Pseudoscience in the NSW Science Programme

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Societies fund and support education in order to promote personal and social betterment that derives from deeper and widespread knowledge of nature and of society. This was the call of the eighteenth-century Enlightenment figures (Locke, Rousseau, Jefferson, Diderot, Condorcet, Priestley, Kant and others) who were so powerfully moved by the new understandings of the world laid out in the Scientific Revolution of the preceding century (Galileo, Huygens, Newton, Boyle and others). The linking of education to social and individual flourishing was powerfully made by John Dewey early in the twentieth century and continues to be made by governments and educators. It underlies the liberal education tradition which anchors NSW schooling.

Science education makes a particular contribution to these educational, social and political ideals. Accordingly, students completing the NSW science programme are expected to develop three core scientific competencies: scientific knowledge, scientific method, and appreciation of science. Together, these competencies constitute 'Scientific Literacy'; a concept helpfully elaborated by many organisations and scholars. For instance, the American Association of the Advancement of Science affirms:

> Taken together, these [scientific] values, attitudes, and skills can be thought of as habits of mind because they all relate directly to a person's outlook on knowledge and learning and ways of thinking and acting. (AAAS 1989, p.133)

The three core competencies, as expanded in the NSW science syllabus, are:

First, subject-matter knowledge. This is expressed in the Outcomes for the Stage 4 (water, life, atoms, geological change) and Stage 5 (energy, disease, evolution, chemical reactions) Focus Areas. These age-appropriate intellectual competencies lead into the Stage 6 (Years 11-12) discipline-specific subjects: Chemistry, Biology, Physics, Earth and Environmental Sciences. This knowledge base is further developed by students in the Stage 6 subject Investigating Science and in the new Year 12 Science Extension subject.

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Second, scientific method, or the capacity to 'Work Scientifically' as the Stage 4-5 and Stage 6 curriculum documents label it. There is some ambiguity about whether 'Working Scientifically' is to apply outside the laboratory. Statements such as *understand themselves and the world in which they live* suggest it should.

For the Enlightenment tradition, the method was relevant and useful for working on problems outside of, as well as inside, the laboratory. Newton believed that there would be beneficial flow-on effects if the methods of the New Science were applied to other fields:

> If natural philosophy [science] in all its Parts, by pursuing this Method, shall at length be perfected, the Bounds of Moral Philosophy [politics, economics, government] will be also enlarged. (Newton, 1730/1979, p.405)

Third, students should have 'positive values and attitudes towards science' as the Forms 7-10 syllabus repeatedly states. The NSW syllabuses unashamedly want, with due criticism and historical awareness, the positive values and attitudes to be adopted and internalised, not just learnt about as a spectator where the learning makes no personal impact. Anthropology and history students are not expected to adopt or value the beliefs and mores of the current and past cultures they study. In contrast, the expectation is that students in NSW science courses will adopt the outlook, mores, and procedures of science in their investigations of the natural and social worlds; they will develop a scientific outlook or habit of mind. In a world first, Jawaharlal Nehru wrote this expectation into the 1950 Indian Constitution calling it Scientific Temper and requiring the state to promote it.

These three competencies constitute the Aim of the *Science Years 7–10 Syllabus* which states (p.12) students are expected to develop the capacity to work scientifically, meaning:

- An interest in and enthusiasm for science, as well as an appreciation of its role in finding solutions to contemporary science-related problems and issues.
- The knowledge and understanding of the nature and practice of scientific inquiry, and skills in applying the processes of Working Scientifically.
- Develop scientific knowledge of and about phenomena within the natural world and the application of their understanding to new situations and events.
- Have an appreciation of the development and dynamic nature of scientific knowledge, its influence in improving understanding of the natural world

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and the contribution of evidence-based decisions in informing societies' use of science and technology.

These knowledge, technique and appreciation competencies are carried through and elaborated in Year 11-12 subjects. The newly introduced Stage 6 (Yr.12) 60-hour, 1-Unit, Science Extension subject has four modules, the first of which (with a 10-hour allocation) is *The Foundations of Scientific Thinking*. It is expected that:

> Students interrogate and refine their ideas of and about science through analysing historic and cultural observations and significant scientific research within the relevant ethical frameworks and philosophical arguments of the time.

The Aims of the Stage 6 Investigating Science subject state:

> The study of Investigating Science in Stage 6 enables students to develop an appreciation and understanding of science as a body of knowledge and a set of valuable processes that provide humans with an ability to understand themselves and the world in which they live. Through applying Working Scientifically skills processes, the course aims to enhance students' analytical and problem-solving skills, in order to make evidence-based decisions and engage with and positively participate in an ever-changing, interconnected technological world.

This HSC subject has 8 modules each of which is anchored in the core foundation of 'Working Scientifically': Module 4 'Theories and Laws', Module 7 'Fact and Fallacy', Module 8 'Science & Society'.

Module 7 of Investigating Science explicitly refers to Pseudoscience:

> using examples, analyse a pseudo-scientific claim and how scientific language and processes can be manipulated to sway public opinion, including but not limited to: astrology, numerology, and iridology. (p.56)

Pseudoscience in Society

Jon D. Miller (University of Michigan), who for decades has published on science literacy and public understanding of science, correctly maintains:

> In addition to understanding basic scientific constructs, it is important for citizens to recognize pseudoscientific constructs that seek to be recognized as scientific. (Miller 2004, p.278)

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YouGov's 2022 poll of 3,500 US adults found that a little more than one-quarter of Americans (27%) – including 37% of adults under 30 – say that they believe in astrology, or that the position of the stars and planets influences people's lives. Can responsible science teachers simply ignore this?

Covid-19 precipitated a multi-million $$$ tsunami of pseudoscientific, make-believe cures and treatments. But this was just the surfacing of an underlying social and economic malady: namely, the extent and depth of credulity and gullibility in society. This has been exploited by snake-oil merchants (and governments) for at least the past two centuries, and by sundry other merchants since the beginning of commerce.

In 2012, the US National Health Statistics Report stated that one third of US citizens spent $30 billion per year on alternative and complementary health medicines and therapies most of which are marketed as scientifically 'based' or 'proven'. A Google search for 'Magnet Healing' returned 16 million results in 0.6 seconds. In 2000, in the US, $300 million was spent on healing magnets and $1 billion spent globally. Whether healing magnets, or more generally alternative medicines, are scientific and reliable or not, are matters concerning the health of the population, the staffing of hospitals, and the cost of health insurance and government medical support. Should healing magnets be claimable on Medibank? Should magnetic healers be salaried staff members of hospital?

In Hong Kong, Taiwan, and increasingly through the USA and some other countries, feng shui principles are, expensively, built into town planning decisions and construction projects. In 2000, the Indian BJP government decreed that Hindu Astrology (Jyotisha) was a science on par with astronomy and consequently needed to be taught in university degree programmes. The decision was twice unsuccessfully appealed by scientists to the Indian Supreme Court. There are now astrology programmes, professorships and degrees throughout India.

And not just India. The University of Wales (not New South Wales) offers an MA degree in Cultural Astrology premised on the supposed unfortunate fact that the 'divorce between astrology and astronomy is (just) a feature of modern western thought'. The degree can be had for the payment of UKP10,400. In 2003, the University of Lund established a professorship and chair in Parapsychology. Many other universities have comparable departments.

The Division of Perceptual Studies at the University of Virginia claims to have vindicated some reincarnation claims. Such claims are a core part of Hindu,

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Buddhist and Jain religions, and commonly feature in indigenous belief systems. The pertinent question is: Does the university's department claim to *scientifically* vindicate reincarnation? If so, then it becomes important whether the vindication is indeed scientific, poor science, or whether if it is pseudoscientific. If no claim for scientificity is made, then the division can say what it likes and bear the consequences. Reincarnation will receive international attention upon the death of the current Dalai Lama. A science class might learn things about science/non-science in following how the choice of the reincarnated Lama is made.

There is no argument that physiotherapy is rightly claimable on Medibank; there should be argument whether hypnotherapy can be claimable. The issue is not that something works in this or that case, for this or that person. It may or may not so work. The issue is whether the practice is based in scientific understanding of physiology and natural mechanisms, and so can be expected to be more generally efficacious. This is a general issue in Examining Holistic Medicine.

The world-wide-web powers alternative, holistic, and complementary sciences, therapies and pseudosciences. A July 2023 web search for PSEUDOSCIENCE returned 6,400,000 results in half a second. Myriad pseudoscience publications and communities are just one click away; related baubles, 'scientifically proven' therapies, therapists and practitioners are as close as a credit-card transfer. The informative Wikipedia entry for Pseudoscience has 640 links and/or citations to different pseudosciences and related literature.

Ignoring, or being relaxed about pseudoscience, does have social costs. Imre Lakatos (1922-1974) correctly observed:

> … the problem of demarcation between science and pseudoscience is not a pseudo-problem of armchair philosophers: it has grave ethical and political implications. (Lakatos 1978, p.7)

As with all personal, commercial and government expenditures, it is important for all pseudoscience expenditure to look at the 'opportunity costs': What else could have been productively done with the money? Instead of healing magnets, snake oil, hypnotherapy, or an astrology degree could a person have bought a good book, had a meal, have an overnight stay somewhere, or enrol in a decent science or philosophy degree? Instead of a new astrology appointment in an Indian astronomy department, could a radio astronomer have been appointed with more tangible benefit for Indian science and society?

Pseudoscience in NSW Curricula

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Pseudoscience is an explicit component of the Investigating Science subject in Stage 6 (Years 11-12). Further, identification of pseudoscience, and how it might be demarcated from science is a component of the separate Stage Six Extension Science course where pseudoscience is elaborated as:

● *The definition of, and problems associated with, pseudoscience.*
● *Historic and contemporary pseudoscience claims.*
● *Using social media to investigate examples of pseudoscience.*
● *How distorting a graph can be used to manipulate data in support of a specific viewpoint.*
● *A set of criteria to identify pseudosciences.*
● *The impact of pseudoscience on the public's trust in science and science-based decision making.*

The NSW *Investigating Science* syllabus explicitly names astrology, numerology and iridology as pseudoscientific practices and beliefs that could be examined in the course. There are countless alternatives that might have been listed. The world, including, Australia is awash with beliefs and practices that claim to generate truths about the natural, social and personal worlds; and seek legitimacy, and room at the educational, therapeutic, health and financial table, by claiming to be scientific. They purport to generate not just truths, but scientific truths.

The two-volume *Skeptics Encyclopedia of Pseudoscience* and the near 50-year-old journal *The Skeptical Inquirer* provide illuminating, if saddening and distressing, overviews of the pseudoscience landscape.

Any of the following are putative pseudosciences could usefully be elaborated and discussed in any NSW science course. Such discussion is an opportunity to combine science with mathematics, economics, social studies, and perhaps religious studies.

For particular examples, the class might be divided about whether they are or are not pseudoscience, but this is not a problem. Disagreement can be a 'teaching moment'. The purpose of classroom elaboration of pseudoscience is to gain a better understanding of what makes some practice and theory scientific; and how such practices can be distinguished from non-science, specifically pseudoscience.

Feng shui
Acupuncture
Chiropractic

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Crystal healing
Homeopathy
Naturopathy
Reiki energy healing
Vitalism
Mesmerism (animal magnetism)
Eugenics
Dowsing
Psychokinesis (Telekinesis)
Phrenology
Graphology
Parapsychology
Biological racism
Psychoanalytic Theory
Magnet therapy
Psychological astrology

Some pseudosciences have had an explicit political-ideological base and purpose:

Aryan Science (German Science)
Lysenkoism (Stalin)
Maoist Science
Dialectical Materialism (Lenin)

Others have an overt religious base and purpose:

Christian Science (Mary Baker Eddy)
Creation Science
Vedic Science
Islamic Science
Scientology

Any of the foregoing might adopt, or even generate, some truths about the world; and could affect cures for particular maladies, or solve particular problems, but doing so is completely removed from whether the putative explanations are true, or the system of beliefs and practices are scientific.

Clearly many non-scientific systems contain truths and solve problems. But merely doing so does not constitute science. Placebo and Expectancy effects have been well documented since 1811 when the terms were coined by sceptics at the height of enthusiasm for Franz Mesmer's (1734-1813) animal magnetism theory and therapies.

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Indigenous Science

There are tens of thousands of Indigenous Sciences or Traditional Ecological Knowledges (TEK) rooted in different cultures, traditions, and places. These might be widely shared across regions or be localised to clans, tribes, or kinship groups. Allegiance can vary from millions to hundreds. Some prominent TEKs are:

Mātauranga Māori (New Zealand)
Australian Indigenous Science
Inuit Science (Canada)

All stable communities develop and pass on techniques, technologies and local knowledge relating to health, medicine, agriculture, fishing, animal husbandry, cooking, construction, the moon, planets, stars, navigation, child raising, social organisation, governance, language, nature, Creation stories, super-nature including spirits, gods and much else. These are all the components of civilization; without such local and transmissible knowledge, societies would not survive.

The Australian National University's (ANU) Indigenous Science and Knowledge major affirms:

> Indigenous knowledge systems consist of complex webs of social-cultural interaction, developed through relationships among communities and within their landscapes.

Whether such complex webs and knowledges are understood (and treated and funded) as science, protoscience, pseudoscience, local knowledge, cultural lore, mythology, or legend — is a matter of significant cultural, educational, economic, and philosophical consequence.

I first encountered these educational/philosophic/political issues thirty years ago, when at the beginning of 1992, I was appointed Foundation Professor of Science Education at the University of Auckland. At my first faculty meeting, there was a motion to allow completion of the Anthropology Department's 'Māori Knowledge' (Mātauranga Māori) course to count as meeting the decades-old 'one science course' requirement for students enrolled in the University's Primary Education degree. One supporter of the motion argued the strong case:

> There is a need to struggle to assert the equal validity of Māori knowledge and frameworks and conversely to critically engage ideologies which reify Western

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> knowledge (science) as being superior, more scientific, and therefore more legitimate. (Smith 1992, p.7)

I spoke against the motion saying, among other things, that Māori Knowledge was not science, and need not be called science in order to be respected and to advance Māori culture and interests. I said there were good national and cultural grounds for making the anthropology course compulsory for education students. There might also be legal grounds anchored in the 1840 Treaty of Waitangi, signed between the British Crown and the Māori chiefs, that required the new government to 'maintain and support' Māori culture. There are ample opportunities for parts of Māori knowledge to be utilized in science programmes to illustrate, sometimes by contrast, scientific concepts, theories and practices. But, nevertheless, the 'one science subject' requirement should be retained.

My arguments failed to convince. The motion was passed: New Zealand primary teachers, at least Auckland-trained ones, could thereafter teach with zero orthodox, or 'Western' as it was called, scientific knowledge.

The New Zealand debate progressed. Thirty years later, in 2021, the NZ Ministry of Education formally moved to place Mātauranga Māori into the NZ school science programme and into the science funding stream. The 1992 'Strong Case' for equality has become normalized, it is almost the default position for Māori and Pakeha. This occasioned a significant national debate to which I made a small contribution while Richard Dawkins made a substantial one.

Serious concern about Indigenous Science recognizes that the teaching of science (Western or orthodox) does have worldview dimensions and implications. Hugh Gauch Jr., a Cornell University agricultural scientist, well describes this in an Open Access article. The worldview dimension of the debate is laid out in the 15-chapter *Science, Worldviews and Education*. It is folly for educators to ignore this. But considered resolution depends on input from philosophy of education and from history and philosophy of science. Two disciplines struggling for space in education.

Charbel Niño El-Hani, a Brazilian biologist, philosopher and educator has, with colleagues, worked extensively over many years with a north-eastern traditional fishing community that has developed extensive knowledge and lore about their coastal environment, fish feeding and migration patterns. He has published extensively on their practices and beliefs. His view is surmised in the title of one article: *Valuing indigenous knowledge: to call it ''science'' will not help* (*Cultural Studies of Science Education* vol.3, 2008).

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Demarcation of Science, Pseudoscience and Non-Science

The Demarcation Problem arises from efforts to separate science from other knowledge systems making truth claims about the world, and from non-sciences that might also make truth claims. Demarcation has exercised philosophers since ancient times and it engages educators and curriculum writers, including writers of the Australian National Curriculum.

NSW science teachers need a rudimentary understanding of demarcation because it is required by having 'Working Scientifically' as a core aim of all NSW science curriculum: What constitutes working scientifically as distinct from working in some other way? The need for teachers to understand Demarcation is further highlighted by having Pseudoscience as an item in the NSW *Investigating Science* curriculum: How is pseudoscience to be identified?

Beyond the foregoing, clarity about demarcation is required for informed decision making about the place of Aboriginal or First Nation's knowledge in the school programme: Should it to be included in the science programme as science or as illustrative of different ways of understanding phenomena? Is First Nation's knowledge better included in a social, cultural, or religious studies programme?

Technology and Technique

At the outset, before considering demarcation, science needs to be distinguished from technology and technique. The latter pair are judged by whether they work, not by whether they are true. They are judged by how effectively and efficiently they do their job: navigating a route between two places, building sturdy and dry habitation, making a cake that rises rather than collapses, growing crops that thrive rather than wilt, curing headaches, and so on. Most such practices have some 'theory' associated with them, but they are not judged on their theory. The theory is often an afterthought that does not inform the technology or technique. Efficacy, not truth, is the overriding consideration for technology.

Many accounts can be given, and passed on, about why something works, but it is the working that counts. Telling children not to go into the bush because a devil resides there can be very effective: Even without devils, children do not go into the bush. Technology can, and has, spurred and enhanced science, but it is not science. Science is a cognitive system making systematic and expandable claims about the world that are meant to be true or false, warranted, or

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unwarranted. Science is associated with and dependent on technology – microscope, telescope, watch, tape measure, weighing scales, compass, magnetic resonance equipment, and so on – but neither the technology nor its capable use, is science.

Classification

Systems making truth claims about the world can be categorized as:

• *Science* which in turn can be *natural* or *social*.

• *Non-science* constituted by practices that falsely claim to be science (*pseudoscience*) and those that make truth claims without claiming to be scientific (humanities, the arts, music, cultural lore).

<table>
<tr><th colspan="7">Systemic Cognitive Truth-applicable Claims</th></tr>
<tr><th colspan="3">SCIENCE</th><th colspan="4">NON-SCIENCE</th></tr>
<tr><th colspan="2">Physical Science</th><th>Social Science</th><th colspan="2" rowspan="2">Claims to be science</th><th colspan="2" rowspan="2">No claim to be science</th></tr>
<tr><td colspan="2">Physics, chemistry, biology</td><td>History, sociology, anthropology, economics</td></tr>
<tr><th>Mature</th><th>Mature and disputed</th><th>Mature and rejected</th><th>Proto-science</th><th>Pseudo-science</th><th>Humanities</th><th>Arts</th></tr>
<tr><td>Newtonianism Darwinism</td><td>Punctuated equilibria</td><td>Phlogiston theory; caloric theory; Ptolemaic astronomy</td><td>Beginning possible sciences</td><td>Feng shui; Christian Science; tobacco industry research</td><td>Literature Poetry Theology</td><td>Music appreciation Art criticism</td></tr>
</table>

To amplify the meaning, sense, or denotation of science it is first required to pool together examples of activities and investigations that can widely be agreed to be science – the exemplars – and then see what they have in common or what specifically identifies them. The pooling begins with the conviction that science is a truth-seeking practice. This is a gate-keeping requirement. The practice might or might not find truths about the world, but if any practice is not even seeking them, if the practice is not ‘in the business’ of finding truths about the world, then it is just not science. It might be other admirable things (business, commerce, theatre, literature), but not science.

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It is a conventional matter whether corrupt science should be put with pseudoscience or kept with science. In July 2023 the President of Stanford University had to resign when it was ascertained that his labs 'cooked' results of their Alzheimer's studies. Was his work pseudoscience or corrupt science? Another conventional, difficult to decide upon, matter is the amount of time allowed for a proto science to turn into a mature science. Perhaps after five decades without results, protosciences should become pseudosciences.

The truths science seeks are not just particular truths about this or that phenomenon – how fast does this rock fall, does this tree lose its leaves in Fall, is tallness present in the third generation, and so on – science seeks general truths normally in the form of causal attribution or support for an appropriate theory. Particular truths can constitute important data, but data collection is not the goal of science; data collection is pursuant to hypothesis evaluation or theory assessment.

The conviction that truth is the *telos* of science goes back at least to Aristotle's separation of *episteme* (scientific knowledge) from mere *doxa* (opinion), and his belief that apodictic certainty characterises science. It is the *telos* or purpose of science. We need not hold onto Aristotle's certainty and absolute truth, but we need to hold onto seeking knowledge of something external, and being somewhat successful, as a hallmark of science.

This is how meaning is given to any concept: begin with exemplars and then intelligently discern their special, and perhaps unique, features. This is exemplified in the species/genus distinction of Linnean Classification. What is it that differentiates species but makes them members of the same genus? Wolves and coyotes are in some way related, but they are different. How is this?

So, Newton, Faraday, Darwin, Einstein can be regarded as scientists and their investigations (conceptual, theoretical and experimental) are scientific. If there is no agreement on this, then the question of What is This Thing Called Science? does not get off the ground. If there is agreement on the exemplars, then historical and philosophical analysis can refine the initial understandings. The strengths and weaknesses of the exemplars can be detailed, and their pool expanded.

Francis Bacon (1561-1626) lauded Galileo's observations and thought that this marked the New Science, but Bacon passed over the centrality of mathematics for Galileo's science and theorizing. This recognition and refinement came later. With refinement, the pool of exemplars can be expanded. The expansion

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could include particular ethnic sciences if they meet the criteria distilled from the original pool.

Just as scientific knowledge has deepened and expanded, so too has the knowledge of science. Or what is oft referred to as the Nature of Science (NOS). Historians, philosophers, sociologists, and reflective scientists have all contributed to the refinement of NOS.

Over the span of about 400 years the Galilean-Newtonian Paradigm (the world's most consequential GNP), or heritage, has developed and matured into modern science with its distinctive ontological, methodological, ethical, and sociological dimensions.

Much about the Scientific Revolution and the birth of modern science, to say nothing of commerce, navigation, astronomy and much else, depended on Galileo's pendulum discoveries. In one publication I wrote:

> Galileo's discovery of the properties of pendulum motion depended on his adoption of the novel methodology of idealisation. Galileo's laws of pendulum motion could not be accepted until the empiricist methodological constraints placed on science by Aristotle, and by common sense, were overturned. As long as scientific claims were judged by how the world was immediately seen to behave, and as long as mathematics and physics were kept separate, then Galileo's pendulum claims could not be substantiated; the evidence was against them.

And proceeded to say:

> Proof of the laws required not just a new science, but a new way of doing science, a new way of handling evidence, a new methodology of science. This was Galileo's method of idealisatioin. It was the foundation of the Galilean—Newtonian Paradigm which characterised the Scientific Revolution of the 17th century, and the subsequent centuries of modern science. As the pendulum was central to Galileo's and Newton's physics, appreciating the role of idealisation in their work is an instructive way to learn about the nature of science.

If something is entirely inconsistent with core GNP characteristics then, whatever it is, it is not science as is commonly understood; the practice is something else and ought to be given a different name. There can, of course, be much knowledge of the world acquired outside of science. Poetry, music, art, folk lore can generate such knowledges. People had a degree of knowledge of the world for millennia before modern science began appearing in Europe in the

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seventeenth century, and many have such knowledge today where science has never reached. But not all such knowledge need be, or should be, called science. It is just knowledge: common knowledge, folk knowledge, folk lore, commercial knowledge, and so on.

History of Demarcation

Efforts to distinguish science from non-science, the original 'demarcation problem', have been pursued since at least David Hume's (1711-1776) time when in his *Inquiry* he advised that:

> When we entertain, therefore, any suspicion that a philosophical term is employed without any meaning or idea (as is but too frequent), we need but enquire, *from what impression is that supposed idea derived?* And if it be impossible to assign any, this will serve to confirm our suspicion. (Hume 1777/1902, p.22, emphasis in original)

Hume was enunciating his empiricist philosophy and using the grounding in sensation as a way of separating 'sensible' ideas from the wide class of non-sensible ideas. He maintained that people should only believe things for which there is evidence.

Ernst Mach (1838-1916), the great Austrian physicist, historian, philosopher, and educator (he was the founding editor of the world's first science education research journal, most of the giants of turn-of-the-century European physics, including Einstein, learnt their physics from Mach; he worked for decades with German science teachers) took Hume's point seriously and argued that a whole raft of central scientific concepts – mass, force, absolute space, absolute time, atom, molecule – were not scientific as they went beyond their sensory anchors, or the observation statements that grounded them (Mach 1910/1992).

Mach famously, or perhaps infamously, said that he would 'leave the Church of Physics' if belief in atoms was required for its membership (Blackmore 1989). These might seem counterintuitive positions for a great scientist, but he was an ontological phenomenalist not a realist. This explains a lot and shows that science and philosophy are intimately linked.

Karl Popper (1902-1994) acknowledged the force of Mach's critique, but rather than accept Mach's conclusion that the bulk of orthodox science was unscientific, he proposed in his 1934 *Logik der Forschung* a new demarcation of science from non-science, namely Falsifiability. Rejecting the Humean/Machian/Positivist experiential confirmatory criterion, he proposed instead:

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> … I shall certainly admit a system as empirical or scientific only if it is capable of being tested by experience. These considerations suggest that not the *verifiability* but the *falsifiability* of a system is to be taken as a criterion of demarcation. (Popper 1934/1959, p.40)

He addressed this foundational demarcation issue in a 1953 Cambridge lecture 'Science: Conjectures and Refutations' published in his 1963 anthology *Conjectures and Refutations: The Growth of Scientific Knowledge* (Popper 1963) which has been cited in 25,000+ other works. He was adamant that his falsifiability criterion was not meant to separate meaningful from meaningless statements (Hume's project) but scientific from non-scientific statements or systems. There, dismissing the positivist link-to-experience (sensation) criterion as a demarcator of science, he says:

> But this criterion is too narrow (*and* too wide): it excludes from science practically everything that is, in fact, characteristic of it (while failing in effect to exclude astrology). No scientific theory can ever be deduced from observation statements or be described as a truth-function of observation statements. (Popper 1963, p.40)

And proposed instead:

> One can sum up all this by saying that *the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability*. (Popper 1963, p.37, emphasis in original)

And later:

> A system is to be considered as scientific only if it makes assertions which may clash with observations; and a system is, in fact, tested by attempts to produce such clashes, that is to say by attempts to refute it. (Popper 1963, p.256)

Popper's original concern, as a young scholar, was to separate and defend good and revolutionary science, as manifest in Einstein's theory of general relativity that had spectacularly been confirmed by Arthur Eddington's 1919 solar eclipse expedition, from popular belief-systems of the time that were also being enthusiastically embraced by millions: Astrology, Psychoanalytic theory, Historical Materialism. Popper was deeply impressed by the testability of Einstein's theory, the preparedness to put its 'head on the block', in contrast to the Laager mentality of the other three popular enthusiasms.

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For Popper, each of the latter was a pseudoscience, and his testability criterion was meant to separate them from the real thing. Despite firm belief by multiple millions, and one of the three having the support of all-powerful states—these practices and belief systems never presented themselves for test and possible refutation. For many, they still have not presented themselves for testing, only for affirmation.

But falsifiability as a demarcation criterion had its problems. On the one hand, many supposed pseudosciences made claims about the world that could be, and were, falsified – creationist science and astrology, for instance. So, these should be science, albeit 'bad' science. On the other hand, many established sciences made claims that were falsified by empirical evidence, (Galileo's pendulum experiments) but this did not result in rejection of the theory. So, these should be pseudoscience.

Karl Popper was correct in identifying the *growth* of knowledge as a hallmark of the scientific tradition. A static unchanging tradition is not scientific. In a 1961 Presidential Address to the British Society for the Philosophy of Science, he stated:

> My aim in this lecture is to stress the significance of one particular aspect of science – its need to grow, or, if you like, its need to progress. … I assert that continued growth is essential to the rational and empirical character of scientific knowledge; that if science ceases to grow it must lose that character. It is the way of its growth that makes science rational and empirical; the way, that is, in which scientists discriminate between available theories and choose the better one or (in the absence of a satisfactory theory) the way they give reasons for rejecting all the available theories, thereby suggesting some of the conditions with which a satisfactory theory should comply. (Popper 1963, p.215)

Fifty years later, the German philosopher Paul Hoyningen-Huene concurred, writing:

> One of the most astonishing facts about science, especially about modern natural science, is its remarkable growth, both in scope and in precision. Science is a dynamic enterprise through and through. This feature probably best distinguishes science from all other knowledge systems, past and present. (Hoyningen-Huene 2008, p.176

Research into the natural and social world, and hence growth and change in knowledge, is a constitutive part of science. Ossification is a mark of bad- or pseudoscience.

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Identifying Pseudoscience

Pseudosciences are look-alike sciences, imitation sciences, Doppelgänger sciences, or simulacrum sciences. All pseudoscience contain some scientific content – scientific words and concepts, mathematics, instruments, recordings – in order to give the practice credibility, to foster the simulacrum. It is of the essence of pseudoscience to appear to be scientific; its 'authority' depends on mimicking science.

Science has journals, so pseudosciences commence their own or 'take over' established journals; science has peer review, so pseudoscience has the same; science has numbers and statistics, so pseudoscience has tables, figures, correlations; science has experiments, so pseudoscientists conduct their own; science has meetings and conferences, so pseudoscience does the same, and so on.

In September 2023, the 76th Tobacco Science Research Conference will be held. Surely a rich hunting ground for the identification of real, fake and pseudoscience. The practical and philosophical task is to reliably separate the real from the mimic and the gimmick.

Consider what the US Wellness Institute says of its Reiki therapy:

> The Reiki practitioner is the conduit between the patient and the source of the universal life force energy; the energy flows through the practitioner's energy field and through her hands to the patient. . . . [She] places her hands in specific energy locations . . . [the] length of time determined by the flow of energy through her hands. . . . The patient experiences the energy as sensations such as heat, tingling, or pulsing where the practitioner has placed her hands. Sometimes, the sensations are felt moving through the body.

This description abounds with scientific words, and careful procedures, but none of the extraordinary Reiki claims about mechanisms have ever found support in a laboratory. Indeed, they are inconsistent with science as they violate the fundamental conservation of energy principle. The violation is even more obvious when the busy, or fastidious, therapist uses 'at a distance' therapy where the patient is not touched, but the therapist's hands are merely moved over the putative energy centre or zone.

Not surprisingly, there are millions of web sites (13 million results in 0.3 seconds for REIKI SUPPLIES) selling Reiki Charkra pendants, stones,

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bracelets, rings and anything else that will separate a gullible citizen from their hard-earned dollars. For a fee, the Wellness Institute also offers instruction in Craniosacral Biodynamics, Polarity Therapy, NeuroEnergetic Therapy and much more. People line up to transfer $$$.

A Reiki therapist writes:

> What we'll be looking for here, within John's auric field, is any areas of intense heat, unusual coldness, a repelling energy, a dense energy, a magnetizing energy, tingling sensations, or actually the body attracting the hands into that area where it needs the reiki energy and balancing of John's *qi*.

One commentator opines: 'Reiki is the hottest new Eastern healing practice making its way into the Western health industry' (Sacks 2014).

Reference to *qi* (or chi) in the above is a give-away; it almost ensures that what comes next is pseudoscience. It is a big task to reconcile manipulation of *qi* energy with the foundational conservation of energy principle. Dr Yan Xin, an internationally known practitioner, and supposed 'sage of our times', who had been at Tsinghua Technical University in Beijing, asserted:

> the mind power or *Qi* emitted by a trained Qigong master can influence or change the molecular structure of many test samples, including those of DNA and RNA, even if these test samples are 6 to 2,000 kilometers away from the master. *Qi* can also affect the half-life of radioactive isotopes and the polarization plane of a beam of light as emitted from a Helium-Neon laser. (Matthews 2019, p.250)

In brief, you can have *qi* or you can have science, but not both. All laboratory effects, positive and negative, can be attributed to projections of *qi* by someone somewhere. Despite 3-4,000 years of reference to *qi*, there is still no instrument to measure it. So, it is a handy construct to explain anything you want. Despite being believed in by millions for millennia, the belief is pseudoscientific. Feng shui is tailor made for Teaching About Science and Pseudoscience and more broadly for integrative cross-curriculum teaching:

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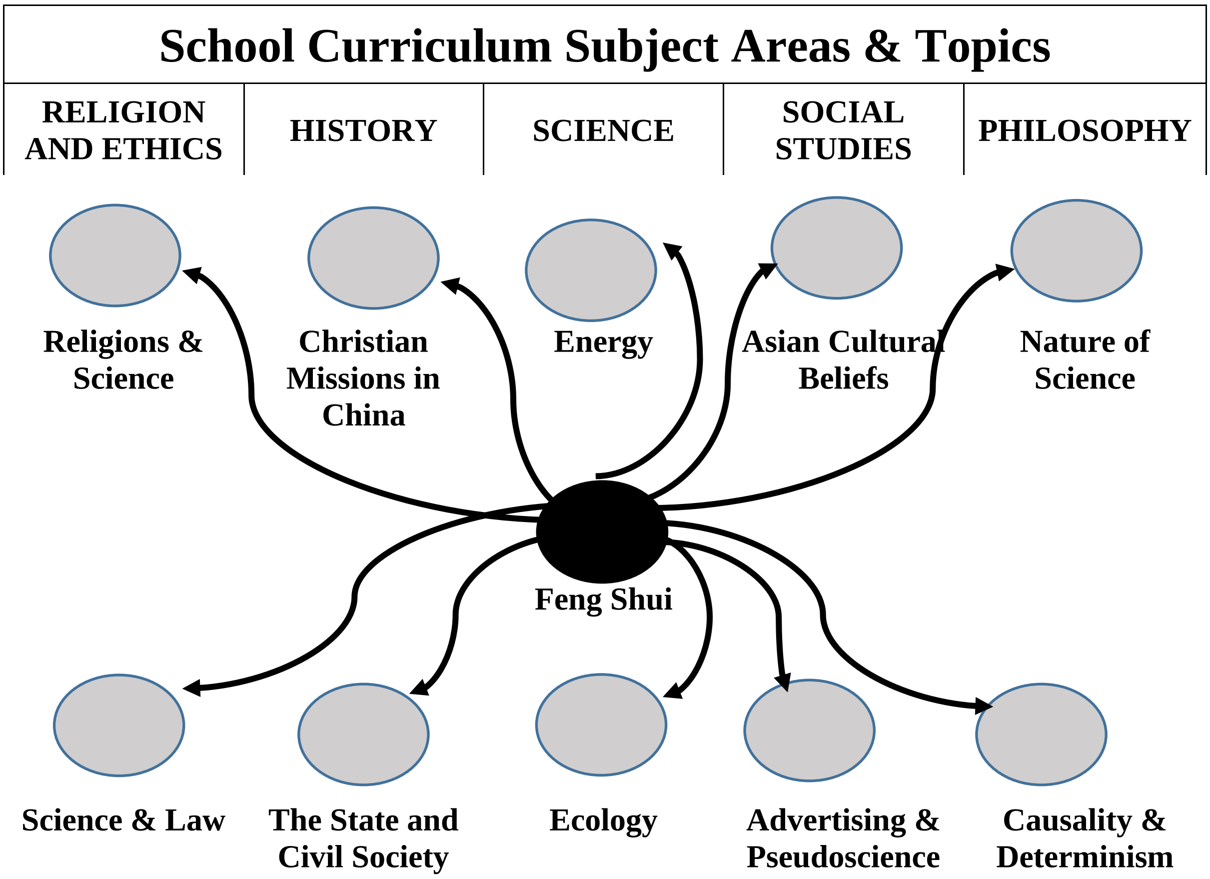

The same template could be utilized with other putative pseudosciences, linking them with topics in other school subjects.

Sven Ove Hansson, a Swedish philosopher, has usefully provided a brief list of criteria whereby any corpus of belief and practice can be judged pseudoscientific:

● There is overdependence on authority figures.
● Unrepeatable experiments are too frequently adduced.
● Data selectivity or cherry-picking of evidence is too common.
● There is an unwillingness to seriously test claims and predictions.
● Confirmation bias is endemic, and disconfirmation is neither sought nor recognized.
● Some explanations are changed without systematic consideration.
● The practice makes scientific claims but refuses to engage with the scientific community by publishing in established research journals and presenting at research conferences. (Hansson 2009)

Identifying Science

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There is a need to identify both necessary and sufficient conditions for a practice or theory to be called science. Not every claim about the world is a scientific claim, and not everyone making such a claim is a scientist. Gardeners do things in nature, but it does not mean they are doing science; chefs do things with ingredients and refine their practices in order to make a better sufflé, but that does not make them scientists.

People might talk of cooking as a 'home science', it used be so labelled in schools back when science was in vogue. Indeed through to the establishment of Comprehensive High Schools in the early 1960s, NSW had Domestic Science High Schools for Girls. But to identify domestic science with science advances nothing. People going to university to do a science degree are short-changed if they are taught how to cook and make dresses. There are acceptable alternative names for such practices: local knowledge, ethnic knowledge, traditional lore, custom, folk knowledge, and so on. Correct and consistent language is important in education and should be used.

The above classification does depend upon demarcation criteria at each level, but these need not be sharp, and they need not be timeless and essentialist. Demarcation criteria can and have changed over time as scientific inquiry matures and institutions develop. In 1938 Robert Merton provided the beginning of a modern classification when he characterized the practice of science as: Communal, Universal, Disinterested, and incorporating Organised Skepticism (CUDOS). These Mertonian Norms have been buffered and refined but have been confirmed and do valuable service in separating genuine science from pretend- and pseudoscience (Merton 1938/1973).

The basic division is not all-or-nothing. Science contains non-empirical elements: mathematics, logic, ethics and metaphysics. Humanities contain scientific elements: archival research, biographical details, and sociological information. Membership of a category is not cut and dried, it is a matter of family resemblance. There are clusters of criteria that mark out the categories, these can change over time, and the borders are to some extent porous. Practices once in a category can over time move up or down.

Mario Bunge (1919-2020) well characterized the marks of a genuine, mature science such as contemporary physics, chemistry or biology. With elaboration, his marks of a mature science are:

(1) A *community* of appropriately trained inquirers or researchers with recognized public means of information exchange. Science is a generative system; the conduct of research is constitutive of science; scientific knowledge has to grow. Science is changeable, not frozen or ossified.

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(2) A *philosophical background* with three components. First, an *ontology* of discernible non-subjective things that do not come into and out of existence dependent on whether someone is thinking about them. Science presupposes a lawlike (legal) reality where events have natural causes. Second, a realist *epistemology* which maintains that knowledge of the world is possible and distinctions can be made between accurate and partial knowledges. Third, an *ethos* supporting the free search for truth as distinct from the search for profit, national dominance, or political advancement. Science requires its practitioners to have an instinct for truth and for this to be supported by society.

Just as science cannot be conducted in a philosophical vacuum, neither can it be conducted in a moral vacuum. If lying, false reporting, misrepresentation, or deference to some external institution (Curia, Party Central Committee, National Business Council) is habitual, then no matter that measurements and tests are being undertaken, the practice is not science, it is something else.

(3) A *domain of investigation* consisting of real, scrutable events and lawful (legal) processes in the world. Science does not study inscrutable, supernatural, non-lawful, subjective processes, events, or episodes.

(4) *Logic and mathematics* are utilized. If a practice shuns or defies mathematics or logical reasoning, then it is likely to be non-scientific. Creativity, novelty, insight is important, but the outcomes of such thinking needs be subject to mathematical or quantitative formulation and appraised in a logical manner. Instead of a prediction about 'some' successes, a mature science makes a prediction about a designated percentage of successes; instead of talking of 'closed' orbits, it will talk about circular or elliptical orbits with specified radii.

(5) Mature sciences have a *specific background* of up-to-date and reasonably well confirmed data, hypotheses, and theories from other fields relevant to the domain. Mature scientific investigations begin with knowledge at hand, with well confirmed general theories. Science utilizes known laws and the established properties of bodies making up the subject's domain. This might be expressed in a literature review or the citation of some extant publications.

Astronomers might make observations using optical or radio telescopes, but these observations presuppose a whole range of established scientific electric and optical theory. There are no stand-alone observations in science. This is well exemplified in Galileo's lunar observations, and the debate they occasioned.

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(6) The *problems or puzzles* engaging a mature science are cognitive (finding truths or warranted hypotheses) rather than practical (determining what works).

(7) The *aims or goals* of science are the discovery of laws or confirmed hypotheses about elements of the domain. That nature is lawlike (legal), and there are laws to be found, is a precondition of science. Finding discrete truths is not the business of science, it might be part of the business (data collection), but it is not the business. General, usually causal, theories are sought.

(8) The methods of mature sciences consist of scrutable, checkable, and justifiable procedures for getting information or conducting measurements. There is no single method in science apart from commitment to hypothesizing and appropriate testing. Testing means methodology; not the collection of relevant information or data (method) but what is done with the data once collected. How does the data bear on the truth or warrantability of the hypothesis being tested?

This is a philosophical matter about how information from samples relates to truth claims about wholes; how particulars relate to universals. Traditional answers have been Inductivism, Falsificationism, and the Methodology of Scientific Research Programmes which is an adjusted form of falsificationism. Now Bayesian methodology is ubiquitous in natural and social science.

Whatever the method, the appeal to unnatural or supernatural explanatory entities is ruled out in mature science which is committed to at least pragmatic methodological naturalism as the basis for evidence collection and theory appraisal. Many have argued that ontological naturalism is either required for science or is a consequence of any consistent science.

The teaching of scientific method in schools is entirely confined to method, the ways of obtaining data. Unfortunately little, if any, attention is given to the philosophically rich and engaging questions of scientific methodology: How does data relate to theory appraisal? More is the pity.

(9) Any mature science has a *significant overlap with other scientific fields* of inquiry; a mature science does not exist in cognitive isolation, in a silo apart from other mature sciences; they learn from and feed off each other. All scientific endeavours and disciplines engage with their neighbours; they need to accommodate adjacent sciences. This is what drives the creation of cross-over or interdisciplinary sciences: biochemistry, electrochemistry, geophysics, paleoanthropology, physicalchemistry, and so on. Scientists look over the fence; pseudoscientists look in their backyard. Intellectual isolationism is an indicator of pseudoscience.

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(10) *External authority is rejected*. In mature science, appeals to political, ideological, cultural or religious authority in the evaluation of empirical truth claims, theory appraisal, or endorsement of any metaphysics—is prohibited. This is assuredly a lesson from the history of science. The lesson is clear in the fate of Galileo, the condemnation of Darwin, the dismissal of Einstein's theory by Lenin, the banishment of major physicists such as the renowned and courageous Fang Lizhi (indeed the banishment of most intellectuals) during Mao's disastrous Cultural Revolution decade (1966-76). And so on.

Genuine science is self-correcting, not other-corrected in its cognitive outcomes. Science is always socially embodied and funded, thus politics and commerce can shape science, but they do not adjudicate its cognitive claims. This then becomes corrupt science. For the petro, tobacco and pharmaceutical industries, employed and funded scientists become Merchants of Doubt.

Ecology of Science and Pseudoscience

Science is not just the product of a thinking head, of an individual. Science occurs in a social-economic-technological context which has its own conceptual and philosophical characteristics. Mario Bunge calls this the 'conceptual ecology of science' and represents it as a pentagram (Bunge 2012, chap. 2).

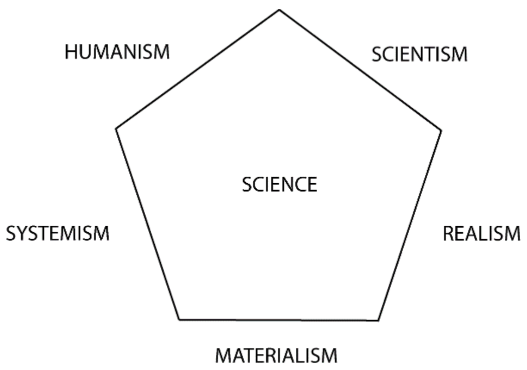

Fig. 1 Cultural Ecology for Progress in Science (Bunge 2012, p.28)

Humanism/Commercialism. Scientists should promote human welfare, not misery, business or political advantage. The latter purposes more easily lead to corruption of science (witness Nazi Germany, Stalinist Russia, Maoist China, or current 'big business' tobacco, oil and pharma science). Gürol Irzik has elaborated the philosophical, social, and scientific ramifications of the commercialisation of science.

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Systemism/Compartmentalism. Competent well-informed scientists recognise that there are no isolated events, mechanisms, or problems in the world. Structures and events are parts of systematic causal wholes. John Donne (1572-1632) famously wrote that 'no man is an island'; so also no event, personal action or social movement is a causal island; and no science can be an island. Consequently, good science generates cross-disciplinary research fields: geophysics, astrophysics, biochemistry, astrochemistry, social psychology, molecular biology, psycholinguists, economic history, political economy, paleogenetics, and so on. Because they do not emerge from science, hybrids as astropsychology or creation science are just labels for pseudosciences.

Materialism/Spiritualism. Scientists seek for causes and explanations within an accepted ontology of science. This is constitutive of a scientific practice. In society there is a spectrum of ontological positions from materialism (only matter exists), to physicalism (matter plus other entities confirmed by and integrated into science – magnetic and electric fields, gravitational forces – exist, to *spiritualism* (existence is not confined to just matter and entities integrated into science).

Methodological Naturalism provides a consistent ontology for science, but evocation of *spiritualism*, *supernaturalism*, *occultism*, or varied *tradition-based* entities violates it. To the degree that a society believes that the gods, spirits or the occult are responsible for earthquakes, then money for geophysical research will be limited; to the degree that societies are fatalistic, believing that 'everything happens for the better', then prevention of disaster and remediation will not be undertaken; where illness is seen as spirit possession, then medical science does not develop, and so on.

Realism/Subjectivism. Scientists maintain that there is an external world independent of human consciousness or experience; science attempts to provide knowledge of such a world; and these attempts are partially successful. Our concepts and theories are human creations, but the reality they conceptualise or explain is not a human creation. The external world, not local authority, judges the efforts of scientists to understand it.. Witness the ultimate collapse of Church-backed Ptolemaic astronomy, Nazi-backed German blood science, or Communist-Party-backed Lysenko non-Mendelian genetics.

Scientism/Irrationalism. Scientists believe that science is rational, indeed it provides a model for social rationality; further, Enlightenment-influenced scientists believe that scientific methods are applicable outside the laboratory and are the only way in which knowledge of the world and society is attained. Without this commitment, social and cultural problems are addressed in wholly ineffective ways: praying for the end of Middle East conflict can be a comforting cultural engagement, but it can shed no light on the conflict, its history, or its remediation. Prayer might motivate such investigation, but equally it can, and often does, by-pass a naturalistic and scientific investigation.

For any society, to the degree that the first member of the above couples is maximised, then science can flourish. To the degree that the second member is elevated, then the society allows and promotes the growth of pseudosciences. So, we have:

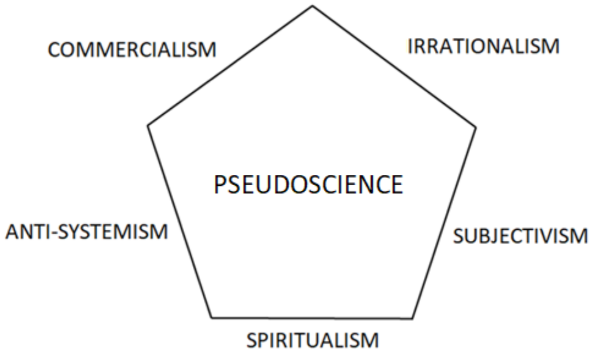

Fig. 2 Conceptual Ecology for Pseudoscience (Bunge 2012, p.33)

In societies and cultures where spiritualism, non-systematism, commercialism, irrationalism, and subjectivism (phenomenalism or instrumentalism) prevail, then science cannot thrive, but pseudoscience surely can and does.

Contemporary USA provides a case study for this claim. It is Fantasyland. Spiritualism is pervasive. God and Gods are evoked everywhere, including on dollar bills; and for every purpose, including the killing of declared enemies, the prevention of natural disasters, and the amelioration of their effects. Megachurches, attended by tens of thousands of congregants led by acknowledged shysters and sexual exploiters, the Divinely Unfaithful, are common; televangelism, with in-studio and at-home miracles, run non-stop, 24/7, on TV and cable networks. Bookshop aisles are filled with paranormal, alternative, and esoteric literatures. The web abounds in fantasy and conspiracy theory.

In US bookshops one expects Ten yards of paranormal for one yard of science and one foot of HPS. In Sedona, the ‘Vortex Capital of Arizona’ there would be twenty yards, or more, of paranormal. Across the US and beyond, many have given up on trying to keep genuine News separate from Fake News. For many, the same arguments used for giving up on identifying serious news are used to give up on identifying genuine science: just as ‘everything is news’ so also

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'everything is science'. A return to Respecting Truth would be the beginning of a cure for this cultural malady.

Anti-systematism is routine. Life is compartmentalised. A general or liberal education is progressively harder to get; specialisation is the academic norm; there are career, funding, and disciplinary barriers to cross-disciplinary research.

Commercialisation and money-making is a preoccupation of dominant US groups; if this was not their preoccupation they would not be dominant. Commercialisation is captured in everyone's image of Wall Street, where excess, self-interest and pursuit of the bottom line is just normal business activity. It is equally captured in the Walmarting of hundreds of towns where whole downtown business and residential communities have been destroyed by the Walton family's pursuit of extra millions of dollars being spent in their own edge-of-town megastores. The High Cost of Low Price has been well documented. Powerful mining, agriculture, transport, tobacco and oil interests have always put commercial interest above community and environmental interest. President Trump rode commercialisation all the way to, and through, the White House.

Conclusion

Pseudoscience is an eminently suitable capstone topic with which to bring together the three competencies (knowledge, technique and affective) aspired to in each of the junior Years 7-10 and senior Years 11-12 of the NSW science curriculum. The identification of pseudoscience, and its much-debated separation from science, focuses the meaning of what it is to Work Scientifically and how this is distinguished from thinking, working, or acting unscientifically.

As with so much else in the curriculum, teaching about pseudoscience is facilitated if teachers have familiarity with the history and philosophy of science. I have argued this position in my 2015 book, and elsewhere including an autobiography. Responsible, competent, professional science teachers should be attentive to basic HPS issues as these illuminate the very subject they are teaching. Further, they resonate with student interest and curiosity: How do we know some claim about dinosaurs to be true? Why did my experiment get a different result from the textbook? Who was Galileo and what caused his troubles? Why was Darwin famous? Should US scientists have built the atomic bomb?

It is not just HPS that is required in order to adequately teach about pseudoscience: a good grounding in philosophy of education is needed. Many

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pupils, parents and their culture will be committed to one or other pseudoscience. How do schools and teachers deal with this situation? This is a bread-and-butter question for philosophy of education. Pupils can learn that respect for individuals or cultures does not require endorsement of their beliefs or remaining silent about them.

One popular answer to the pedagogical problem was the NOMA (Non-Overlapping Magisteria) position popularised by Stephen Jay Gould (Gould 1997), Michael Ruse (Ruse 2011), and others. This formalised the separation of science from other disciplines, specifically theology. Supposedly, one cannot judge the other; they exist side-by-side in a live-and-let-live arrangement provided each stays in its own domain, its own magisteria.

But the NOMA option has been well criticised (Slezak 2012). It has problems and certainly NSW Extension students can, with intellectual benefit, be introduced to them. But with Australian pre-service and in-service teacher education to be consumed by mastery of classroom management technique, how such familiarity with either HPS or philosophy of education will be facilitated is a moot question.

But the situation has not always been such. Nearly one hundred years ago, Frederick W. Westaway published *Science Teaching* (Westaway 1929). It was a much-used, much-reprinted, textbook utilised throughout UK Teacher Training Colleges. It opens with the assertion (along with his apology for use of the masculine pronoun) that:

> a successful science teacher is one who knows his own subject . . . is widely read in other branches of science . . . knows how to teach . . . is able to express himself lucidly . . . is skilful in manipulation . . . is resourceful both at the demonstration table and in the laboratory . . . is a logician to his finger-tips . . . is something of a philosopher . . . is so far an historian that he can sit down with a crowd of [students] and talk to them about the personal equations, the lives, and the work of such geniuses as Galileo, Newton, Faraday and Darwin. More than this he is an enthusiast, full of faith in his own particular work. (Westaway 1929, p.3)

With the passage of 100 years, Westaway's ideal of a science teacher has been little improved upon. Westaway's teacher would be well prepared to teach the Pseudoscience items in the NSW curriculum. To prepare such teachers, a five-input programme such as the following would be ideal:

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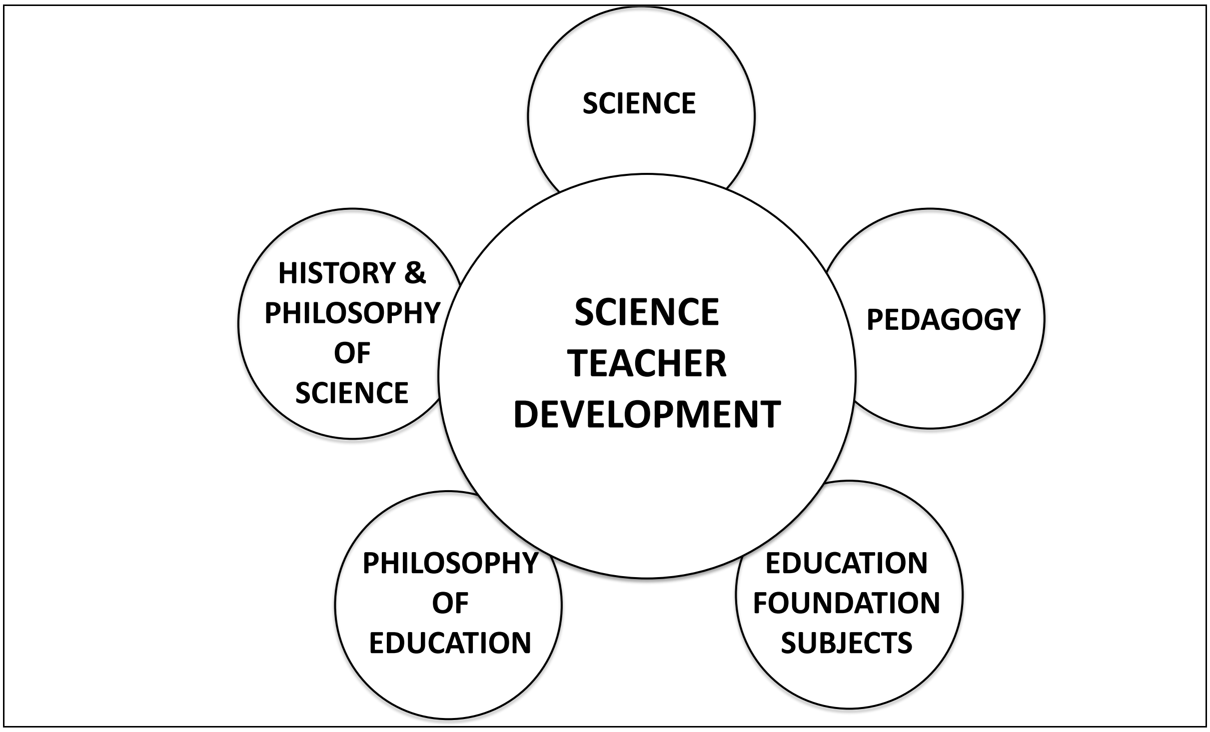

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