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Beliefs and Science Education

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Introduction

Beliefs and commitments

Science teaching is not about persuading students to believe things. Indeed, it will be suggested in this chapter that it is - usually - inappropriate for science teachers to think about learning objectives in terms of what their students should believe.

This chapter will consider the nature of belief, and the nature of scientific knowledge, and explain why the role of the science teacher is not to tell the students things we want them to believe, but rather to teach students things we want them to doubt! The chapter will also explore some things that scientists generally need to accept to make it sensible for them to work in science. We might consider these as scientific beliefs, although it will be suggested that the term 'commitments' is preferred as it carries different associations to 'belief'. The chapter also considers the potential for science teaching to be resisted due to students' existing beliefs.

Things that students might believe

There are many things we teach in science that students might go away from science lessons 'believing'. They might believe that:

- the pH of a strong acid is 1
- pure water has a pH of 7

- the methane molecule is a tetrahedral shape
- the Sun gives out light and heat
- ionic bonds form when metal atoms donate electrons to non-metal atoms
- the molecule ATP has energy-rich phosphate bonds
- a child gets their genes from their two parents equally
- the particles in solids are tightly packed with no space between them
- oxidation is the addition of oxygen or the loss of hydrogen
- everything is made of atoms

The reader might wish to pause at this point and consider their own response to each of these statements. You might consider:

- Which, if any, of these statements are worthy of belief?
- Would you want your students to believe all, or some, of these statements?
- Are there any statements here that you would be concerned about your students believing?

Is science a factual subject?

One issue that has recurred in some studies of science teaching and learning is an association of science with facts. Sometimes some younger children are actually attracted to science because of its high factual content: after all, our students often think, scientists actually know about the world because they do experiments to prove things and so can know things 'for a fact'. However, whilst a factual association attracts some younger pupils, older students - adolescents - often find that science lessons - in some countries at least - comprise an endless parade of (what they perceive to be) facts to be learnt. This is often considered to make science difficult and - even - boring. Indeed even some of the students with the greatest potential for achievement in science - those with the most creative imaginations for example - may find classes packed with things to learn (rather than think about) dull.

Scientists certainly do collect a lot of information about the world, and much of this may seem 'factual' - it is certainly not fiction. However, science is centrally about understanding and explaining (and so being able to make predictions with some confidence) and so is inherently about developing theoretical knowledge, rather than simply accumulating facts. Theoretical knowledge is never certain, as it coordinates concepts and categories and generalisations, rather than simply cataloguing facts (Taber, Billingsley, Riga, & Newdick, 2015).

To consider an extreme example, to state that scientists at the European Organisation for Nuclear Research (CERN) have observed the Higgs boson (an elementary particle predicted to exist under the conditions of the early universe according to some theories) may seem like a simple statement of fact. However, the process of 'discovering; this particle involved thousands of scientists working for years with especially designed (and extremely expensive) apparatus and looking for very indirect evidence of the Higgs in extremely complex and voluminous data from especially built detectors. The observation depended upon building, testing and calibrating apparatus, and designing analytical protocols able to offer the scientists confidence to 'know' when they found the 'signal' they were seeking among the 'noise' (Knorr Cetina, 1999).

The 'discovery' of the Higgs boson at CERN in 2012 is then not a fact in the normal sense of the word, but the outcome of a highly complex process of construction and interpretation - a theoretical deduction more than an empirical observation. It may make sense to believe that scientists at CERN have reported their conclusion that they have observed Higgs: that might reasonably seem to be a fact; but it may be less appropriate to believe that scientists now know that the Higgs does exist, i.e. 'for a fact'. As scientists we should consider such knowledge as substantially theoretical, and open to possible revision in the future.

Things that are no longer true

One problem with believing what we are taught in school science, is that scientific knowledge moves on. There are a great many instances that could be considered, but here are just a few examples from the main branches of science.

When I was at school I was taught that there were two main kingdoms of living things - the animals and the plants. The biota of planet earth has not changed significantly since I completed school, but science has - and more sophisticated ways of understanding living things has been developed. To the scientist, animals and plants (and fungi) are in important ways quite similar compared to the rather different bacteria and archea. Of course, plants have not actually become any more like animals (or animals any more like plants) but as scientists have developed their understanding of the nature of living things, new ways of thinking about how to most usefully classify organisms have been proposed. (So animals and plants now seem much more alike to scientists than they once did.) In particular, during the twentieth century cellular and genetic perspectives became increasingly central to the life sciences. Theoretical perspectives can be considered to be like mental filters that enable us to see the world in particular ways. It is almost impossible for a biologist trained today to appreciate what biology was like in the time of, say, Charles Darwin as - once acquired - the theories, ideas, and conceptual frameworks offered by modern biology inherently influence the very ways of looking at and thinking about the living world (Kuhn, 1970).

Another telling example concerns the noble gases (helium, neon, argon, etc) which used to be called the inert gases. The name 'inert' gases implied that these elements did not undergo any chemical reactions. The noble gases do tend to be pretty non-reactive, so this was not a completely foolish idea. In part, the notion that the noble gases did not react was associated with a misuse of the octet rule in chemistry. The octet rule is a useful heuristic which helps students work out likely charges on simple ions (Mg^{2+} not Mg^{3+} or Mg^{-}) and the stoichiometry of simple compounds (NH_3 not NH_2 or NH_4) on the basis that stable species tend to display particular electron structures. However, this is only a general indication of stability: there are relatively stable species where the rule is not 'obeyed' and it certainly does not suggest that any species where the rule is followed will be so stable it does not react. Indeed, most chemical reactions occur between reactants that are stable according to the octet rule. We now know that some of the noble gases do form compounds, but it seems likely that this discovery was long delayed by the 'fact', the belief in effect, that these were 'inert' gases (Greenwood, 1964).

A similar brake on scientific progress was the idea that DNA codes for RNA which codes for proteins. This scheme for a one way flow of information became known as the 'central tenet' of molecular biology, and because it came to believed (i.e., seen as factual knowledge, not theoretical knowledge) it delayed the recognition of occasions when there are exceptions to the scheme. Such exceptions include retroviruses that are able to use their RNA to code for new DNA within a host cell. These exceptions are not of purely academic interest - as for example HIV, the virus associated with AIDS - is a retrovirus of immense significance to human wellbeing.

Another example of note comes from cosmology. The astronomer Fred Hoyle proposed a possible explanation of the origin of life on earth in terms of it being seeded from space in the form of very primitive organisms. The suggestion that living organisms, even simple ones, might survive being in space was generally considered fanciful. However, space scientists now find this idea perfectly reasonable - as we now know of extremophiles that can survive conditions that would not have been thought able to support life a few decades ago. A parallel case might be the geneticist Barbara McClintock who suggested the idea that genes sometimes 'transposed', or 'jumped', around a chromosome at a time when other scientists knew (i.e. believed) this was not possible (Keller, 1983). McClintock's particular scientific heresy eventually became scientific orthodoxy, and she was awarded the Nobel prize for her pioneering work.

As a final example, consider how it is that a heavy, largely metal, aircraft can fly. (The reader may wish to pause and consider if they know the scientific explanation here.) Physics textbooks and websites often suggest this is because of the Bernoulli effect. If one considers a closed system comprising a circuit of pipes of different radii, containing a circulating incompressible fluid, then the fluid must flow around all parts of the circuit at the same rate. If there are 10 ml of fluid passing some point each second then the flow rate must also be 10 ml/s at every other part of the circuit (as the fluid cannot 'back up' anywhere as there is no free space for that). Yet if the pipes are of different radii then in order to maintain a constant rate of flow (i.e., in mass or volume per second) the speed at which the fluid flows must vary around the circuit - the fluid must move faster in the narrower pipes so that the same amount of fluid (with its narrower cross-section) passes points there in any given time. Bernoulli suggested, from considerations of the conservation of energy, that where the pipes were narrower, and the fluid moved faster (so had more associated kinetic energy), the fluid pressure would be less. This can be tested, and shown to be the case.

The careful reader will have spotted that aircraft were not involved in this account of Bernoulli's principle (and indeed were not around when he published his idea in 1738). The ability of planes to stay in the air is often explained in terms of the cross-section of the wing (aerofoil). The modern aircraft wing has a shape such that there is a longer distance from the front to back of the wing across the upper surface than across the lower surface. Therefore, the argument goes, the air must move faster over the top surface of the wing, and so (according to the Bernoulli principle) the pressure is lower than on the bottom surface. The difference in pressure leads to a net upward force, which provides the lift the aircraft needs (i.e., the force that balances its weight when in flight).

This may seem a convincing explanation, worthy of being believed. After all, it draws on some basic scientific ideas about force, and pressure, and the conservation of energy. However, many aircraft can fly upside down (as during air displays for example) when the 'lift', as well as the weight, should (according to the Bernoulli based account) act downwards. Wind tunnel tests show that the air flow over the two surfaces of the aerofoil wing does not take the same amount of time (Babinsky, 2003) - and indeed there is no reason why it should, as the air is not an incompressible fluid trapped in a closed pipe! This should remind us not to believe everything we find in science textbooks. It is then more in keeping with the nature of science for teachers to encourage students to question and critique, than to believe, what they are taught in science lessons.

Belief

What is meant by belief

A person's beliefs are those things they take to be true and certain. A person can certainly have beliefs about matters that can be tested empirically. Usually, however, when we think of people's beliefs we are concerned with matters where there is a strong commitment that is unlikely to be readily revised. Such commitments are often about matters that cannot be subjected to straightforward empirical testing.

Consider some examples of things that a person might believe:

- that they live in a material world that can be experienced through their senses;
- that they share the world with others who experience the world in similar ways, through similar perceptions, ideas, and feelings;
- that this world was created and its maintained by a supernatural being, God, who exists outside of the material realm of the creation;
- that illness is a result of the activity of spirits, immaterial beings that are either mischievous or evil, or that are being invoked through magical practices of another person.

People tend to become very committed to these kinds of beliefs, and do not tend to change such beliefs readily.

Metaphysical commitments

A person's beliefs about the basic nature of the world that are not open to empirical testing are sometimes referred to as being metaphysical commitments (after the Aristotelian term 'metaphysics'). Consider, for example, the belief that that we live in a material world that we experience through our senses. This might seem a pretty sound belief - after all, it may seem self-evident that this is indeed the case. However, philosophers might suggests that we have no absolute certainly about this. Perhaps we are dreaming that we live in the material world and are only imagining we sense it; or perhaps our brain has been carefully removed and is bathed in a sustaining fluid, whilst false information is being fed into its sensory nerve connections; or perhaps we have been involved in an accident and some novel new technique has been used to transfer our consciousness into an artificial neural matrix; or perhaps an omniscient God decided to think of a world He might create with sentient beings to inhabit it - and being all-knowing did not need to actually go beyond imagining it. Some of these scenarios may seem fanciful, but the point is that we would have no way to be certain that the world we think we perceive is real and not an illusion, dream, or distorted perception of some kind. (The reader is challenged to suggest a test of this assumption - bearing in mind that they cannot assume sensory information is valid as that is part of what is being tested.) Even the apparent consistency of the world relies on a commitment to a belief that the memories we have now actually do reflect some previous experiences and are not being formed anew at this moment. It is not suggested here that such metaphysical commitments are unreasonable (although memories are not as fixed and reliable as people tend to think), just that they are just that - commitments (beliefs) that we logically have to adopt prior to examining any empirical evidence.

Our belief in others who experience the world much like us is a theoretically based belief - as again we can never be sure. Leaving aside the idea that other people might be imaginary, or automatons made to look like people, or even that they are evolved beings like us, but lack the conscious experience we uniquely do, we can have no way of knowing directly how other people experience the world. We can empirically test whether other people classify the same objects as 'red' as we do, but have no way of knowing just what their mental experience of seeing red is. Perhaps they experience red as we experience red - but perhaps they experience red as we experience blue, or indeed in a way that is different to anything we experience.

It seems reasonable that other people experience emotions as we do (they are genetically similar, and living in the same environment, and have learned to respond to what are usually seen as emotionally charged situations as we do) but it is not possible to be sure what they are feeling. They say they feel happy, or sad, or guilty or elated, and we may think we know that that is like - but we only know for sure what that is like for us, and not them. Yet in everyday life, we can only function in the social world by adopting a 'theory [sic] of mind' (Wellman, 2011) and assuming that - in effect committing to the belief that - other people's experience of the world is basically similar to our own.

Metaphysical commitments of science

It was suggested above that science should not be considered to be about belief, and that science teaching is not about getting students to believe in scientific ideas - which are often theoretical. However, science does involve the adoption of something like a belief system, a set of metaphysical commitments, which are necessary to make science a viable enterprise. So scientists do accept the existence of a material world which exists beyond our imaginations. This means that scientists believe that even though people may have different viewpoints or biases, or may have different sets of evidence available to them, we all share the same material world, and so there is an objective level of reality which is common to everyone. For example, the scientific model of how atoms emit radiation of different frequencies may be theoretical knowledge which is in principle open to revision, but whatever the reality is, it will be the same for any of us. This can be contrasted to a relativist stance that sees reality as relative to a particular context. Relativism may be sensible in the social world, but not in the natural sciences. If a researcher wanted to study the nature of progression from school science to university science then it would be foolish to expect there to necessarily be one answer that applied across different times and cultural contexts. Yet scientists assume that the charge to mass ratio of an electron will be the same in 1950, 1980 or 2010, and regardless of whether the measurement is made in the Netherlands, or in Nigeria, or in New Zealand.

So science makes a commitment to the possibility of objective observations and measurements - the idea that replacing one qualified and careful researcher by another should not in principle make a difference to the results of an observation. Scientists also make a metaphysical commitment to the stability of the material world. That is, despite observing many changes, scientists believe that at some fundamental level there is a stable reality such that foundational principles that apply today will have applied in the past and will continue to apply in the future. If the universe is expanding, if the sun will burn out, if perhaps even the universal gravitational constant [sic] may change during the evolution of the universe - there are still underlying fixed principles from which these changes logically follow (and which scientists can aspire to investigate).

Scientists also make a metaphysical commitment to the idea that the world is knowable and can be understood. Scientists believe that human senses (often aided by various apparatus constructed by human ingenuity) are sufficient for observing the universe and that human cognition is sufficient to understand it. Scientists will differ in the degree to which they think humans are capable of understanding nature - so some think there are limits, and others feel that one day everything will be revealed through science (a 'scientistic' notion). However, for anyone to sensibly work as a scientist, they need to commit to the belief that human perception and cognition are sufficient and suitable to develop useful (if not absolute and unerring) knowledge of the world.

Scientific values

These metaphysical commitments are often supported by a value system that most scientists will adopt - what have been labelled as constitutive values of science because they are "the source of the rules determining what constitutes acceptable scientific practice or scientific method" (Longino, 1983, p. 8). Scientific values include always seeking to avoid bias influencing scientific work, evaluating scientific work in terms of evidence and arguments rather than the authority of particular scientists, always being open to reconsidering a conclusion in the light of new evidence, always exploring alternative explanations before adopting a persuasive explanation - and in general to question everything and never take anything for granted. These are of course ideals, which are lived up to to varying degrees by the real humans doing science.

Some scientists may adopt personal metaphysical commitments that inform their scientific work which are not common commitments across all scientists. One common heuristic which may become a commitment for scientists is that the simplest explanations with the least number of auxiliary assumptions are to be preferred (Occam's razor). Some scientists are guided by metaphysical commitments that nature is elegant, beautiful and/or highly symmetrical at a fundamental level (Girod, 2007).

Some centuries ago a common stance among scientists in Europe was natural theology - the idea that the world was the work of God, and doing science was a way to come to know God through his works. If, on religious grounds, a scientist believes that people can understand nature (because God has set up the world such that people can come to know his works) then this can motivate the metaphysical commitment that science can provide reliable knowledge of the world - i.e., that human senses and cognition are suitable for making good sense of nature (Yeo, 1979).

Scientism and materialism

There are various forms of what is known as 'scientism' (Stenmark, 1997). As suggested above, some people take very optimistic views about science, such as that everything can be explained, that science is able to explain it, and even that one day scientists will understand and explain everything. That is quite an act of faith, and probably only a minority of scientists adopt such extreme scientistic views. Some people who adopt scientism consider that science is the only source of genuine and reliable knowledge .

A complementary position to considering that everything should be open to scientific explanation is to adopt the attitude that only things that are open to scientific investigation should be considered as real. This implies atheism - the denial of the possibility of the existence of a God or any other entity considered to be supernatural (i.e., to exist outside or beyond the natural world). This is a form of materialism sometimes called ontological materialism. Some scientists suggest that all their scientist colleagues should adopt this position as a common commitment, but very many scientists would reject such a view (Berry, 2009). In an earlier time it was suggested that the natural stance for a scientist was to remain uncertain about God or other entities which were not open to scientific investigation - something sometimes labelled agnosticism. (It is common for people who are unsure of the existence of God to call themselves agnostic, but the true agnostic holds that it is not possible in principle to be certain about the existence or otherwise of God.)

Many scientists around the world have religious beliefs (Coll, Lay, & Taylor, 2008) and so are clearly not ontological materialists nor agnostics. But there is a sense in which scientists are usually expected to be 'agnostics-at-work' or what is termed methodological materialists. This does not involve denying the existence of the supernatural, but rather committing to limiting scientific explanations to natural causes. It is widely considered that a 'God of the gaps approach' (where God is invoked as an explanation for the things science cannot yet offer an explanation) is both bad science and bad theology. Instead, scientific explanations should seek to be limited to material causes and mechanisms, but are not considered to exclude the possibility of a complementary explanation. For example, many scientists may believe both that the world is as it is because this is God's will and creation, but also that science (cosmology, evolutionary biology, geology, etc.) tells us the mechanisms by which this creation was brought about. Clearly these are independent beliefs and individuals may commit to both, one, or nether.

A commitment to methodological materialism leads to a rejection of 'intelligent design' ideas that suggest that because science cannot (yet) explain all of the details of evolution, we should assume the hand of some deliberate designer. Whether such a designer (God?) exists or not, scientists are committed to explaining all aspects of the natural world in terms of natural causes and mechanisms. Just because it may not be obvious how - for example - natural selection led to the bacterial flagellum, that is not a good reason to give up looking and simply explain it away as a 'design' feature. If a student asked a science teacher why a microscope was able to magnify an image, it would be a poor teacher whose 'explanation' was limited to replying that it had been designed to do just that! That might be an accurate response, but not a scientific explanation.

Students' beliefs and learning science

Students come to their science lessons with various beliefs about the natural world, and sometimes - quite often actually - these are inconsistent with scientific accounts. For the present discussion, we will distinguish three categories of student beliefs:

a) those which concern natural mechanisms and causes for natural phenomena;
b) those which concern supernatural causes underlying the natural world;
c) those which concern supernatural mechanisms and causes for natural phenomena.

It is important here to distinguish beliefs that relate to values and practices from those that are actually about how the world works. For example, students from some indigenous cultures believe in showing respect for, and recognising dignity in, all living things. This may means such students are uncomfortable about being taught in a science classroom where living animals are kept in cages. Such beliefs are not inherently anti-scientific, even though they reject some common scientific practices. (We might note that some scientific practices in relation to animals that were commonplace at one time are now widely seen as unethical and unacceptable.) Faced with such a situation the sensitive science teacher may decide the inclusive approach is to respect the values of these students and not keep caged animals in the classroom.

Alternative conceptions of natural mechanisms

There is a vast literature revealing that students have their own takes on many natural phenomena (Duit, 2009). Often these ideas are inconsistent with scientific accounts, and sometimes (but by no means always) students are strongly committed to their alternative conceptions. One example would be that most of the material in a tree has come from the ground through the roots. Such conceptions can seriously interfere with science teaching (and they are the topic of chapter 8).

Religious beliefs that may be compatible with science

Many students come to science lessons with strong religious beliefs. They may for example believe that the world was created by God and is maintained by His grace. As suggested above, such beliefs are neither supported, nor contradicted, by science and such beliefs are shared by many scientists and science teachers in parallel with the conviction that science offers us the best way to understand the natural mechanisms at work in the world.

A problem for the science teacher here is that students may not appreciate that scientific and religious accounts may be understood to be complementary (Taber, Billingsley, Riga, & Newdick, 2011). So, for example, a student may consider that the big bang model of the origin of the universe necessarily competes with the idea of the world being God's creation. Here the science teacher needs to help students appreciate that science is not seeking to refute or compete with religion, but rather offers a different layer of explanation. An analogy might be a scientific analysis of a painting which can reveal information, for example, about the pigments used, without competing with an artistic evaluation of its aesthetic qualities or a biographical account of why the painter made that particular artwork.

Beliefs in supernatural mechanisms that compete with science

Sometimes, however, students may have strongly committed beliefs that are inconsistent with scientific accounts of the natural world. One example is some of the teachings of 'young earth creationism' in some branches of Christianity (Long, 2011). These may include the belief that the earth is no more than 10 000 years old (rather than more like 4 600 000 000 years suggested by scientific evidence) and that each main type of living thing was created separately with evolution only producing variations on these basic kinds (where the scientific account has all living things on earth descending from one common ancestral type). As another example, students from some communities may hold alternative notions of ill health and disease based on beliefs in such ideas as magical spells and spirit possession (Foster, 1976). These ideas are clearly inconsistent with scientific models of disease based on - for example - infection with microorganisms.

In this situation the science teacher will wish to persuade her students of the merits of the scientific accounts - especially when these are well established and supported by overwhelming evidence. However, it may be counter-productive to proceed by setting out to show students their existing beliefs are false. Often student beliefs of this kind are strongly based on family and community commitments, and reinforced by (and associated with the authority of) parents and elders, so setting up a competition between science and existing beliefs may be counterproductive and damage students' attitudes to science as a school subject and more generally.

Teaching Science as Theoretical Knowledge

Earlier in this chapter it was emphasised that science should not be taught as facts to be believed, but rather as theoretical knowledge. This means we are teaching viable explanations consistent with evidence, but bearing in mind that sometimes there may be other possible explanations that could fit the evidence as well, and that we should always be aware the evidence base could shift. Science presents models, that are simplifications, and often have limited application (or at least are broad generalisations that have only been tested under limited ranges of conditions.)

Whilst not a total solution to the challenge of student beliefs being inconsistent with scientific accounts, such an approach to teaching science avoids a head-on confrontation between what we teach in science and what our students may believe. Our job is not to persuade students to believe that natural selection or the germ theory of disease is true - but to get them to see why these are strongly motivated by the extensive evidence available; to understand the scientific account; and to be able to see how to apply the ideas where relevant (Taber, 2017).

This also addresses the pedagogic problem that most of what we teach in school science comprises of curriculum and teaching models that simplify the science, and will need to be developed, extended, and complemented if the student continues with their studies. Students should never need to be told that what they have studied before was 'wrong' and must be 'forgotten' - but they will need to progress to more sophisticated models (see Table 1). We should avoid teaching over-simplifications, but as long as we teach scientific ideas as models (and students have been taught to understand what that means) and not facts, then shifting to more sophisticated accounts will be less problematic.

Proposition that might be learnt in science	*Why belief in the proposition as a fact may impede science learning*
The pH of a strong acid is 1	This is what universal indicator paper suggests when testing typical lab samples - but the pH depends upon both strength and concentration. A very dilute solution of a strong acid could have, e.g. pH4, and at the usual concentration 'bench' acids have pH<0.
Pure water has a pH of 7	the degree of ionisation of water is temperature dependent so the pH (and pOH) of pure water is less than 7 at 0˚C and greater than 7 at 100˚C.
The methane molecule is a tetrahedral shape	It is not clear how we best understand the shape of something on the scale of molecules where matter is more 'fuzzy'. An electron density map will not follow a tetrahedral pattern for example. (We get a tetrahedron by treating the hydrogen centres as points, joining them up, and considering the result as a solid shape. That does not fully represent the actual arrangement of matter in the molecule.)
The Sun gives out light and heat	Heat is often defined in science as energy transferred due to a difference in temperature, so then the light (and u.v. and infrared radiation) emitted by the sun and absorbed by the cooler earth is part of the net heat transfer.
Ionic bonds form when metal atoms donate electrons to non-metal atoms	The common ways of forming ionic compounds in the school lab (precipitation reactions, or neutralisation followed by evaporation) involve ionic bonds formed between ions that already existed in the reactants. Even when there is a direct reaction between the elements, the reactants do not comprise discrete atoms.
The molecule ATP has energy-rich phosphate bonds	Breaking the 'energy rich' bond in ATP (as in breaking any bond) requires an input of energy,
A child gets their genes from their two parents equally	The Y chromosome has less genetic material than the X chromosome. (The Y chromosome is like an incomplete X chromosome, that seems to be slowly getting smaller over successive generations.) Mitochondrial genes are only passed down the female line.
The particles in solids are tightly packed with no space between them	Yet we teach that a solid can contract or expand when the temperature changes according to the amount of space the particles have to vibrate around!
Oxidation is the addition of oxygen or the loss of hydrogen	Or it could be the loss of an electron, or an increase in the formal oxidation state. These definitions may apply when there is no oxygen or hydrogen involved.
Everything is made of atoms.	This could mean everything was made from atoms - but actually this is a way of conceptualising, not a 'historically' accurate notion - little of the material in the universe from which material on earth has formed is atomic (rather than plasma, or molecules, or ions). This could alternatively mean that everything contains atoms - but again this is a way of conceptualising (like thinking of a person as just a torso, head, arms and legs, placed together rather than connected through continuous tissues) as very few common materials actually comprise of atomic matter. E.g. a molecule is a different arrangement of subatomic particles, not just atoms placed next to each other.

Table 1: If ideas learnt about science are seen as 'facts' then they may impede the development of more sophisticated scientific accounts

Conclusions

Science teachers should not see the science curriculum as comprising of known facts to be believed and taught as truths. Rather, science teaching should be about presenting students with the models, principles, theories etc developed by scientists and trying to get them to see why on the basis of observations and other evidence, scientists feel these are the most useful ways currently available of thinking about the world (but not proven, absolute truths). Such a perspective gives a better reflection of the authentic nature of science, helps avoid clashes with some students' religious and cultural beliefs, and provides a more educationally sound way of helping students cope with the progression of increasingly more sophisticated models they will meet as they progress through their science education.

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