shared metaphysical assumptions about the nature of the material world and how we can come to knowledge of it (but not whether it reflects a purpose). These fundamental assumptions are therefore at the 'level' of a worldview, and so may be considered potential components or facets of a worldview, but do not in themselves constitute a worldview. There is therefore scope for a range of different worldviews that may encompass these assumptions.

Consensus scientific values

There is unlikely to be a simple consensus on the precise nature of such a list (or indeed on who exactly might be considered as a member of the scientific community). Given this proviso, I would suggest that the following candidates for metaphysical commitments to underpin science (as it is generally currently understood within the scientific community):

- O1: There exists a (natural) physical world;
- O2: The physical world has a degree of permanence and underlying order;
- E3: Experience offers a meaningful guide to the nature of that world;
- E4: It is possible to construct useful 'knowledge' of the world;
- E5: It is possible to develop knowledge of the world, which is objective in the sense that it is independent of the standpoint of the particular observer.

I suspect it is very likely that any reader will find things to quibble with on this list, especially in the choice of phrasing. The term 'knowledge' here certainly will not match the philosophical notion of 'justified, true belief' (Matthews, 2002). Moreover, scientists will show a range of views on the extent to which the natural world is 'knowable' to human minds: (E3, E4) varying from those who are strongly realist, to those who take a much more instrumentalist approach, i.e. whether our theories and models are good approximations to reality or best just considered useful tools that often do a good enough job for us (Taber, 2010). Scientists will also take a range of views on quite how much the objectivity of science (E5) is best seen as an ideal and aspiration (Springer, 2010), rather than something that is regularly achieved.

Whilst the diversity in such matters might be quite significant (and probably in part varies from field to field within the sciences), it would seem these assumptions, or at least something quite similar to them, are essential for what we *currently* understand as science. There would seem little point in doing science if one thought the world was an illusion; or that it was continually and fundamentally changing its nature in unpredictable ways; or that it was completely beyond human comprehension; or that at the most basic level it was really different for different observers.

My argument would be that:

a) these ontological (O1-2) and epistemological (E3-5) commitments, or a set quite similar, are necessary to what we understand as science;

b) moreover, that these commitments are also sufficient as a starting point for doing science.

That is, that what is excluded here, is *not essential* to science as currently (but see below) understood. What is excluded includes both greater specification of the statements above; and what is not mentioned. So, for example, O2 refers to the physical world having *a degree of* permanence and underlying order. This does not specify total permanence and order (although *some* individual scientists might certainly assume something at least approaching that), but rather implies enough permanence and order to make systematic observation meaningful and worthwhile.

Not referred to above, is any sense of extra-scientific values. So for example, *many* scientists might share an axiological commitment along the lines:

- A6: Scientific work should be carried out for the benefit of all the peoples of the world, and taking care not to damage the ecosystem

We might like to see all science informed by such a principle: but it is *not* part of science as currently understood, and there has been a great deal of science that has been motivated quite differently. Perhaps, in some more perfect future, such a commitment would be shared by all scientists, but it would still be 'prior' to science itself, in the sense that like the ontological and epistemological assumptions O1-E5, it informs science rather than making up part of its content.

Relating worldviews to science

Space limitations here do not allow a detailed exposition of the idea that different worldviews may be consistent with science, but some exemplification is possible. I will here simply illustrate the general point with brief consideration of a small range of examples.

Natural philosophy and belief in God

Many of those considered as leaders of the first generations of scientists (in a modern sense), or natural philosophers as they would have seen themselves at the time, would have seen no problem with committing to something like my list of metaphysical commitments for science, without seeing any conflict with deeply held religious beliefs. Indeed, it has long been argued that religion was among the factors contributing to the social nexus which was "favorable to scientific interests" in England in the seventeenth century (Merton, 1938). These early scientists commonly shared a worldview that included commitments to God as the creator of the Universe. Indeed, to suggest that such luminaries did *not see their scientific activities in conflict* with their faith would not do justice to the motivation of someone like Isaac Newton. It seems clear Newton was a devout believer, who saw his science as finding out *how* God worked through His creation, for "if you believe, as Newton did, that God has created our world and all of its operations, then you cannot invoke God to function as an explanation for the cause of any particular effect. You must assume that God provided a natural cause for that effect, and it is the task of the natural philosopher to discover it" (Grant, 2000, p. 290).

Newton's work was clearly influenced by metaphysical commitments. He recognised that the spectrum he obtained by passing white light through a prism did not give distinct colours with sharp divisions, but rather included "an indefinite variety of intermediate graduations" (quoted in Wörne, 2008, p. 19). Yet he revised his early view that the spectrum should be described in terms of five colours to the now canonical seven. Scholarship suggests that in this Newton was strongly influenced by an analogy with the musical scale, that derived from his commitment to certain ideas we might now describe as numerology (Pesic, 2006), that is metaphysical commitments that would now be considered external to science. How such a cognitive 'bias' compares to contemporary physicists expecting to find symmetries in nature is an interesting theme: but arguably this is an example of another extra-scientific commitment that was part of Newton's worldview, but is *not* a core scientific value. This might be considered simply part of the variety encompassed by the less specific commitment that the physical world has a degree of permanence and underlying order (O2).

It is suggested here that it is useful to consider the views of an individual such as Newton in terms of his metaphysical and scientific commitments, and how these match to the scientific consensus (which of course is historically labile). Clearly many of Newton's scientific ideas are still influential and accepted as useful within science today. Some of his work, however, such as his alchemical ideas, would not today be considered as scientifically acceptable, and in such cases it is easy to suggest how he was led to misinterpret nature due to the influence of metaphysical ideas external to science (Dobbs, 1982): but it is just as much the case that aspects of Newton's thinking that are now established as canonical parts of science and the school science curriculum were also influenced by his metaphysics. This is reflected schematically in figure n.2, which includes some examples of ideas associated with Newton.

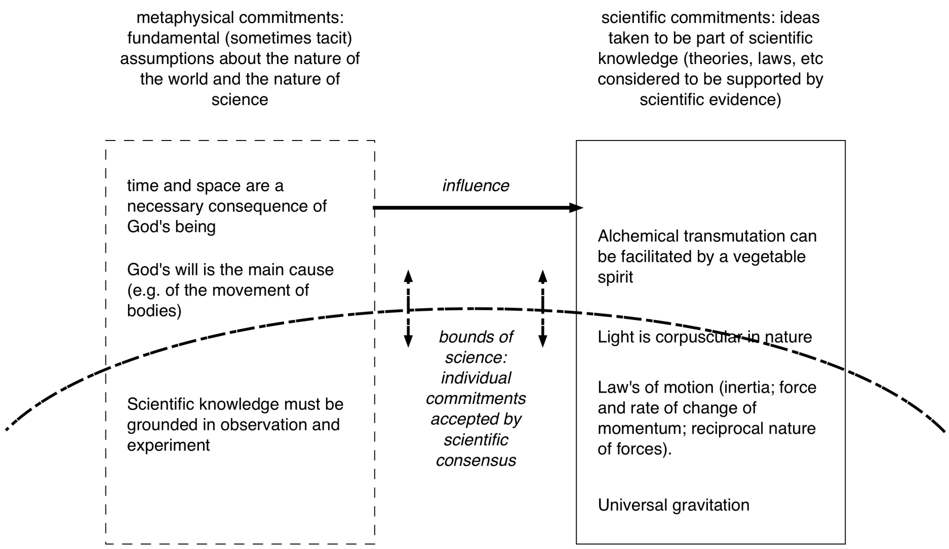

Figure n.2 An individual (such as Newton)'s thinking is informed by metaphysical commitments, and includes various ideas about the material world: which may fit to the current scientific consensus to different degrees.

In this regard, although Newton's cosmology is sometimes described as a 'clockwork' universe, implying that God had set it up (and metaphorically wound it up) and left it to play out; Newton seemed to consider that it was necessary for God to occasionally intervene to make fine adjustments (Cooper, 1980): even the Omni-powerful was apparently unable to set up a celestial mechanics that did not need some occasional tinkering! It may seem arrogant of Newton (and he has been accused of that) to assume that if he could not calculate stable orbits for the planets, then God could not set them up: yet perhaps if one holds an epistemological commitment that the world should be comprehendible because that is God's intention, then this seems less arrogant. The point, however, is that even Newton with his establishment of universal principles and mathematically described laws, did not assume such a high inherent order to the world (re-O2) to exclude supernatural intervention in natural laws.

Scientific creationism

That many of the early pioneers of science were theists, who considered God created the World, is a point that was commonly made by Henry Morris, who was a leading advocate of young earth creationism in the U.S.A. Morris considered himself to work within science (being trained as an engineer, and having taught at various universities), and I suspect would have no problems ascribing to my list of core scientific commitments above. However, his worldview also included not only a commitment to a belief in a creator God, but also a commitment to the mode of creation being *as* described in Christian scripture. Now the Christian Bible includes two accounts of God creating the World in 6 days, by a series of discrete acts of special creation for each kind of living thing. The Bible also includes a good deal of genealogical detail, which if assumed to be complete and accurate, allows scholars to date the life of Christ relative to the creation, leading to the conclusion that the creation of world was a historical event that occurred at most about 10 000 years ago. Within this perspective, all living things alive today are the descendents of, and are of the same kinds as, those created directly by God. From this perspective, it is generally accepted that the original stock has given rise to variations, but only within the basic types of living thing created by God (just as suggested by Hokayem & BouJaoude's interviewee, reported above).

As the geological sciences suggest the world is billions of years old, and astronomy that the universe is further billions of years older than the earth; and as modern biology considers all life on earth to have evolved from a common ancestor stock that was single-celled; there are some clear contradictions between the currently accepted conceptual frameworks of science, and some of the metaphysical assumptions incorporated in the worldview of Morris and others who share his stance. So Morris (2000, p. 18) describes evolution: as "completely anti-biblical and even anti-theistic".

Yet, Morris, just as Hokayem & BouJaoude's (2008, pp. 407-408) informant above, is able to consider that his worldview is quite consistent with science, as he is able to support his view, with *his* interpretation of the available scientific evidence

> "creationists do not reject the actual, factual data of any of these sciences. They are all legitimate sciences (the founding fathers of which, incidentally, were almost all creationists!), and they have contributed immeasurably to our knowledge about God's created world and our ability to use its resources for man's benefit. All of the real data of these sciences can be understood much better in the context of creationism".
>
> (Morris, 2000, p. 32)

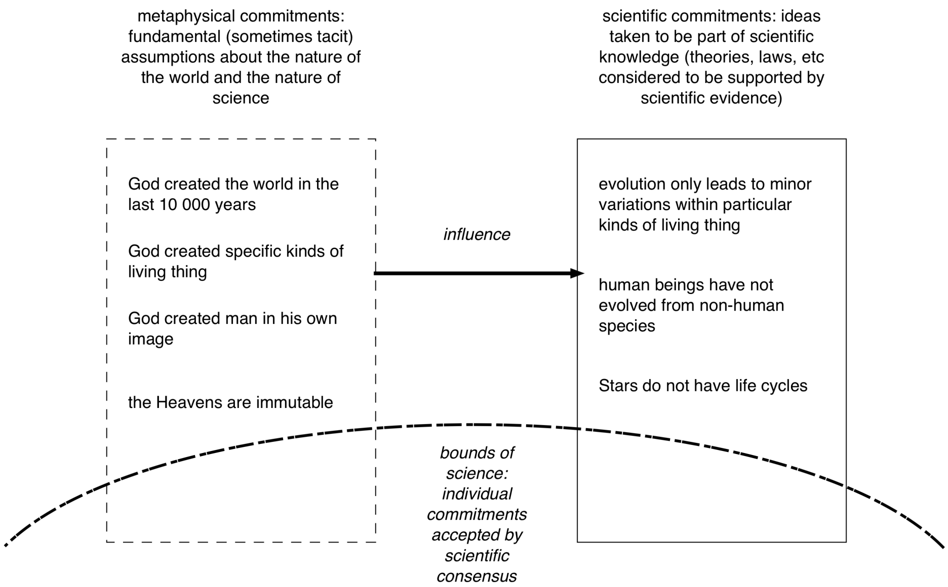

Figure n.3 Young earth creationism: Empirical evidence is interpreted differently when thinking is channeled by prior commitments to how the world must necessarily be

His rhetoric again reflects the work of Gilbert and Mulkay (1984), i.e., that his own position (see figure n.3) is empirically supported, whilst it is others who are misinterpreting the available data,

> "The fact is, however, that although the natural sciences are commonly interpreted in an evolutionary framework, no one has ever observed real [sic] evolution to take place, not even in any of the life sciences, let alone the earth sciences or the physical sources. True science is supposed to be observable, measurable, and repeatable. Evolution, however, even if it were true, is too slow to observe or measure and has consisted of unique, non-repeatable events of the past. It is therefore outside the scope of genuine [sic] science and has certainly not been proven by science."
>
> (Morris, 2000, p. 23)

So according to Morris (2000):

- "The most significant feature about the fossil record is the utter absence of any true [sic] evolutionary transitional forms" (p.27);

- "...the real scientific evidence in both domains of science [i.e. the earth sciences and the life sciences] is firmly opposed to evolution" (p.28);
- "As long as people have been observing the stars, no one has ever seen a star evolve from anything" (p.30);
- "...evolution is quite false and is utterly devoid of any scientific evidence..." (p.91).

Morris refers to the empirical support for the second law of thermodynamics as excluding the possibility of evolution (p.31) – a rather surprising misconception of the law from an engineer - and refers to claims of "the great age and evolution of the cosmos" as "arbitrary" (p.124). Nothing in Morris's claims would put him outside of science in terms of his espoused commitments to the fundamental ontological and epistemological commitments underpinning of science as listed above (O1-2, E3-5), yet he was able to *interpret* scientific evidence generally considered highly stacked in favour of evolution, as consistent with, and indeed supportive of, the anti-evolutionary commitments in his worldview. That he could interpret scientific evidence is this way must seem just as puzzling and bizarre to evolutionary biologists such as Niles Eldredge, as Eldredge's publisher's claim that "no one doubts that Darwin's theory of evolution by natural selection is correct" would have seemed to Morris.

Scientific materialism

Where fundamentalist Christians such as Morris are able to see science as fitting with a theistic worldview, some scientists who are committed atheists have not only managed to see science as consistent with their own worldview, but have argued that science itself is inherently atheistic. For these individuals, the natural world is all there is, and is not only open to scientific investigation, but ultimately only capable of being meaningfully understood in scientific terms. For such extreme materialists, i.e. "people who believe that because there is no evidence of God in nature, God must play no role in the development of the cosmos or of life on earth", their own atheistic worldview is considered as a (the) scientific worldview, leading to "the belief that science and religion must inevitably conflict" (Brickhouse, Dagher, Letts, &

Shipman, 2000, p. 349).

In view of the model presented in this chapter, these individuals argue for the adoption among the fundamental assumptions shared by scientists, of additional (materialistic, atheistic, scientistic) commitments from their own worldviews (see figure n.4), and "hope science, beyond being a measure, can replace religion as a worldview and a touchstone" (Cray, Dawkins, & Collins, 2006). So for example, whereas many scientists would not exclude miracles from occurring (because their worldviews encompass a God capable of acting in the World), Richard Dawkins would argue that "any belief in miracles is flat contradictory not just to the facts of science but to *the spirit of* science" (Cray et al., 2006, emphasis added).

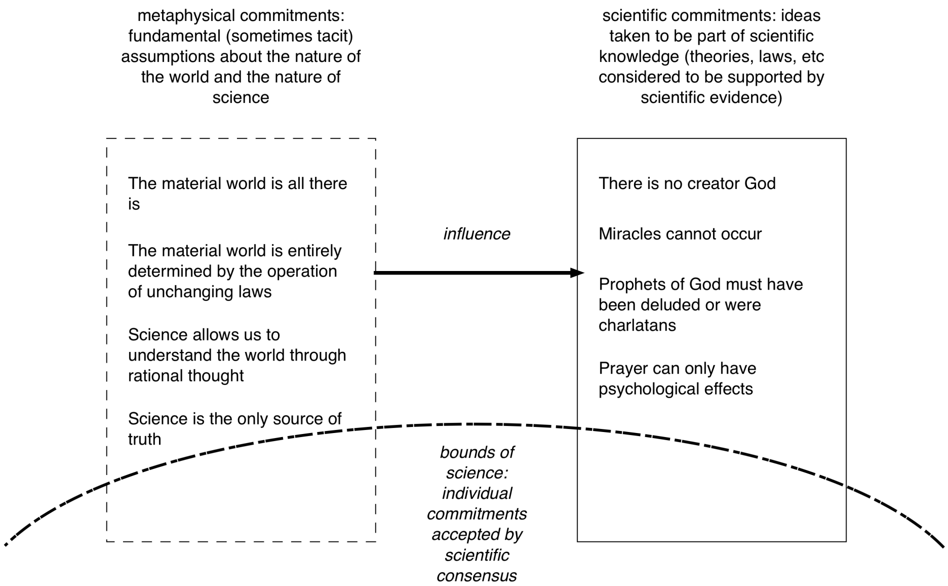

Figure n.4: Materialistic metaphysical assumptions lead to interpretations of phenomena for which there is no empirical evidence or viable mechanism being assumed to be imaginary

That is, that (i) if one assumes that the material realm is all there is, and therefore all there is will be open to scientific investigation and explanation, then these (metaphysical) assumptions exclude the possibility of miracles; and (ii) if one considers such commitments as necessary for and inherent in science, then it follows that *science itself excludes* the possibility of miracles. This is of course tautological, because the metaphysical sets bounds on the scientific interpretations possible, so that what is scientifically accepted *necessarily* fits with those original assumptions: just as Morris assumed evolution could not be the case because he saw it contrary to scripture, and then found that all the evidence seemed to him to fit his prior assumption.

Natural theology

In both the cases of Morris and Dawkins it is possible for *a form of science* to fit their worldviews. However, in both cases they understand science in terms of fundamental commitments, some of which fall well outside the common ground of the current scientific community (figures n.3 and n.4). To the extent that science is part of culture, it can change. At one time the scientific consensus would have reflected theologically based metaphysical assumptions that are now no longer part of the common commitments of science (i.e. that science is the study of God's work). Indeed there developed a whole tradition of 'natural theology' where the 'book of nature' was to be 'read' and considered to offer insights into God's work and his nature (Grumett, 2009; Sagan, 1985/2006), alongside but independent from the revealed Word in the book of scripture. From this perspective, it was easy to adopt a commitment that 'the physical world has a degree of permanence and underlying order' (O2), because it was ordered by God; and a commitment that 'experience offers a meaningful guide to the nature of that world' (E3) was more than just an 'article of faith' in science, but actually derived support from a worldview commitment to God having set up the world with humans in mind: humans who would come to know Him and appreciate the glory of His work, perhaps something along the lines:

- E7: the World can be understood by man, because God has created man in the image of God, to appreciate His works

However, this is no longer a shared commitment of the scientific community (whilst being retained as a commitment by some members of that community). Other such shifts may occur in the future. So, for example, if the scientific community were over time to come to adopt scientistic metaphysical commitments as part of the common core of fundamental assumptions underpinning science then it would in principle be possible that science may become secularised, and Dawkin's prescription for what science should be would indeed have become a descriptive account.

Islam and science

However, such a shift to adopting atheistic and materialist commitments as common values in science is certainly not imminent. Indeed, in much of the Islamic world the Worldview of Muslims includes metaphysical commitments to the existence of God at work in the world, whilst sharing commitments necessary for empirical science,

> "From an Islamic perspective, science is the study of the material processes and forces of the natural world. Science is not about belief; it is about how things work. Science is about the exploration of natural causes to explain natural phenomena. Science is empirical, which means that questions of truth are established through experimenting and testing. There are no absolutes in science; all issues are open to retesting and reconsideration. In contrast, religion is about belief, meaning, and purpose. Religious truths are evaluated by an appeal to authority, by contextualization in history, by their philosophical coherence."
>
> (Mansour, 2009, p. 109)

This is in contrast to the materialist position that would not grant epistemological power to authority, history or philosophy (or indeed anything other than objective, reproducible empirical evidence), and so would consider religious truth as something of an oxymoron. Islamic scientists traditionally, as in Christian natural theology, saw nature as reflecting God and the study of nature as a way of coming to know God better. This type of thinking is still reflected in science curricula in some Arab states. So in Jordan, one goal of the science curriculum is to enable students to better understand the universe, as this should strengthen their faith in its creator (Dagher, 2009). Similarly, there are explicit references to Islam in the science curriculum in Oman. For example, the biology curriculum aims to help students strengthen their Islamic beliefs through learning about the cell (Ambusaidi & Al-Shuaili, 2009). From the prior assumption that God created the world, then the cell as a building block of all livings things becomes interpreted as an aspect of God's way of creating complex organisms. So science education in these states reflects shared metaphysical commitments of the culture, which become adopted as part of the metaphysical underpinning of science itself. In terms of the common core of assumptions shared by the *international* scientific community, these commitments to the World as God's handiwork are just as much local adjuncts as the materialist's commitment to excluding such notions.

Evolutionary creationism

Something of the mentality of natural theology led Charles Darwin to ask what kind of a God would have set up the wasteful world of excessive suffering that his scientific work (as well as his personal experience of the loss of loved children to disease) seemed to imply: a question that led *him* to reject a personal God that loved and cared about each of his subjects (Phipps, 2002). A caricature of the science and religion debate often suggests that Darwin's 'discovery' of evolution challenged the established Christian Church's model of creation and the origins of man, by providing scientific evidence that Biblical accounts were false. This is far from an accurate account, both as evolution was not a new idea with Darwin, and because there had long been a tradition in Christian thinking that where scientific evidence seemed to contradict scripture, then the interpretation of scripture needed to be revisited – a point raised for example by Galileo in his sometimes troubled dealings with the Church (Johnston, 1993). The Darwin-Wallace notion of natural selection (Darwin & Wallace, 1858) certainly did not rule out a creator God, although it did for Darwin and others raise issues of what kind of God would go about His work in such a way.

However, while Darwin's faith was challenged by his scientific discoveries, a great many religious people (in accord with the natural theology tradition) accepted that science had made progress finding out more about how God had gone about his work. From the perspective of many believers, i.e. those people who had a theistic worldview, evidence that strongly implied that certain traditional ideas (such as a six day creation of the world; the special creation of distinct species; a worldwide flood leaving four couples to repopulate the world etc) were not accurate historical accounts, did not count as evidence against a creator God – only evidence that scripture needed to be understood figuratively as offering narratives with moral truth rather than scientific truth (Alexander, 2008).

From such a perspective, evolution can be seen as part of the mechanism of God's ongoing creation (after all, although according to scripture the world itself was created *ex nihilo*, Genesis suggests that Adam and Eve both derived from materials that God had already created as part of the World). Today, as in the more immediate aftermath of Darwin's publication of his '*Origin of Species*' (1859/1968) and '*Descent of Man*' (1871/2006), there are a great many scientists able to commit to the core scientific values (e.g. as represented in my list O1-E5 above) without finding any conflict with their theistic worldview. Indeed it has been argued that "a more systematic integration can occur if both science and religion contribute to a coherent worldview elaborated in a comprehensive metaphysics" (Barbour, 2000, p. 34).

Coda

So here I have just sketched a few of the positions taken by people with different worldviews, who understand science in accordance with their own metaphysical commitments. Slezak (2008) has argued that "the Gospels only support Christianity if you already believe it. If that's the best that philosophers can offer, it's hard to see how Christian theism could provide a 'metaphysical' alternative to the naturalism of our best science". Yet any deeply held metaphysical commitments (theism, atheism, young earth creationism etc) will necessarily inform the interpretation of empirical evidence to construct conceptual frameworks about the world which are consistent with, and so can readily seem to support, those particular metaphysical underpinnings.

We each live our lives as a personal version of a scientific research programme (Taber, 2009, pp. 92-110) in the sense of Lakatos (1970): building up and revising our model of the world in view of ongoing experience (Glasersfeld, 1989), and sacrificing auxiliary ideas in order to maintain conceptual frameworks consistent with our 'hard core' assumptions. This is why Lakatos referred to these auxiliary ideas as making up a 'protective belt'. For most theists in the Christian tradition, the place of the earth at the centre of the universe, the recent creation, the global nature of Noah's flood, special creation of species and so forth are (in Lakatosian terms) 'refutable variants' that have been allowed to fall to maintain congruence between empirical evidence and the core notions of theistic creation. What seems from outside that programme as desperate patching-up of a faith position; makes perfect sense from within the programme as indications of a progressive programme.

We each start from a metaphysical position that will seem to be supported by empirical evidence (because of its role in influencing our interpretation of that evidence). Such commitments will inform our science, and also our teaching of science. Hodson suggests that 'border crossing' into science classrooms,

> "is inhibited not so much by the cognitive demand of the learning task as by the discomfort caused by some of the distinctive features of science, features that are often exaggerated and distorted by school science curricular into a scientistic cocktail of naïve realism, blissful empiricism, credulous experimentation, excessive rationalism and blind idealism"
>
> (Hodson, 2009, p. 121)

That is, inappropriate representations of the nature of science put up barriers for some students. This is surely going to be the case when science is presented as, for example, inherently about studying God's work, or as inherently excluding the possibility of God being at work in the world, when such assumptions (themselves external to science itself) are contrary to the strong personal convictions, and community commitments, of learners.

Ways forward?

Cobern has argued that

> "it is important for science educators to understand the fundamental, culturally based beliefs about the world that students bring to class, and how these beliefs are supported by students' cultures; because, science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural milieu of students"
>
> (Cobern, 1994, p. 22)

Of course, this does not mean compromising on scientific values. Logical analysis of empirical evidence remains at the core of science. But as science educators we must be very careful to ensure that the nature of science we present reflects the shared commitments of the scientific community, and is not an amalgam including extra-scientific features imported from our own individual worldviews. As Cobern suggests,

> "teachers and curriculum developers need to examine and then come to understand the fundamental, culturally based beliefs about the world that they bring to class through teaching and the curriculum. They likely will find that some of these fundamental beliefs are neither necessary for science nor for the effective teaching of science"
>
> (Cobern, 1994, p. 22)

This will allow us to be clear with learners about which metaphysical commitments are inherent in science, and those which are not, but which may be adopted by some individual scientists (Hansson & Redfors, 2007). This is especially important given that research suggests that many school age students adopt "a stereotyped image of scientists [that makes] no distinction between their personal and professional concerns" (Driver, Leach, Millar, & Scott, 1996, p. 84).

Martin-Hansen (2008, p. 318) suggests that "by involving students in explicit nature of science activities which illustrate the boundaries of science, they can begin to see that an acceptance of a scientific theory does not eliminate the existence of a supernatural entity". I would add that such activities should equally make it equally clear that the acceptance of a scientific theory should not follow from the existence of a supernatural entity. Science teachers are generally not in a position to offer informed instruction on religion(s) - but an exploration of the possible metaphysical bases of science, and how these may be congruent or not with different worldviews, could be considered as a key feature of the nature of science.

This is of course going to be a sensitive matter, and rather than directly engage students in considerations of their own worldviews (which may in part be tacit, and in any case are by definition going to be beyond question) an alternative may be to consider historical cases. These should of course be both inclusive (e.g. not just male European Christians), and selected to be linked to curriculum topics such that learners can realistically be expected to understand enough of the science to engage with.

One framework that might be suitable for this, is that drawn upon earlier in this paper, which distinguishes metaphysical ('background') assumptions from scientific ideas, and considers:

- which background assumptions that the scientist brought to bear would (and would not) be considered as agreed scientific values by the scientific community today; and
- which of the scientific ideas the scientists adopted are still considered sound today, and which would no longer be considered supported by the available evidence.

This will illustrate both how background assumptions can lead to conclusions we would not accept today, and how the same ideas can sometimes be supported form very different starting points.

Whether such an approach will prove helpful is an empirical question. Research would be needed both to identify teaching schemes and resources that can be effective at helping students tease out scientists' metaphysical assumptions from their scientific ideas - including the development of teaching models that are accessible to school age learners, whilst offering intellectually valid simplifications (Taber, 2008) – and then to determine whether time spent exploring such ideas helps students 'cross the borders' when material met in science classes is potentially strange from, or indeed antithetical to, their own worldviews.

This is of course only one outline idea for tackling this issue. However, if as science educators we are not able to disentangle scientific from extra-scientific commitments when we present science to learners, we will both be offering a biased image of the nature of science, and risk setting up uninviting border controls that make visits to the scientific landscape seem even less inviting to many learners.

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