Learning from the Past: Reappraising Constructivist Philosophy in the Covid Era

Michael R. Matthews, School of Education, UNSW
[revised and resubmitted to *Science & Education* December 2021

ABSTRACT. The Covid pandemic has occasioned an unprecedented international degree of trust in science. All communities and societies, even the most isolated, are aware of the pandemic's staggering death toll (5.2M, late November 2021), infection rate (260M) and extensive vaccination]comprehensively dismissed. In all communities across the globe, science has become the only game in Covid time. Thus, the pandemic presents bountiful 'teachable moments' for educators in all science-related disciplines in schools and colleges and, of course, numerous teaching moments for humanities, civics, and the arts. This paper highlights just one teachable moment for the science education research community: namely reappraising the community's earlier (1980s-2010s) embrace of constructivist philosophy.

The past two years of successful Covid research and vaccine development is incompatible with the ontological idealism and epistemological relativism that was at the core of the earlier historical constructivism. Importantly, the challenge which Covid research presents for historical constructivism is the same that it presents for indigenous science: The widely held thesis of the equality of indigenous and 'orthodox' science can only be asserted with affirmation of constructivist philosophy. But the success of Covid research shows, as has been known all along, that this is an untenable philosophy, that idealism and relativism cannot be reconciled with science.

Reappraising the philosophy of historic constructivism also gives clarity to contemporary concerns about a 'post-truth' culture in the academy and society. One takeaway lesson from this study is the clear benefit of including history and philosophy of science (HPS) in teacher training programmes and in education graduate courses.

Key Words: constructivism, idealism, relativism, indigenous science

In late-2021, two years into the Covid Pandemic, there is an unprecedented global awareness of science, more specifically of bio-medical science. To an encouraging degree this has engendered a global affirmation of science. The devastation of Hiroshima and Nagasaki in 1945 and Neil Armstrong's 1969 walk on the moon brought science to the attention of millions and demonstrated its power but did not lead to any largescale affirmation or appreciation of science. Indeed, the former did the reverse. The current tsunami of Covid research, and massive vaccination campaigns, have put the benefits of science in front of the bulk of the world's population with a documented flow-on effect for trust in scientists and in science.

In 2021, the Wellcome Global Monitor surveyed 119,000 people across 113 countries, finding that both trust in scientists and trust in science increased since 2018. For western Europe, 58% of respondents expressed a trust in science.[1]

The Covid tragedy is exhaustively documented. As of late-November 2021: deaths (5.2M) and rising by 6,000+ per day, confirmed infections (260M), and global spread (200+ countries).[2] The pandemic is the subject of non-stop, saturation coverage by print, electronic and social media. Nightly news has clips of medical staff taking vaccines to the furthest recesses of the Amazon, the most remote valleys of the Himalayas, and isolated Central African communities.

Across all nations, the bulk of citizens and governments recognize that it is only through science that medical professionals and policy makers can get a correct understanding of the disease: how its causative virus is transmitted; how the disease can be prevented; and if not prevented, how those infected can be managed and treated. There are only a minority of 'anti-vaxxers'. In Australia, the vaccine 'hesitancy' rate is 12%[3] in some other countries it is lower (Ecuador 3%), while in others it

[1] See Gallup/Wellcome poll HERE.
[2] See WHO site HERE. The recorded figures are all, for obvious reasons, massive underestimates. Epidemiologists suggest 15M deaths is closer to the current (late November 2021) real mark.
[3] See Melbourne University site HERE.

is higher (USA 50%).[4] And not all anti-vaxxers are anti-science; many accept the science but refuse vaccination on political and other grounds.[5]

Most citizens do understand that, though science is necessary for understanding and treating the disease, science is not sufficient. Many Covid decisions clearly involve social, political, ethical and ideological considerations vaccine selection, costing, distribution, and prioritising of different groups; setting social-distancing and mask-wearing protocols; selection of lockdown zones and their durations; triaging of patients for admission to limited hospital rooms; removing patent protection of vaccines; pressuring rich countries to support vaccine campaigns in poor countries. In all countries there is a trade-off between economic activity and community health; science can inform the trade-off but not make it.

In this respect, dealing with the Covid pandemic is no different from dealing with climate change, whole-country malnutrition, species extinction, and much else: competent science and accurate information is necessary but not sufficient for decision making. Ethics, politics, religion, social psychology, and much else feeds into decisions. Trade-offs will be part of any feasible response to pressing and serious issues.

Only some corruption of scientism, suitably called 'pseudoscientism', would suggest that science alone can settle the above decisions and policies. Scientism is the straightforward, respectable view that science gives us the most reliable, accurate, grounded, and cumulative knowledge of the natural, social, and historical worlds; where natural, social or historical information is needed for decisions and policy formulation, science can best provide this. Such is the conviction of Newton, Hume, Dewey, all thinkers in the Enlightenment tradition, and many others besides. Following Hayek, 'scientism' has been used pejoratively to name a position that holds that science can make aesthetic, literary, and moral decisions. There are few, if any, people who would maintain such a view.[6]

Globally, across all national borders and school programmes, the pandemic presents numerous 'teachable moments' that can be utilised in science, social science, health, civics, politics, history, mathematics, philosophy, art, drama, and religion programmes. In science programmes, where *Socio-Scientific Issues* (Ratcliffe & Grace 2003, Sadler 2011, Zeidler & Sadler 2008), *Science-Technology-Society* (Solomon & Aikenhead 1994), *Social Justice* (Finkel 2018, Hansson & Yacoubian 2020), and *Nature of Science* (Flick & Lederman 2004, Matthews 2015) themes have been adopted as organising principles – then Covid presents a plenitude of content topics. Within all of these organising principles, the very idea of trust in science - what it is and what it is not - can be explicated (Oreskes 2020, Irzik & Kurtulmus 2019, Wilholt 2016).

This paper is concerned with just one lesson that the science education research community can take from the pandemic: namely, reappraising the discipline's past commitment to constructivist philosophy, specifically its idealist ontology and its relativist epistemology. These commitments were most widely and strongly held during the high-tide years (approximately 1980-2010) of constructivism. A time when at a NARST plenary lecture it was announced, with barely a dissenting voice, that 'we are now all constructivists'.

As detailed below, faculty commonly taught, and students learned, a diet of idealist constructivism ('there are many worlds, and each is made by and dependent upon the observer and/or the observer's community'), epistemological constructivism ('we cannot have knowledge of the world'), and relativist constructivism which took a variety of forms ('all understandings of the world are equally true and valid', 'there is no universal science', 'there are as many sciences as there are cultures'). Some educators proudly enunciated versions of Bishop Berkeley's ontological constructivism ('there is no external world'). Given that many constructivists now distance themselves from these positions, they 'walk them back', the period might be called 'Historic Constructivism'.

---

[4] See National Institute of Health site HERE.

[5] A mid-2021 study in *Nature* on vaccine hesistancy can be found HERE.

[6] This false attribution is seen in Susan Haack's widely read paper (Haack 2012). On scientism and pseudoscientism, see Bunge (1986) and contributions to Boudry & Pigliucci (2017). For elaboration of scientism, and references, see Matthews (2019b).

Although widespread, and held at the highest level, these commitments should never have been made. They were the result of widespread philosophical naivety in the science education research community. The commitments did not withstand initial philosophical scrutiny. This should now be obvious to all, as idealism and relativism cannot be reconciled with the successes of the contemporary Covid campaign: The SARS-CoV-2 virus does actually exist, independently of anyone recognising it; so also, its mutant Alpha, Beta, Gamma, Delta, Omicron variants, and the mutants that will surely follow.[7] The conjunction of ontological idealism and epistemological relativism provides succour to denialisms of all kinds and props up the minority non-scientific responses to the Covid pandemic (McIntyre 2019, 2021).

There needs to be a serious reckoning with the community's 'high tide' embrace of constructivism, not least because the philosophical positions have lingered on, and even when abandoned, they have reappeared in new guises and in new clothes. As detailed below, this is especially evident in serious conversations about indigenous science and appropriate science education for indigenous students.

The Turn to Science

Less than two years after recognition of Wuhan 'influenza' as something different and more deadly, there is no longer any serious competitor to science as the key to understanding and dealing with the Covid pandemic. While there are intra-scientific debates and disagreements about some aspects of the aetiology and treatment of Covid-19, these are just 'family disputes': Is the Omicron spike protein the cause of its resistance to vaccine? Is Sinopharm vaccine effective against mutant Covid variants? Is surface cleaning worth the cost and resource use? Is Omicron more or less transmittable than earlier variants? Despite these family disputes, scientists, medical researchers, and paramedics have become the 'go to' people for dealing with Covid. To put it colloquially, 'there is no other game in town'.

Governments, and the overwhelming majority of citizens, expect science to determine at least the following: How to identify the Covid-19 virus and its mutants? What are the components, and their sequence, of Covid genetic RNA? How to understand, map and control mutations? How to formulate and develop vaccines? How to judge the efficacy of the basic four different vaccines (whole virus, protein subunit, messenger RNA, and DNA) and their impact on different demographics? What are the long-term effects of the disease? How effective are non-pharmacological practices such as surface cleaning, mask wearing and social distancing? And so on.[8]

There have been massive and widely reported research efforts to answer such questions. As of November 2021, the US National Institute of Health's PubMed site lists 83,000+ published research papers on Covid-19.[9] In the first nine months of 2020, the *New England Journal of Medicine* had received 30,000 Covid-related submissions. And the *NEJM* is just one of a score of reputable English-language medical research journals. Many journals instituted 'rapid review' of Covid-19 studies. The international reviewing task is beyond imagination but there have been reviews sufficient to justify the not unexpected mid-2020 claim that: 'the poor choice of research questions, use of suboptimal study designs and the failure to coordinate research activities will result in wasted research resources'.[10]

There have been at least 105 different vaccines developed and tested, with at least seven (Pfizer-BioNTech, Oxford-AstraZeneca, Moderna, SinoPharm, Sinovac, Johnson & Johnson, and Bharat Biotech) being administered to multiple millions.[11] The Pfizer and Moderna vaccines function by inserting fragments of Covid RNA into people's cells, prompting the immune system to prepare antibodies to neutralize the infection when it arrives. This is the so-called 'messenger RNA' system.

---

[7] See US Centers for Disease Control site HERE.

[8] Though for political and other reasons, there are significant 'anti-vaxxers' in all countries. A good many of these are not anti-science, they are just anti being-told-what-to-do; they are anti expansion of State power; they have political objections, not scientific ones, to vaccination.

[9] See National Institute of Health site HERE.

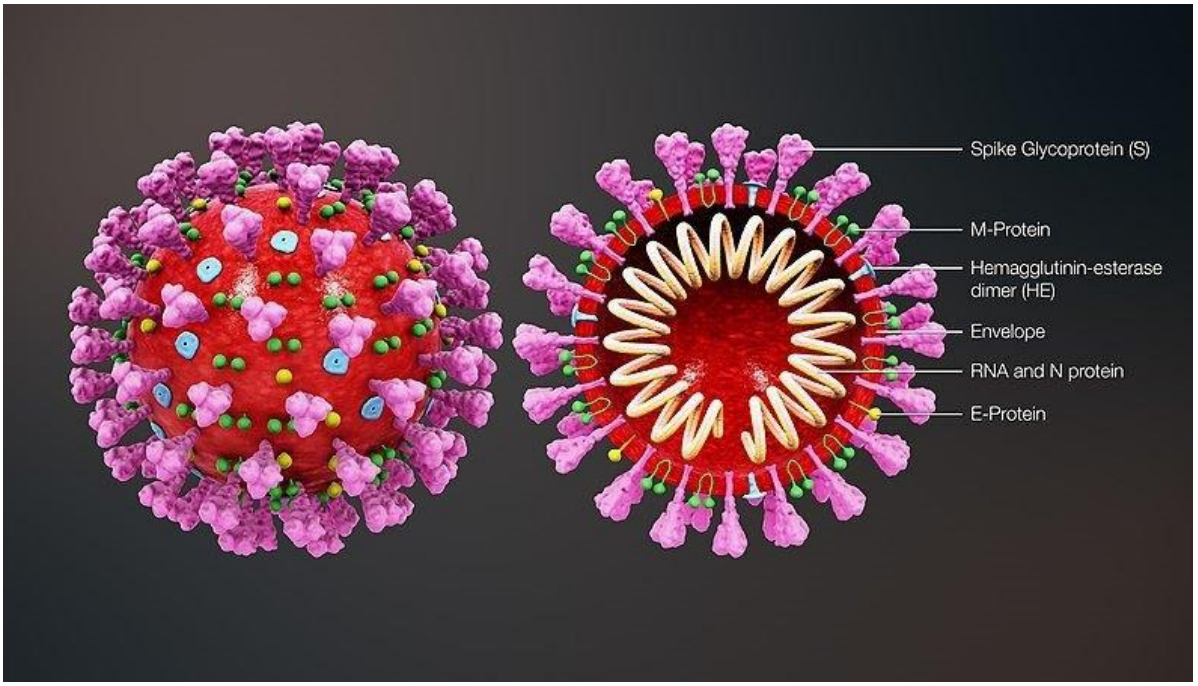
[10] In *BMJ Open* HERE. The bio-medical research response to Covid-19 is well covered in Jong 2021.

[11] See *New York Times* site HERE.

One hundred years ago no one had ever seen a virus. Their existence had first been suggested in a 1898 study by Martinus Beijerinck of a common tobacco disease; now they are represented down to the position of individual atoms. Seventy-five years ago, John Desmond Bernal, the Irish molecular biologist and historian of science, well captured the realist, culumative and fallibilist assumptions of scientific viral research:

> Among the viruses, we find a whole range, from the relatively large and complex animal viruses that cause such diseases as measles and smallpox, to the very small viruses that cause the innumerable diseases of plants, and some such as poliomyelitis in animals. There are viruses of even the bacteria themselves, the bacteriophages, the last link we may imagine in the chain of the 'larger fleas having smaller fleas on their back to bite them'. In their action in causing disease, which can be transplanted from one organism to another and may even lead to epidemics, the viruses differ in no essential way from the bacteria. . . . Now that we have the electron microscope, viruses can be seen and much of their gross structure distinguished. (Bernal 1954/1965, p.912)

The science of Covid genomics has exploded. The number of virus-connected research papers has exploded, at one stage doubling week-by-week (Yong 2021). A one second 'Covid Research' search on Google turned up six billion items (20 May 2021). There is an unprecedented and staggering amount of research into the virus, its mutants, transmission mechanisms, and mitigation strategies. A standard depiction of the Covid-19 virus, illustrating its structure, components, protein types, spiralled RNA is:



Standard Depiction of SARS-CoV-2

Scientists are united in a realist interpretation of this picture, and a realist understanding of its corrections and refinements.

Within weeks of its first discovery in South Africa in mid-November 2021, a great deal has become known about the Covid-19 mutant B.1.1.529 (Omicron). It is agreed that: 'It has 32 mutations in the spike protein, the part of the virus that most vaccines use to prime

the immune system against Covid. That is about double the number associated with the Delta variant'.[12]

The Covid RNA genetic string has 29,903 individual nucleic acid blocks, and these have been progressively sequenced. Correct identification and sequencing constitute the scientific, genomic grunt-work behind epidemiological study of the relatedness, or otherwise, of Covid outbreaks such as are reported almost worldwide on nightly news and in the daily press. The value of the staggering and expensive epidemiological 'surface' studies of the spread and magnitude of infection, hospitalisation, recovery, and deaths, is greatly reduced without genomic understanding. Variants are not discernible at a surface level, only a genomic level.

Worldwide, citizens are not just enormously informed about Covid matters, but letters-pages, opinion columns, social media, everyday conversations - to say nothing of mass demonstrations for and against public health measures - suggest there is an encouraging degree of public interest in and, to a lesser degree, understanding of Covid science. The expressions 'flattening the curve', 'delta variant', 'genome sequence', 'modelling', 'herd immunity', even 'spike protein' are, to varying degrees, intelligible to a good portion of the population. The public understanding of Covid has been extensively monitored.[13] Three University of New Hampshire sociologists concluded a long and heavily referenced study on beliefs about science during Covid times with the expected observation:

> The COVID-19 pandemic dominated headlines throughout 2020 and scientists were inextricably connected to discussions of threats from the coronavirus. "Follow the science" was an ever-present part of the discourse and this mantra became the foundation for pandemic-related health policies in the United States and around the globe. (Safford, Whitmore & Hamilton 2021, p.1)

And further:

> The importance of science in guiding policy has never been more apparent than during the COVID-19 crisis. Overall, the focus on science-based approaches has reinforced the authority and key social role of scientists in society. Studies from around the world have shown that trust in science is a key factor affecting understanding of coronavirus-related risks, adoption of preventive measures, and support for science-based policy responses. (Safford, Whitmore & Hamilton 2021, p.13)

Whether this Covid-connected 'trust in science', this Enlightenment orientation to solving human problems, flows on to other social challenges, remains to be seen. Although one swallow does not a Summer make, the global Covid response is an encouraging start to a widening affirmation of science. Informed, alert, sensitive, competent HPS-informed science teaching and commentary can strengthen this trust by making pupils and citizens aware, among other things, of the inherent self-correcting, fallibilist, internationalist, experimentalist, public nature of science. The mere surfacing of disputes and disagreements should not provoke distrust of science if folk are well informed about HPS. Likewise for the exposure of cases of politically- or commercially-driven corrupt science Big Pharma, Big Petro, Big Agrico (Oreskes & Conway 2010). Mature, HPS-informed trust in science can accommodate all this.

Non-scientific Responses to Covid

In early 2020, at the beginning of the pandemic, the global trust in, and affirmation of, science was something over the horizon. Perhaps a majority in the developed world hoped, indeed expected, that science-informed medicine would cope with the pandemic, in the way it had so successfully done with earlier epidemics and pandemics – polio, influenza, SARS, MERS, AIDS, whooping cough (Pertussis), smallpox, measles, yellow fever, and many others. But there was no immediate evidence for this expectation; it was hope. The alternative was all manner of folksy, superstitious, spiritual, fanciful, religious, and non- natural causes and remedies for Covid.

[12] See *The Guardian* 25 Nov. 2021 HERE.
[13] See Penn State Social Science Research Institute site HERE.

In Thailand, Japan and elsewhere in Asia, Buddhist temples provided 'yant' talisman objects to ward off demonic spirits which are regarded as culpable for spreading the disease. Vajrayana Buddhism, promoted by the Dali Lama, advocated the chanting of mantras to Bodhisattva Tãrã, a female goddess associated with compassion and well-being, to gain her protection from Covid.[14] In India, a good many devout Hindus, including professionals, turned to traditional 'Cow-dung cleaning' to ward off Covid. Many believers have been going to cow shelters once a week to cover their bodies in cow dung and urine in the expectation it will boost their immunity against, or help them recover from, the coronavirus.[15]

Different Islamic factions saw the pandemic as divine retribution for Western infidelism; and when it struck in Islamic countries, it was due to that particular country's failure to uphold authentic Islamic teaching, with what is authentic varying from country to country. For Saudi Sunnis, the obvious cause of Iran's outbreak was its adherence to Shiite Islam. Conservative Sunni clerics blamed Shiites and atheists for triggering the worldwide pandemic. Some clerics in Egypt, Iraq, Jordan and Morocco debated whether the outbreak was divine punishment against nonbelievers.[16]

Hundreds of thousands of Feng Shui websites claimed that because they deal in the mysterious chi energy, they could, for a price, 'flood members with positivity' and so inoculate them against Covid ravages.[17] A significant number of Evangelical Christians, particularly in the USA but also elsewhere, already had a latent doubt and hostility towards science, and they simply reject Covid science along with masks, social distancing and especially vaccines. Instead, they promote a multitude of conspiracy theories, including blaming Bill Gates and 5G Technology, to account for Covid's origin and transmission.[18] In August 2021, the Vice-President of the National Christian Broadcasters Association was fired for advocating vaccination as a preventative measure for Covid.[19]

Along with these non-scientific and anti-scientific cures there were others - ingesting hydroxychloroquine - that sounded scientific but were just folksy and unscientific, even if promoted by presidents Trump and Bolsonaro (Colson et al 2020).[20] These 'non-scientific' (both natural and non-natural) responses to the multiplying and mutating Covid virus, though disappointing, are routine, predictable and explainable. Invocation of the unnatural and the supernatural; resort to mysterianism, spiritualism, racism, religion, gender, class, nationalism – have always been an immediate personal and social response to dramatic, large-scale devastating events. They were famously displayed in responses to the catastrophic 1755 Lisbon earthquake that killed about 60,000 people and destroyed one-third of the city (Shrady 2008). All epidemics and pandemics hitherto have elicited the same spectrum of responses (Snowden 2019). Nicoli Nattrass, an economics professor at the University of Cape Town, wrote of her country's AIDS tragedy that:

> This leap—from the critique of mainstream biomedical science on AIDS to the promotion of unproven and unregulated alternative therapies—is a replay of the classic quack-marketing strategy of promoting belief in alternative remedies by sowing disbelief and skepticism about the medical establishment. It is thus not surprising that AIDS denialism has been used by vitamin salesmen (notably the Dr. Rath Health Foundation), self-styled alternative healers, and some traditional healers to promote their worldviews and products. (Nattrass 2007, p.32)

Constructivism Appears

[14] *The Conversation*, 15 May 2020 HERE.
[15] See Reuters site HERE.
[16] See Wilson Center site HERE.
[17] See International Feng Shui site HERE. For background on feng shui, see Matthews 2019a.
[18] See Deutsch World site HERE.
[19] See *USA Today* site HERE.
[20] See *The Conversation* site HERE.

Beginning in the mid-1970s constructivism became, and stayed for 20-30 years, an overarching and dominating pedagogical, educational, psychological and philosophical theory in science and mathematics education; constructivism was hegemonic in university and college Faculties of Education. Ken Tobin, a champion of constructivism, notes:

> A look at the literature published in high impact journals identifies more than three thousand publications that used the keywords 'constructivism' or 'constructivist' from the mid-1970s to the present [2006]. (Tobin 2007, p.291)

And he recognises that this is just 'the tip of the iceberg' as many publications, course notes, and so on, are not included in the Web of Science data base.

Educational constructivism grew out of two sources. The first was Piaget's 1950s, Kantian-informed, clinical studies of children's reasoning and cognitive maturation. This showed the staged development of mind by processes of accommodation and assimilation as subjects engage with their environment. The mind was structured, it was not a Lockean *tabula rasa*; and it developed capacities as children grew. Many have remarked that he grounded the Kantian theory of mind in biology. This culminated in his famous *The Growth of Logical Thinking* (Inhelder & Piaget 1958) which laid out the programme of his self-called *Genetic Epistemology*.[21] He identified the supposed universal four stages of cognitive growth: Sensorimotor (birth to age 2), preoperational (2-7 years), concrete operational (2-11 years) and formal operational (11 years on). Notoriously, Piaget paid little attention to language and socialisation, and even less to education. The physical, not social, environment was at the forefront of his attention.[22] But the early constructivists, who accepted and extended his theory, did pay attention to education.[23]

The second source of constructivism was the mushrooming classroom studies of children's thinking about nature; the documenting and study of children's 'proto-scientific' concepts and understandings that began in the 1970s. Rosalind Driver at Leeds University and Joseph Novak at Cornell University were guiding figures for these investigations (Driver, Guesne & Tiberghien 1985, Novak 1977a). These studies of children's science were initially called 'misconceptions' research,[24] but then, under relativist pressure, became relabelled as 'alternative conceptions' research (Gilbert & Watts 1983, Fleer 1999).

Jon Magoon coined the term 'constructivist' to designate the Piagetian tradition of educational research (Magoon 1977). Shortly after, Rosalind Driver adopted the name for the conceptual change research programme (Driver & Bell 1985). Once so named, the traditions blossomed.[25]

Both Piagetian and Alternative Conceptions strands agreed that constructivism is, as stated in a UNESCO report:

> A learning theory which places the learner at the centre of the educational process on the understanding that the learner actively constructs knowledge rather than passively receiving it. Thus, an individual's knowledge is a function of one's prior experiences, mental structures, and beliefs that are used to interpret objects and events.[26]

The two strands were united against, the then dominant, Pavlovian and Skinnerian behaviourist accounts of learning where the mind was a Lockean blank slate written upon by sensory impressions. But constructivists were strongly divided between themselves about how much the architecture of cognition is dependent on nature and how much on nurture. Could nurture (informed teaching) hurry up nature? (Gilbert & Swift 1985).

---

[21] A thorough account of Piaget's philosophy is Kitchener (1986).

[22] The effect of language and socialisation, of nurture, on the development of mind had been studied in the 1930s by the Soviet *troika* of Vygotsky, Luria and Leontiev. The West first read of this in Vygotsky (1962) then his essays *Mind in Society* (Vygotsky 1978).

[23] See for example: Fosnot (1993), Kitchner (1992), Lawson (1985), and Carey (1986).

[24] The first massive international research conference on the subject held at Cornell University in 1983 was titled 'Misconceptions and Educational Strategies' (Helm & Novak 1983). The even bigger second 1987 conference had the same title (Novak 1987).

[25] This history is traced in Matthews (2000, updated in 2021).

[26] See UNESCO-IBE site HERE.

In 1991, Russell Yeany, a former president of the National Association for Research in Science Teaching (NARST), who as a graduate student at University of Georgia was, like

Ken Tobin, was significantly influenced by Ernst von Glasersfeld who was on faculty at Georgia, noted in a NARST Newsletter Editorial that:

> A unification of thinking, research, curriculum development, and teacher education appears to now be occurring under the theme of constructivism ... there is a lack of polarised debate. (Yeany 1991, p.1)

In 1992, Peter Fensham the doyen of Australian science educators and recipient of the 1999 NARST 'Distinguished Contribution' award, wrote:

> The most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning. (Fensham 1992, p.801)

The same year, an editorial in the *Journal of Teacher Education* declared:

> Constructivism is the new rallying theme in education. .... professional education groups as diverse as the National Association for the Education of Young Children and the National Council of Teachers of Mathematics have based revisions of their standards for practice on the constructivist assumption ... (Ashton 1992, p.322)

The following year, Ken Tobin, a past president of NARST and the 2007 recipient of its 'Distinguished Contribution to Research' award, wrote in the Introduction to an AAAS Constructivism anthology:

> there is a paradigm war waging in education. Evidence of conflict is seen in nearly every facet of educational practice. ... [but] there is evidence of widespread acceptance of alternatives to objectivism, one of which is constructivism. (Tobin 1993, p.ix)

He elaborates, saying the objectivist approach to problems means 'to seek objective solutions and to identify causal relationships among salient variables' (Tobin 1993, p.ix). This does not sound such a bad thing. But good or bad, it is completely independent of whether a learner needs to be 'actively involved in the creation of knowledge'. Whether a learner is active - and how could someone who is learning something be inactive?[27] - has nothing to do with whether their knowledge or solutions are objective. This is the much-taken Kantian slide from learning theory to idealist ontology.

In 1995, Denis Phillips formerly an Australian academic then Stanford University philosopher and education researcher, observed:

> Across the broad fields of educational theory and research, constructivism has become something akin to a secular religion. (Phillips 1995, p.5)

In 1996, Reinders Duit, at the University of Kiel, who for 30 years maintained a cumulative bibliography of constructivist research,[28] and who had published a paper fittingly titled 'The Constructivist View: A Fashionable and Fruitful Paradigm for Science Education Research and Practice' (Duit 1993) reiterated:

> There is certainly something fashionable about constructivism in science education nowadays. It is further true that constructivism is by no means a consistent movement, there are many variants of this view in use. Furthermore, it appears that constructivism, for some science educators, in any case, has become the new ideology of science education that provides a cure for every problem of teaching and learning science. (Duit 1996)

---

[27] Only the most extreme of conditioning theorists could say that learning does not require some degree of learner agency; some 'use of the mind'. Further, any learning connected with the acquisition of knowledge and understanding, that is educational learning, requires engagement by the learner. On this, see Hamlyn (1967, 1973, 1978).

[28] The bibliography was first published in 1983; its final version, containing 8,400 entries, was posted on the web in 2009. See University Keil site HERE.

In 1998, as the century closed, US researcher Michael Bentley opined:

> For several years now, across the country, preservice and in-service teachers have been considering constructivism as a referent for their philosophies of education and for classroom practice. (Bentley 1998, p.245)

In the first year of the new century, Edgar Jenkins of Leeds University, wrote a review of science education research - 'Time for a Health Check' - and made the undisputed claim that:

> In the last couple of decades or so, the science education literature has been dominated by research findings concerned with children's understanding of natural phenomena and it has become almost impossible to escape some reference to constructivism among the papers published in the principal research journals. (Jenkins 2000, p.5)

He observed that:

> Work drawing upon constructivist perspectives now constitutes something of a research orthodoxy within science education, although this judgement may be more applicable to research in science education in countries such as the USA, Australia and New Zealand than to its counterpart in much of Europe. (Jenkins 2000, p.7)

Two researchers reported that in the year 2000 there were 1,000 items in the ERIC (Education Resources Information Center) data base and:

> As for the quantities of materials intended for or developed by practicing teachers, a sense of their proliferation might be gleaned from the internet, where the hits for 'constructivism + education' number in the tens or hundreds of thousands, depending on the search engine used. (Davis & Sumara 2003 p.409)

Both AERA and NARST had large Constructivist SIGs (Special Interest Groups). It was oft, and only half-jokingly, remarked that having 'constructivism' in the title was a requirement for having a paper accepted for an education conference. It was common for faculty job advertisements to have 'commitment to constructivism' as an employment condition; and 'teaching constructively' as a condition for pay rises and permanency for school teachers.

Constructivism had impact beyond the academy. It has been adopted as the 'official' pedagogical theory in a number of countries, states and provinces. These include at least: Ontario Province of Canada, Thailand, Greece, Turkey, New Zealand, India, Taiwan, Spain, the Australian state of Western Australia, and some states and school districts of the USA. It is ubiquitous in North American teacher education programmes. In his review article, Ken Tobin says: 'The adoption of constructivism in education was to be global in extent' (Tobin 2007, p.293). And he claims: 'a stake in it being successful' (Tobin 2007, p.291).

But just what was it that everyone was committing themselves too? The theory was part pedagogy, part psychology and part philosophy. The exact make-up was always unclear; it was a Chameleon doctrine; different components were foregrounded, and others backgrounded, depending on the occasion or purpose. One review identified at least the following varieties: contextual, dialectical, empirical, information-processing, methodological, moderate, Piagetian, post-epistemological, pragmatic, radical, realist, social and socio-historical (Good, Wandersee & St Julien 1993). To this list could be added humanistic constructivism (Cheung & Taylor 1991), didactic constructivism (Brink 1991), pluralist rational constructivism (Moshman 1997), ontic constructivism (Boden 2010), and doubtless many others.

From the outset there was confusion occasioned by the very loose, unteathered, use of the word 'constructivism'. Many thought that just being interested in children, or teaching in a sensitive manner, or not lecturing to classes and not being overly didactic, sufficed for being a constructivist. This was, and is, more properly called 'trivial constructivism'. It has no connection with the argument thread of this paper, which is concerned with articulated, serious constructivism.

Catherine Fosnot, a New York constructivist, in a much-cited anthology, makes explicit the connection or, less kindly confusion, between psychology (a theory of learning) and philosophy (an epistemological position). She writes:

> Constructivism is a theory about knowledge and learning; it describes both what 'knowing' is and how one 'comes to know'. Based on work in psychology, philosophy, science and biology, the theory describes knowledge not as truths to be transmitted or discovered, but as emergent, developmental, non-objective, viable constructed explanations by humans engaged in meaning-making in cultural and social communities of discourse. (Fosnot 2005, p.ix)

But, of course, anything will count as 'emergent, developmental, non-objective, viable constructed explanations by humans engaged in meaning-making'. Saying this says not very much. It obfuscates rather than illuminates; it rules nothing out of the field of putative knowledge; the words occupy space but pay no communicative rent.

If whole systems, provinces, and countries are adopting constructivism as their official educational guide, then it is important to ascertain just what the doctrine stands for. The authoritative Constructivist Foundations website gives guidance.[29] It asserts that the common denominators of constructivist approaches can be summarized as:

- Constructivist approaches question the Cartesian separation between the objective world and subjective experience.
- Consequently, they demand the inclusion of the observer in scientific explanations.
- Representationalism is rejected; knowledge is a system-related cognitive process rather than a mapping of an objective world onto subjective cognitive structures.
- According to constructivist approaches, it is futile to claim that knowledge approaches reality; reality is brought forth by the subject rather than passively received.
- Constructivist approaches entertain an agnostic relationship with reality, which is considered beyond our cognitive horizon; any reference to it should be refrained from.
- Therefore, the focus of research moves from the world that consists of matter to the world that consists of what matters.

In other words, constructivism is both ontologically idealist and epistemologically relativist.

As with all disciplines and academic associations, science education needs to look back, examine, and draw lessons from major theoretical commitments that punctuate its history. To some extent this has happened with the discipline's 1950s and '60s commitment to Behaviourism that was so manifest in Gagné (1965), and Torsen (1973). It has barely happened with its equally huge commitment to Constructivism. Tellingly, neither AERA nor NARST now has a Constructivist SIG. Either the position has become so mainstream and orthodox that it no longer needs separate identification, everyone is a constructivist; or the name was too associated with positions that are now embarrassing. As with car driving, occasionally looking in the rear-vision mirror can be informative; indeed, it is necessary. Historical sensibility is the mark of a mature discipline. Contemporary understanding of the Covid crisis is a way of ascertaining the strengths and weaknesses of historic constructivism.

[29] See Constructivist Foundations site HERE.

The Grand Vision of Constructivism

Whatever it was, great hopes were held for it. Ken Tobin, an early and enthusiastic promoter of the doctrine and science education professor at Florida State University, placed no limit on constructivism's mandate; the sky was the limit. For him:

> To become a constructivist is to use constructivism as a referent for thoughts and actions. That is to say when thinking or acting, beliefs associated with constructivism assume a higher value than other beliefs. (Tobin 1991, p.1)

In earlier times the same was said, by others, about Communism, and in still earlier times, about Catholicism. Indeed, any significant ideology can take the place of 'constructivism' in the foregoing. In the same year, Beverley Bell, New Zealand's most powerful proponent of constructivism, penned a position paper when introducing the country's new Forms 1-V science curriculum. The vaulting ambition of constructivism can be seen in the paper's sub-headings: 'A constructivist view of learning', 'A constructivist view of teaching', 'A view of science', 'Aims of science education', and 'A constructivist view of curriculum development' (Bell 1991). Hundreds of books have been written about each topic, but they are lightly touched upon by confident constructivists.

Two years later, Nancy Davis and constructivist colleagues from Florida State University, expressed the same unbridled expectations for the new theory, or perhaps more correctly at this stage, the new worldview or *Weltanschauung*:

> Constructivism offers a viable alternative view of knowledge, reality, science and education. ... The constructivist view of education provides us with a hope for the future as individuals value their own and others' understandings, take responsibility for their own destinies, and lead us forward into a changing but promising world. (Davis *et al.* 1993, pp.628, 635)

The difference between a 'promising world' and the 'promised land' was easy to miss amid bouts of constructivist enthusiasm verging on revivalism. It is this that prompted Denis Phillips' 1995 observation (above) that constructivism was 'akin to a secular religion'. Not long after, Yvon Pépin, the Canadian researcher, proclaimed:

> ... the constructivist point of view makes it possible to develop a vision of the whole of educational phenomena which is comprehensive and penetrating and which, at the same time, is both viable and even fertile. (Pépin 1998, p.173)

Such breadth of vision, such an all-encompassing, wide-ranging view, is commendable; coherence and breadth should be lauded and sought in education and elsewhere. But to be beneficial such coherent views need to be informed and substantiated. Historic constructivism was neither. It is an open question whether contemporary constructivism is so informed and substantiated.

Much of its enthusiasm and, bluntly, arrogance came from knowing little. Ignoring the roll-call of prominent realist scientists and philosophers,[30] Wolff-Michael Roth and co- author simply announced that: 'constructivism is the most mature epistemological commitment' (Roth & Roychoudhury 1994, p.28). When reviewing constructivism's role in science education Ken Tobin, without qualification, remarked:

> constructivism is a subversive process that got people thinking about the purposes of education and the nature of teaching and learning. (Tobin 2007, p.291)

[30] Among those known personally to the author are: Michael Ruse, Bob Cohen, Ernan McMullin, Clark Glymour, Stathis Psillos, Michael Devitt, Cliff Hooker, Nicholas Rescher, James Ladyman, Nicholas Maxwell, Gerald Holton and Mario Bunge. None of these scholars would consider constructivism 'the most mature epistemological commitment'. See also contributors to Agazzi & Pauri (2000), Leplin (1984), and Agazzi (2017).

No informed person had to await constructivism in order to begin thinking about the purposes of education and the nature of teaching and learning. People have been doing this since, at least, the time of Plato. Courses on just these topics used be part of any decent Foundations of Education programme in teacher education. More is the pity that such courses are progressively being eliminated (Colgan & Maxwell 2020).

Kuhnian Origins

Educational constructivism came into being during the 1970s 'Science Wars' (Gross, Levitt & Lewis 1996, Brown 2001) that were precipitated by the Kuhnian revolution in philosophy of science. Thomas Kuhn was arguably the most influential historian of science in the twentieth century. His impact has been felt in all academic fields, and even beyond the academy. The first edition (1962) of his *Structure of Scientific Revolutions* (Kuhn 1970) sat, as Hume said of his 1739 *Treatise*, largely unexamined on the publisher's floor. The first edition, published as a volume in the positivist *Encyclopedia of Unified Science*, was read only by a handful of professional historians and philosophers of science. The second edition (1970) exploded over the philosophical, and more generally, the scholarly and cultural landscape.

One million copies were sold in seventeen languages. It impacted on everything. The Arts and Humanities Citation Index listed Kuhn's *Structure* as the most cited book in the years 1976-1983. The words 'paradigm', 'incommensurability', 'normal science', 'conversion', 'multiple worlds' and so on, became commonplace in every discipline from economics to theology and beyond, they were found in the Leader and Opinion pages of newspapers and heard on talk-back radio around the world. Kuhn's thoroughly idealist claim, in a purple passage that opened Chapter Ten, that 'when paradigms change, the world itself changes with them' (Kuhn 1970, p.111) became the new normal for so many scholars.[31]

The tragedy for 'infant' educational constructivism is that it was born in 'Kuhnian' times; it ingested, so as to speak, Kuhnian philosophy with its mother's milk.[32] Educators constituted a 'cheer squad' for Kuhn and rushed lemming-like over the Kuhnian cliff (Loving & Cobern 2000). The standard logical-empiricist – oft-called 'objectivist' or 'positivist' – view of science as an objective, truth-seeking, incrementally successful, cumulative, progressive project was challenged by relativists such as Thomas Kuhn, Paul Feyerabend and other philosophers. And then by the tsunami of 'sociology of scientific knowledge' research that was aptly labelled the 'Edinburgh Strong Programme'. The Kuhnian revolution has been exceedingly well documented, studied and appraised by philosophers.[33]

The Kuhnian revolution has not been so carefully studied by educators; particularly not studied by those most influenced by Kuhn and who most loudly appealed to his authority. The more confidence put in his authority, the more carefully he should have been read. This was not the case. It is noteworthy that many of the Kuhn citations in education lack pagination; merely writing *Structure (1970)* sufficed to justify any claim no matter how contentious or disputed. Thus, Marilyn Fleer, a senior professor at Monash University,[34] who in 2003 affirmed that 'Constructivism has provided us with a useful pedagogy and a powerful methodological framework for over twenty years' (Fleer & Robbins 2003, p.405) also claimed:

> In recent years, the rational foundations of Western science and the self-perpetuating belief in the scientific method have come into question .... The notion of finding a truth for reality is highly questionable. (Fleer 1999, p.119).

The only evidence advanced for this, itself 'highly questionable' claim, is an unpaginated reference to Kuhn 1970.

---

[31] Later in the same chapter, Kuhn qualifies the idealism, saying that after paradigm changes, 'scientists work in different worlds' (p.121). Well yes, but also no: the building, parking lot, laboratory, instruments, computers, lunch room all stay where they were.

[32] It is sensible to distinguish 'Kuhnian' philosophy from Kuhn's philosophy. Famously, Thomas Kuhn dissociated himself from a lot of what was propounded in his name.

[33] See Suppe (1977), Horwich (1993), Hoyningen-Huene (1993, 2015), Nickles (2003), and Devlin & Bokulich (2015).

[34] Having a citation count of 2,500 (mid-November 2021).

Founding constructivists such as Joseph Novak, as with so many educators and scholars from all disciplines, were awed by Kuhn and the 'new wave' in historical-relativist philosophy of science that Kuhn's *Structure* launched. Novak wrote:

> In philosophy, a consensus emerges that positivism is neither a valid nor a productive view of epistemology . . . What is emerging is a *constructivist* view of epistemology, building on ideas of Kuhn (1962), Toulmin (1972) and others. (Novak 1977b, pp.5-6)

It is telling that, forty years later, Novak in his autobiography says that although he carefully read Conant and Toulmin, he did not do the same for Kuhn (Novak 2018, p.132).

Nancy Davis speaks for thousands of Education faculty when she, and Florida State University colleagues, wrote:

> Using Thomas Kuhn's (1970) work as a basis to support change in guiding epistemological paradigms, this article contrasts objectivism with constructivism. Three persistent problems in education, curriculum, evaluation and discipline, are presented and reconceptualized from a constructivist perspective. (Davis et al 1993, p.627)

It is more than unfortunate that Educators rarely study the arguments of philosophers, nor indeed of psychologists. Despite teaching subjects reliant, or parasitic, upon these fields, Education faculty do not study the fields as a discipline. At best, they are met as one subject among many in a graduate programme. And even this opportunity is shrinking as Foundation Subjects are progressively removed from Education graduate programmes (Colgan & Maxwell 2020).

Peter Fensham in his comprehensive study of the research discipline of science education remarked that lack of rigorous preparation for science education research is evidenced by the extent of shallow learning theory in the field, saying that:

> science educators borrow psychological theories of learning . . . for example Bruner, Gagne and Piaget. (Fensham 2004, p.105)

He goes on to say, damningly, that:

> The influence of these borrowings is better described as the lifting of slogan-like ideas from these theories. (ibid., p.105)

Even more slogan-like is the lifting of philosophical ideas, with Kuhnian ones being lifted more than any others.

For undermining trust in science, the two most deleterious Kuhnian theses were ontological idealism and epistemological relativism. Both were promoted by influential, sector of education researchers during the high tide of constructivism, and they were 'waved through' by others who were more occupied by refining and defending constructivist pedagogy and were prepared to go along with whatever philosophy was being propounded by leading figures in the movement. Frequently heard was: 'constructivism is simply about engaging and caring teaching'.

In 1985, Yvonna Lincoln and Ergon Guba, two leading constructivist methodologists, published a much-cited piece on naturalist inquiry asserting that there were multiple incompatible realities; essentially as many realities as there were inquirers (Lincoln & Guba 1985). Such claims prompted the National Research Council's Committee on Scientific Principles for Education Research to publish *Scientific Research in Education* (Shavelson & Towne 2002) Subsequently, Norman Denzin and Yvonna Lincoln, authoritatively wrote in the Introduction to their Sage *Education Research* Handbook that:

> The constructivist paradigm assumes a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent cocreate understandings), and a naturalistic (in the natural world) set of methodological procedures. (Denzin & Lincoln, 2005, p.24)

They reaffirmed constructivism's commitment to idealism and relativism. For them, and for so many others, such commitment was the entry ticket for conducting constructivist research in education. This confirmed all the earlier fears of the NRC.

Constructivism's Ontological Idealism

Constructivists embrace an idealist ontology concerning the existential status of scientific and everyday objects; that is, they variously maintain that the world is created by and dependent upon human thought and cognition. This is the view succinctly expressed in the 18th century by Bishop George Berkeley and forever connected to his name: *esse est percipi* (to exist is to be perceived). Various Kuhn-inspired sociologists of science repeatedly state that different observers 'live in different worlds' and, further, that they create the worlds they live in.

Steve Woolgar acknowledges Thomas Kuhn as the inspiration for the discipline of STS (Science-Technology-Society) that to some extent was taken up in science education (Bybee 1987, Gallagher 1971, Solomon & Aikenhead 1994). He writes that his own version of constructivism:

> is consistent with the position of the idealist wing of ethnomethodology that there is no reality independent of the words (texts, signs, documents, and so on) used to apprehend it. In other words, reality is constituted in and through discourse. (Woolgar 1986, p.312)

And later he claims that STS study:

> undermines the standard presumption about the existence of the object prior to its discovery. The argument is not just that social networks mediate between the object and observational work done by the participants. Rather, the social network constitutes the object. (Woolgar 1988, p.65)

These astounding claims rest on a major ambiguity: On the one hand the complete truism that different observers and different groups have different experiences; on the other, that the world in which they live varies from observer to observer and group to group. The latter is not a truism and requires some argument, as does the more advanced claim that these various worlds are created by the observer. Notwithstanding the lack of convincing argument, this 'everything is language' banner waved over many university Education, and other, departments.

Ernst von Glasersfeld's version of Berkeley's idealism has been, in virtue of his immediate influence on leading educators such as Ken Tobin and Wolff-Michael Roth, the most influential in science education.[35] This influence is reflected in him twice, in successive years, being an invited plenary speaker at NARST annual conferences. His *Radical Constructivism* book alone (Glasersfeld 1995) has 5,000+ citations in Google Scholar; his 'Introduction to Radical Constructivism' paper (Glasersfeld 1984) has 2,000+ citations (early May 2021). In the latter publication (in an anthology appropriately titled *The Invented Reality*) von Glasersfeld affirms:

> The concept of "nature," for Hume no less than for Kant, was the totality of objects of experience. That is to say, whatever we infer from our experience . . . necessarily concerns our

[35] Von Glasersfeld says that 1710 was one of the greatest years in the history of philosophy: it being the publication year of Berkeley's *Principles of Human Knowledge*. His autobiographical essay, 'Growing Up Constructivist' (Glasersfeld 1995, chap.1) describes his encounter with Berkeley's books and thinking.

> experience and not that mythical experiencer-independent world of which metaphysical realists dream. (Glasersfeld 1984, p.26)

Elsewhere he writes:

> The realist believes his constructs to be a replica or reflection of independently existing structures, while the constructivist remains aware of the experiencer's role as originator of all structures . . . for the constructivist there are no structures other than those which the knower constitutes by his very own activity of coordination of experiential particles. (Glasersfeld 1987, p.104)

A decade later, he repeats these claims writing that constructivism:

> … replaces the notion of 'truth' … with the notion of 'viability' within the subjects' experiential world. Consequently, it refuses all metaphysical commitments [it] claims to be one more than one possible model of thinking about the only world we can come to know, the world we construct as living subjects. (Glasersfeld 1995, p.22)

These thought-to-be Kantian and Piagetian positions were taken up by numerous science educators; they were close to becoming the new disciplinary normal. John Staver, a prominent USA science educator, stated, in a much-cited article, the ontological idealist position as:

> For constructivists, observations, objects, events, data, laws, and theory do not exist independently of observers. The lawful and certain nature of natural phenomena are properties of us, those who describe, not of nature, that is described. (Staver 1998, p.503)

The late Rosalind Driver, a rightly famous and influential British science educator who was in 1997 awarded the NARST Distinguished Research award, frequently affirmed the idealist position. For instance:

> science as public knowledge is not so much a "discovery" as a carefully checked "construction" . . . and that scientists construct theoretical entities (magnetic fields, genes, electron orbitals . . .) which in turn take on a "reality" ' (Driver 1988, p.137).

Yvon Pépin maintained:

> The visible world does not exist as such but assumes a form when it is constructed by the eye. (Pépin 1998, p.175)

Here it is not even the brain doing the constructing, but the eye. Plato long ago recognised that 'we do not see with the eye, but through the eye'; and even when looking at shadows on the cave wall, the shadows were being cast by something real and existing outside the cave.

Jacques Désautels, who co-authored a national Canadian Science Education Report, unabashedly writes:

> Science as knowledge is an intellectual construct, and what are referred to as the laws of nature are merely the result of this human activity. Nature as such does not have laws. (Nadeau & Désautels 1984, p.19)

Hugh Munby, in an earlier report for the Science Council of Canada, contended that:

> Scientific thinking . . . is a human invention which involves using language to paint the perceptual world . . . we construct our own realities. (Munby 1982, p.21)

While Grayson Wheatley wrote:

From a constructivist perspective, knowledge originates in the learner's activity performed on *objects*. But objects do not lie around ready made in the world but are mental constructs. (Wheatley 1991, p.10)

Bishop Berkeley had become so normalised during Historic Constructivism times that none of the above variants of the idealist 'objects-are-mental-constructs' claim were struck out by reviewers or editors. Ontological idealism had become the disciplinary norm. Observations and theory clearly depend upon us; this is a trivial truism. But only modern-day Berkeleyans could believe that the objects which are observed, and the events theorised about, depend upon us. Philosophical alarm bells should ring when authors run together, and do not separate, 'observations' from 'events' and from 'objects'. Continents drifted prior to Wegener proposing that they did. Dinosaurs roamed the earth during the Triassic period some 240 million years before humans were seeing or experiencing anything. For a realist, and for any serious scientist, there are categorical differences between objects and events both of which carry on without us, and observations and theorising which do not exist without us.

Constructivists came close to a fundamental philosophical point, but they did not recognise it: there is a difference between *natural* objects and *theoretical* objects; between objects in the world and those objects when brought within scientific theories when they become theorised objects or *theoretical* objects. Apples in the world have texture, irregular surfaces, heat, solidity and any number of other properties and relations. And apples as experienced, as 'lived' apples also 'have' secondary qualities of colour and taste. But when they become the subject matter of physics, they are merely point masses with specified accelerations; when apples are considered by economists, they become commodities with specific exchange values; when dieticians consider apples, they become calorie sources. And so on. All the secondary qualities are shed along with most of the primary ones. Failure to appreciate this is at the heart of Romantic criticism of science: science does not immediately deal with the world as experienced.

It is rightly said that the *theorised* objects are created or constructed by scientists; but contrary to the claims of many constructivists and sociologists of scientific knowledge, the *real* objects are not so created. Failure to recognise this is the cause of much philosophical, and subsequently, educational confusion. If Grayson Wheatley, above, had said that 'theorised objects are mental constructs' this would be unexceptional but an important point to make. Instead, he made the thoroughly discredited idealist claim that 'objects are mental constructs'.

A consequence of the constructivist position is that, along with magnetic fields, genes, protons, electrons, X-rays and much else, the Covid virus does not exist or have a structure until the biochemist imposes it; there are no Covid mutants until the scientific community proposes and finds them. Against the obvious realist objection that things (trees, houses, people) continue to exist when no observer is present, Bishop Berkeley maintained that 'God was always observing; he never slept'. The bishop could confidently have God on his side, modern constructivists could less confidently call on God. It is only in a select number of Education and Philosophy lecture rooms that such positions could, today, be stated.

Constructivism's Relativist Epistemology

Anti-scientific, idealist ontology is one side of the constructivist philosophical coin, the other side is sceptical, relativist epistemology which is also antithetical to the scientific endeavour. Constructivist scepticism says that any knowledge of the external world is impossible. Such scepticism is not scientifically helpful; it is destructive. In contrast, genuine scientific scepticism says that knowledge is possible, but we need to recognise that particular claims, even the most foundational, might be revised or abandoned. This underpins scientific fallibilism; it is Merton's final 'scientific scepticism' norm for identifying science (Merton 1942/1973). Similarly, constructivist relativism is the view that knowledge claims, or systems, cannot be judged against each other, all are equal. This is not to be confused with scientific fallibilism which is the view that we can identify the best scientific knowledge, yet recognise that the best is not permanent; it can be, and likely will be, improved.

Ernst von Glasersfeld asserts:

> The fact that scientific knowledge enables us to cope does not justify the belief that scientific knowledge provides a picture of the world that corresponds to an absolute reality. (Glasersfeld 1989, p.135)

Just as his ontological idealism was picked up, repeated, and amplified by numerous constructivists in education, so also was his epistemological relativism. As was seen earlier, Ros Driver in many places repeats the claim:

> Although we may assume the existence of an external world, we do not have direct access to it; science as public knowledge is not so much a discovery as a carefully checked construction. (Driver & Oldham 1986, p.109)

For Ken Tobin and Deborah Tippins:

> Since constructivism acknowledges the impossibility of ever knowing the truth, it is possible to alter the metaphor of researcher as truth seeker to one of researcher as learner. . . . Data collection is essentially an objectivist idea that implies that data are out there to be gathered up. . . . From a constructivist perspective data are not collected but are constructed from experience. (Tobin & Tippins 1993, p.15)

Elsewhere, perhaps by way of elaboration, Tobin and co-author Roth announce that the 'epistemology undergirding science . . . is phallogocentric' (Roth & Tobin 2007, pp.99). Here the two leaders of international science education are appealing to, or just lifting, Jacques Derrida's deconstructivist neologism. Apart from being an unsubstantiated claim about the epistemology of science, it is an offensive slogan. It is hardly an invitation for girls and women to study and pursue science. But, according to Hélène Cixous and Catherine Clément, the 'crumbling' of this way of thinking will take place through a Derridean-inspired, anti-phallo/logocentric philosophy of indeterminateness.[36] That is a relief.

For Jere Confrey, a US constructivist:

> Put into simple terms, constructivism can be described as essentially a theory about the limits of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts. We can have no direct or unmediated knowledge of any external or objective reality. (Confrey 1990, p.108)

For Stephen Fleury, another US constructivist who, agreeing with von Glasersfeld, dismissed 'trivial constructivism' because it ignored the serious advances of radical constructivism, went on to claim:

> The function of cognition is to organize one's experiential world, not to discover an ontological reality. (Fleury 1998, p.158)

To ask just what it is that scientists discover, is besides the point; they do not discover, they make up, they reorganize their experiential world. For Albert Morf, a Canadian constructivist:

> I consider knowledge as *experience-generated potentialities for action.* (Morf 1998, p.36)

And in a classic understatement, he goes on to observe that:

> Knowledge which is defined in this manner . . . . Does not necessarily conform to the categories of classical epistemology (ibid)

[36] See literature HERE.

It certainly does not so conform. Knowledge defined in Morf's manner excludes nothing. Anything, and everything, is an 'experience-generated potential for action'. And some knowledge, mathematics and logic for instance, is not experience-generated at all.

All of the foregoing ontological and epistemological affirmations were made by senior, enormously cited and influential science education professors who collectively had supervised hundreds, if not thousands, of doctoral students who have gone on to be professors in their own right teaching current researchers and classroom teachers. The seventeen scholars whose words are quoted in this paper have a collective Google Scholar citation count of 205,000+; citations, not mentions.[37] It was not young, inexperienced, junior faculty saying all the above; it was some of the most senior scholars in science education, indeed perhaps the most senior and most cited scholars in science education.

A near-common denominator of all the quoted educators making philosophical claims is that they have minimal, if any, training in philosophy; philosophical conviction far outruns philosophical competence. This is a significant disciplinary problem. It was recognised by Jay Lemke, a constructivist and linguist, who observed:

> Science education researchers are not often enough formally trained in the disciplines from which socio-cultural perspectives and research methods derive. Most of us are self-taught or have learned these matters second-hand from others who are also not fully trained. (Lemke 2001, p.303).

As with idealist ontology, relativist epistemology is impossible to reconcile with the progressive and accumulating successes of Covid research and policy development. Both of which progress on the assumption that there is something out there to be known, and that efforts to know it can be judged in terms of their grip on Covid reality. The claim that the virus in a particular individual, or even community, is a delta mutant or a new Omicron variant can be determined to be true or false by standard scientific and technological means. To say that it cannot, in principle, in this case or in any other, be so determined, is to undermine not just Covid research, but the whole scientific programme.

Appraising Kuhn

Berkeley and Kant are the distal sources of constructivist philosophy, Thomas Kuhn is the proximal source. He had launched 'social constructivism' in philosophy of science. The programme supposedly accounting for scientific theory change in terms of social factors (political, economic, religious or others). Educators married the new social constructivism in philosophy to the emerging social constructivism in educational psychology. On account of the separation of Education Departments from Philosophy Departments, and the stripping of philosophy from teacher education and graduate programmes (Barrow 2020), educators did not read the detailed historical and philosophical criticisms of Kuhn. These began with Dudley Shapere who acknowledged the 'vast amount of positive value in Kuhn's book' (Shapere 1964, p.393), but went on to argue that his truly revolutionary account of theory changes in the history of science:

> ... is made to appear convincing only by inflating the definition of "paradigm" until that term becomes so vague and ambiguous that it cannot easily be withheld, so general that it cannot easily be applied, so mysterious that it cannot help explain, and so misleading that it is a positive hindrance to the understanding of some central aspects of science; and then, finally, these excesses must be counterbalanced by qualifications that simply contradict them. (Shapere 1964, p.393)

Israel Scheffler advanced an 11-point critique of Kuhn's arguments, one of which dealt with Kuhn's charge of irrationality in paradigm choice:

---

[37] A Google Scholar citation search shows citation totals for the following scholars cited (mid- November 2021) here: Reinders Duit (6,700), Wolff-Michael Roth (44,000+), Ken Tobin (23,000), Nancy Davis (400), Joseph Novak (50,000), Peter Fensham (3,200), Jay Lemke (25,000), Ernst von Glasersfeld (22,500), John Staver (2,600), Rosalind Driver (15,700), Yvon Pépin (300), Jacques Désautels (800), Hugh Munby (3,800), Deborah Tippins (1,200), Glen Aikenhead (15,100), Grayson Wheatley (3,000), Nancy Brickhouse (6,300). A total of 200,000+ citations.

> [it] fails utterly, for it rests on a confusion. It fails to make the critical distinction between those standards or criteria which are internal to a paradigm, and those by which the paradigm is itself judged. (Scheffler 1966, p. 84).

David Stove argued:

> Kuhn's entire philosophy of science is actually an engine for the mass-destruction of all logical expressions . . . [he] is willing to dissolve even the strongest logical expressions into sociology about what scientists *regard as* decisive arguments. (Stove 1982, p.33)

Alexander Bird provided a sympathetic appraisal of Thomas Kuhn (Bird 2012) but correctly maintained that:

> Kuhn's treatment of philosophical ideas is neither systematic nor rigorous. He rarely engaged in the stock-in-trade of modern philosophers, the careful and precise analysis of the details of other philosopher's views, and when he did so the results were not encouraging. (Bird 2000, p.ix)

The historian Jan Golinski was equally dismissive:

> I see Kuhn as having little positive influence on philosophers and almost none (directly) on historians. His most significant influence within science studies was mediated by sociologists, whose reading of his work he specifically repudiated. (Golinski 2012, p.15)

Abner Shimony, a physicist and philosopher, said of the key Kuhnian move of deriving methodological lessons from scientific practice that:

> His work deserves censure on this point whatever the answer might turn out to be, just because it treats central problems of methodology elliptically, ambiguously, and without the attention to details that is essential for controlled analysis. (Shimony 1976, p.582)

Wolfgang Stegmüller made the severe judgement that the crux of Kuhn's theory of science was 'a bit of musing of a philosophical incompetent' (Stegmüller 1976, p.216). This sounds harsh, but Kuhn freely acknowledged that he had never studied philosophy and, consequently was denied appointment in Philosophy at the University of California (Berkeley). It was in their History department that he wrote *Structures*. Any casual reading of the book shows that it is largely devoid of any engagement with the philosophical tradition.

Mario Bunge recounts in his autobiography that he attended an influential 1966 colloquium on causality convened in Geneva by Piaget in which Kuhn participated. Bunge observed:

> Kuhn's presentation impressed no one at the meeting, and it confirmed my impression that his history of science was second-hand, his philosophy confused and backward, and his sociology of science non-existent. (Bunge 2016, p.181)

Not only did educators miss the initial criticisms, crucially they missed Kuhn's recanting of his positions. In his Robert and Maurine Rothschild lecture at Harvard University in 1991 Kuhn appraised the sociological turn in the history and philosophy of science, acknowledging hat the redirection was 'emphasized and developed by people who often called themselves Kuhnians' (Kuhn 1991/2000, p.3). He damningly added: 'I think their viewpoints damagingly mistaken, have been pained to be associated with it, and have for years attributed that association to misunderstanding' (ibid). Robert Nola, the Auckland philosopher who is no friend of subjectivism and relativism (Nola 2003), was so moved by the widespread misreading of Kuhn that he endeavoured to 'rescue Kuhn from the sociologists' (Nola 2000).

Kuhn, in reviewing his achievements, regretted writing the 'purple passages' in *Structure*. Unfortunately, it was often these passages that were taken up in the education community and repeated

to students. By the time Kuhn regretted them and tried to close the stable door, they appeared in thousands of higher degrees, multiple thousands of articles, and hundreds of Kuhn-inspired books.[38]

Glen Aikenhead, a leading Canadian science educator, enthusiastically embraced Kuhnian STS scholarship, saying that, *in toto*, it revealed science as:

> mechanistic, materialist, reductionist, empirical, rational, decontextualized, mathematically idealized, communal, ideological, masculine, elitist, competitive, exploitive, impersonal, and violent. (Aikenhead 1997, p.220)

In other words, not something parents would wish their children to be taught. Though at that stage science had not been revealed as 'phallogocentric'. That was coming with the research of Jacques Derrida.

Michael Peters, the influential educator and editor, confidently wrote:

> There is no universal metalanguage in which to understand science. The reality is that there are [as] many sciences as there are languages and, as Wittgenstein argued, new languages are added to the old ones, like suburbs to an old town. (Peters 2020, p.1229)

Peters, as with so many others, simply swallows Kuhn's Incommensurability Thesis which claimed the competing theoretical accounts of any phenomena - alternative systems - cannot be compared; there is no shared observational or theoretical language.

Not everyone swallowed this.[39] Nicholas Maxwell,[40] the English philosopher of science, and proponent of Aim Orientated Empiricism, succinctly stated that:

> Incommensurability was Kuhn's worst mistake. If it is to be found anywhere in science, it would be in physics. But revolutions in theoretical physics all embody theoretical *unification*. . . . It always astonished me that anyone took incommensurability seriously for a moment, especially as Michael Faraday solved the problem around 1834, long before Kuhn and Feyerabend invented it. . . . It is at once clear that the picture of science Kuhn gives us in *Structure* is very seriously inadequate. (Maxwell 2014, pp.133, 140)

With incommensurability and epistemological relativism, any account of Covid is as good as any other account; the CCP account of the Wuhan outbreak is as good as the WHO account; an indigenous group's 'spirit possession' account is as truthful as the Centers for Disease Control's account. There is no truth of the matter, or even no best of the matter. Trying to ascertain either is a mistake; incommensurability says there is nothing to ascertain.

Scepticism about Science

Constructivism's rejection of the Enlightenment's commitment to science as the surest and only way to understand natural (and social) causal action in the world is now the common default position in science education. The Enlightenment education tradition of John Locke, Joseph Priestley, Nicolas de Condorcet, Thomas Huxley, Ernst Mach and John Dewey has become, if not the enemy, at least an embarrassment for many in the science education community.[41]

---

[38] The Kuhnian episode in science education is documented and appraised in Matthews 2004.

[39] For overview of philosophers' critiques of incommensurability, see Newton-Smith (1981).

[40] For all publications, see Maxwell's website HERE.

[41] For elaboration and references, see Matthews (2015, chap.2).

Wolf-Michael Roth, one of the most published, cited, and awarded researchers in the field,[42] confidently asserted the antithesis of the Enlightenment's universalist and realist position:

> .... we live forever in our own, self-constructed worlds; the world cannot ever be described apart from our frames of experience. This understanding is consistent with the view that there are as many worlds as there are knowers. ... Our universe consists of a plenitude of descriptions rather than of an ontological world *per se* .... (Roth 1999, p.7)

Consistently, in a later co-authored paper, he argued that the task of teachers is to learn:

> ... how to deprivilege science in education and to free our children from the 'regime of truth' that prevents them from learning to apply the current cornucopia of simultaneous but different forms of human knowledge with the aim to solve the problems they encounter today and tomorrow. (Eijck & Roth 2007, p. 944)

Nancy Brickhouse, a prominent feminist researcher (6,300 citations) and now Baylor University Provost, also turned to Derridean deconstructionism to opine:

> Science cannot produce culture-free, gender-neutral knowledge because Enlightenment epistemology of science is imbued with cultural meanings of gender. This feminist critique of Enlightenment epistemology describes how the Enlightenment gave rise to dualisms (e.g., masculine/feminine, culture/nature, objectivity/subjectivity, reason/emotion, mind/body), which are related to the male/female dualism ... in which the former (e.g., masculine) is valued over the latter (e.g., feminine). (Brickhouse 2001, p.283)

These anti-Enlightenment claims gained the assent of many by appealing to two falsehoods. First, identifying the Enlightenment tradition with positivism whose ontology was explicitly anti-realist.[43] Second, identifying the Enlightenment with scientism but so characterising the latter that it should more properly be called pseudoscientism. As mentioned in the opening section of this paper, proponents of serious and informed scientism never claim that literary, artistic, musical, political or ethical disputes can be adjudicated simply by science. Science (natural, social, historical) can usually, if not always, contribute to informing such debates, but does not make the final call.

There is a major problem for educators who swallowed constructivist philosophy along with its pedagogical pill: How to reconcile the volume of effective, knowledge- generating Covid research with idealism and relativism? For the 'true-believers' quoted above, it is a 'positivist' delusion to think there is something 'out there' and, further, that science can provide knowledge of it.

Not surprisingly, many have lost their constructivist philosophical faith, though remaining loosely tied to its pedagogy. Wolff-Michael Roth announced his apostasy from constructivism, writing that it 'turned out to be plagued with considerable contradictions' (Roth 2006, p.326). This was something that many philosophers had said from the outset.[44] In 1992, Wallis Suchting, an Australian philosopher, provided a detailed line-by-line critique of one of von Glasersfeld's hugely popular constructivist publications, concluding that:

> First, much of the doctrine known as 'constructivism' ... is simply unintelligible. Second, to the extent that it is intelligible ... it is simply confused. Third, there is a complete absence of any argument for whatever positions can be made out. ... In general, far from being what it is claimed to be, namely, the New Age in philosophy of science, an even slightly perceptive ear can detect the familiar voice of a really quite primitive, traditional subjectivistic empiricism with some overtones of diverse provenance like Piaget and Kuhn. (Suchting 1992, p.247)

Ken Tobin, a promoter of von Glasersfeld in science education who takes some credit for the latter being plenary speaker at NARST, AERA and IHPST, was not moved by such criticism, saying:

---

[42] Google Scholar lists 44,163 citations (11 November 2021).

[43] Positivists, most notably Ernst Mach, lauded the Enlightenment but rejected its realist ontology.

[44] See Suchting (1992), Nola (1997), Phillips (1997), Slezak (2000), and Boden (2010).

> I did not need or benefit from the line-by-line philosophers' critiques of a single EvG manuscript taken in isolation from a lifetime of scholarship. The critiques were a distraction, a storm in a teacup that for a short time diverted precious resources from good scholarly practice. (Tobin 2007, p.295)

Unfortunately, what counted for much of 'good scholarly practice' was, as Peter Fensham observed above, 'the lifting of slogan-like ideas from [disciplinary] theorists'. Just a little careful line-by-line examination can guard against this. Tobin did 'move on' from constructivism (Tobin 2000) but it was not so much 'moving on' as putting on new clothes – something he acknowledged. In 2006, Tobin and Roth jointly founded the Springer journal *Cultural Studies of Science Education* which took a relaxed view about the need for philosophical competence by its contributors.[45] Tobin says constructivism 'was subsumed in a new wave of sociocultural theory that is just as subversive as constructivism' (Tobin 2007, p.291).

Tobin is doubtless correct in saying that sociocultural theory is one of the new faces of constructivism, though one should notice the caveat expressed by John Frow, the founder of Cultural Studies in Australia:

> 'Cultural studies', on the one hand, designates less a formed disciplinary space than a relatively formless potential which is taken up in different and often quite contradictory ways. (Frow 2005, p.1)

This is very constructivist. All commentators, including Reinders Duit, the chronicler of constructivism, tell us that constructivism is minimally heterogenous if not formless. But such an opening caveat does not augur well for a new coherent research programme, its effective evaluation, much less any guide to pedagogy and curriculum development. It is, literally, a 'theory-free' zone, a theoretical *tabula rasa* upon which can be written anything.

In 2015, Tobin enunciated his new position as:

> In contrast to the mainstream of research in science education, I advocate a multilogical methodology that embraces incommensurability, polysemia, subjectivity, and polyphonia as a means of preserving the integrity and potential of knowledge systems to generate and maintain disparate perspectives, outcomes, and implications for practice. In such a multilogical model, power discourses such as Western medicine carry no greater weight than complementary knowledge systems that may have been marginalized in a social world in which monosemia is dominant. (Tobin 2015, p.3)

This statement, as with so many other cultural studies assertions, minimally cries out for a word-by-word, phrase-by-phrase, sentence-by-sentence application of the standard philosopher's question: What do you mean by? It does sound like constructivism in new dress: epistemological relativism is plainly there, and ontological idealism is not far beneath the surface. How funding bodies might decide to fund, or not fund, research so conducted is a puzzle. Some of the puzzle was laid out by the NRC's Committee on Scientific Principles for Education Research (Shavelson & Towne 2002).

It is worth recalling Nicholas Maxwell's above observation that 'incommensurability was Kuhn's worst mistake' (Maxwell 2014, pp.133). It was also, perhaps, the most widely and easily adopted of the Kuhnian theses: Incommensurability was a 'get out of jail' card for purveyors of any contentious position; it is one of the most commonly lifted Kuhnian slogans.

Indigenous Science

The Kuhnian impact on, and misdirection of, multicultural and indigenous science education was dramatic. There were well known, and disturbing, anticipations of Kuhn's 'multi- and incommensurable-sciences' position being used to promote alternative sciences. In 1930s Germany, it was Aryan Science; in the Soviet Union, Stalin's 'two sciences' thesis justified Lysenkoist displacement of Mendelian genetics; in Mao's China, it justified Maoist Dialectical physics; in BJP-controlled India, Hindu Science is authorised; in many Muslim countries, it is Islamic Science; in the USA, Kuhn-inspired positions have been used to justify the teaching of, first, Creation Science,

[45] See journal site HERE.

then Intelligent Design, instead of evolutionary theory (Ruse 1988 Pt.3, 2000, Alters & Alters 2001, Chap.4).

Glen Aikenhead, in a much-cited paper, has advocated a 'border-crossing' strategy (Aikenhead 1996). Just as tourists when they cross borders do not lose their cultural identity even though they temporarily adopt foreign customs about driving, eating, dressing and language, so also science students should not lose their cultural identity (as a traditional Roman Catholic, a fundamentalist Christian, an Intelligent Designer, a PNG highlander, and so on) just because the science laboratory has no place for their own rich beliefs. Students should simply leave their culture's worldview (ontology, epistemology, metaphysics, authority structure, religion) at the classroom door, and pick it up when they leave. This bespeaks a certain, but unargued, pragmatist philosophy of education and instrumentalist philosophy of science.

This programme can only be rendered intellectually consistent when constructivist ontological idealism and epistemological pluralism is adopted. But if they are not adopted, then there is intellectual inconsistency and psychological dissonance: Is Covid-19 disease caused by a spell having been cast by an enemy or by SARS-CoV-2 virus whose picture can be pointed to in textbooks and that can be made harmless with vaccines? Without multi- worlds and multi-truths, both claims cannot be true.

In New Zealand in the early 1990s, the same arguments had been used, successfully, to have an anthropological course on Māori Science (Mātauranga) substitute for what were compulsory science courses in teacher education programmes at University of Auckland. This was supposedly because what was being taught in the anthropology course was indeed a science (Matthews 1995). The argument presented at the time by Graham Smith, [46] a Māori educator, was:

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

In recent years there has been a strong and successful campaign to have Māori knowledge, specifically science, incorporated into the National Certificate of Educational Attainment (NCEA) at all school levels (Hikuroa 2017). A Māori science educator went so far as to maintain:

> Since Māori knowledge includes 'the gods' or knowledge of spiritual realms, while science does not, I drew [for a class] a diagram in which mātauranga Māori (Māori knowledge) is a large circle, and science is a smaller circle inside it. This differs from the more typical 'Venn diagram' model with two intersecting circles used to show the overlap between science and Māori knowledge (Roberts 1998; Simon 2003). The benefit of my 'superset' model of the relationship between science and mātauranga Māori is that it makes all of science, not only in some domains such as ecology, relevant to Māori and Māori school students. (Stewart, 2019, p. 66)

An article published in the journal of the Royal Society of New Zealand is explicit regarding the autonomy or equal status of Māori Science:

> Although there will be opportunities to work together, that is not the goal of revitalising mātauranga. The goal is not partnership; it is tino rangatiratanga and instituting mātauranga as a primary and independent knowledge system. (Broughton & McBreen, 2015, p.86)

[46] Graham Smith was appointed professor shortly after being awarded his PhD. He became a very influential figure in New Zealand academic and political environs.

The simmering in-house debate became public and national when seven University of Auckland professors (Philosophy, Psychology, Biology and Education) published a 400 word 'Defence of Science' letter in the popular *New Zealand Listener* magazine, saying among other things:

> Indigenous knowledge is critical for the preservation and perpetuation of culture and local practices, and plays key roles in management and policy. However, in the discovery of empirical, universal truths, it falls far short of what we can define as science itself.
>
> To accept it as the equivalent of science is to patronise and fail indigenous populations; better to ensure that everyone participates in the world's scientific enterprises. Indigenous knowledge may indeed help advance scientific knowledge in some ways, but it is not science. (Nola et al 2021)

Within two weeks an Open Letter 'Against the Professors' was circulated and signed by 2,000+ academics, school principals, teachers and graduate students. The signatories included 250 New Zealand professors and associate professors (which is no small thing given there are only a handful of universities in the country). The University Vice-Chancellor, Dawn Freshwater, disavowed herself, and the University, from the published position of the 'Defenders of Science', saying in a communication to all staff and students that the Defenders' letter had 'caused considerable hurt and dismay among our staff, students and alumni' and that it pointed to 'major problems with some of our colleagues'.

The multi-signed 'Against the Professors' letter affirmed, among other things, that:

> Indigenous knowledges - in this case, Mātauranga - are not lesser to other knowledge systems. . . . However, Mātauranga is far more than just equivalent to or equal to 'Western' science. It offers ways of viewing the world that are unique and complementary to other knowledge systems. (Hendy et al, September 2021)[47]

Shortly after, five complaints were made to the Royal Society of New Zealand, asking that three of the seven professors, who were members of the RSNZ and signed as such the original letter, be expelled from the society on account of expressing racist views and bringing the society into disrepute. The RSNZ has convened a complaints committee to process the request. One of the 'Defenders' was Professor Garth Cooper FRSNZ, a Māori and one of the country's most prominent bio-medical researchers.[48] This consequence should alert signatories to the letter; bad philosophy has impact.

To say that Mātauranga is 'unique and complementary' to mainstream science is fine. 'Unique' means one of a kind, and 'complementary' means alongside, or different from. Broadly, this can initially be said of the multitude of indigenous knowledge systems, of which there are hundreds if not thousands throughout the world. Some have thousands of adherents (different localised Australian aboriginal systems and folklore, different north, central and south American indigenous groups); others have millions (the scores of Hindu and Chinese systems, Mary Baker Eddy's 'Christian Science', Creation Science, countless Feng Shui systems, and so on). All of them are unique, though there is accidental overlap of cosmology, ontology, epistemology etc. And they are all complementary to science.

US Creation Science debates parallel Mātauranga debates in New Zealand. The latter should be informed by the former. Evolution is rejected and Creation Science is affirmed by 18% of adults in the USA (50 million people).[49] Notwithstanding its large contemporary and historical cultural footprint, significant and widely-publicised court cases have repeatedly determined that it was unconstitutional to teach Creation Science as science in the US; and it was not allowed even to be taught alongside standard science. Judge William R. Overton, in a 25-page judgement in the famed 1981 Arkansas trial, determined that Creation Science was not science and said, among other things, and under the influence of Michael Ruse an Expert Witness, that the essential characteristics of science are:

---

[47] The text of the Open Letter, along with the names of 2000+ signatories, is available HERE.
[48] Cooper's career and accomplishments can be seen HERE.
[49] See Pew Research Centre research HERE.

(1) It is guided by natural law.
(2) It has to be explanatory by reference to natural law.
(3) It is testable against the empirical world.
(4) Its conclusions are tentative, i.e., are not necessarily the final word.
(5) It is falsifiable. (Overton 1982, p.318)

In other words, a standard, widely agreed upon account of science.[50]

This decision notwithstanding, a number of states (Ohio, New Mexico, Minnesota) legislated 'Teach the Controversy' laws whereby both Evolution and Intelligent Design were to be taught in science programmes. In 2005, the whole gamut of constitutional, educational, philosophical and theological issues was rerun in the equally famed Dover, Pennsylvania, School Board case. There Judge John E. Jones III in a 139-page judgement expanded upon the Overton decision, determined that 'Intelligent Design Theory', a scientifically dressed version of Creation Science, likewise failed the scientificity test and, additionally, ran afoul of the US legal separation of state and religion (Pennock & Ruse 2008).

In formally Muslim countries, there are no such legal cases; teaching evolution is simply prohibited (Edis & BouJaoude 2014). The majority of the population in countries such as Indonesia, Afghanistan, Iraq, and Saudi Arabia reject evolution and the whole naturalistic worldview from which it comes. The Quran is the final arbiter of scientific, philosophical, legal and most other truths. In these countries, as in formally Hindu countries, constructivism was welcomed by powerful nationalist parties, and orthodox religious, groups. Constructivism effectively rendered science intellectually powerless; science had no definitive truths; indigenous Islamic and Hindu sciences could not be measured against it; orthodox science could not be a threat to traditional culture. Vedic Astrology is taught in Indian universities and colleges; astrologers are hired alongside astronomers; making Sati (widow immolation) illegal was opposed as being an act of 'epistemic violence' (Nanda 2003, chap.5).

Many ethnoknowledge systems (TEKs) have an ontology wherein there are non- material, active, non-legal (not lawful bound) entities such as angels, spirits, jinn, devils and the like who regularly intervene in the world, possess people, cause and cure illnesses, speak from 'the other side', respond to prayers and entreaties, and so on. The spirit world is omni-present and active in most traditional worldviews (and a good many Western ones). Such ontologies allow for animism wherein trees, rocks and landforms are not inanimate, they have their own spirits and, for some, consciousness.

The institution of indigenous knowledge is, characteristically, not democratic, liberal, or open. It is usually rigidly hierarchical (receiving knowledge is age, grade and status contingent); sexist (some knowledge is women's business, other knowledge is men's business); and positionist (some knowledge is the preserve of particular positions, with sacred knowledge being especially preserved for a designated few and cut-off from the many). Typically, the ethno- 'book of knowledge' is not open for everyone to read; some can read some chapters, others can only read other chapters. This is the common pattern for human societies; liberal, democratic, open societies are the exception. All of this oft enough applies to orthodox science but does so *de facto* not *de jure*: any science textbook can be opened and read by anyone; and as the language, concepts, ontologies and methods are universal, the book can, in principle, be read by anyone in any country.

Epistemologies vary between TEKs with some having a frankly authoritarian epistemology: Truth is sought in sacred books or Scriptures, in the tradition of cultural teaching, and in the judgement of elders or authority figures; not in looking at the world, measuring, or conducting experiments.

This kaleidoscope of ethnic knowledges, each with their own ontology, epistemology, institutional structure, and guiding values, cannot easily, if at all, be reconciled with the ontology, epistemology, experimental practice and institutions of mainstream science; the science so globally displayed in Covid research. To talk of 'equal time', much less 'integration', is to talk too

[50] Though some philosophers, Laudan (1982), vehemently disagreed.

glibly, things are not that simple.[51] An epistemological argument is not needed for teaching ethnoscience in a social studies programme, there just need to be educational arguments; but an epistemological argument is needed for teaching ethnoscience in a science programme, and even more so for teaching it as science. Of course, ethnoscience can, and in many cases should, be used to illustrate, or contrast with, some scientific claim or procedure. Ethno-understandings and practices can be an effective 'lead in' to routine science topics.

Consider sensible advice in a recent South Australian Science Teachers Association journal thematic issue on the subject of *Teaching Indigenous Science*. The opening article lists a number of valuable lead-ins for science classes:

> • Traditional rope provides a cultural context to explore the properties of natural and processed materials. The pitch angle of laid strands is related to tensile strength. (Sambono 2021, p.5)
> • Stone knapping using percussion and pressure flaking techniques provides many rich connections to AC [Australian Curriculum]: Science such as geology, physics and chemistry. (Sambono 2021, p.5)
> • First Nations Australians food processing technoglogies allow for exploration of chemistry concepts such as chemical change and rates of reaction. (Sambono 2021, p.6)
> • Many First Nations Australian adhesives are thermoplastics and exemplify the concept of reversible change. (Sambono 2021, p.7)
> • All traditional fire lighting techniques utilize kinetic energy and friction. As such they provide excellent hands-on cultural contexts for students to learn about First Nations Australians and experience first-hand the physics concept of energy transformations. (Sambono 2021, p.10)

After elaborating common First Nations procedures for making edible flour from poisonous Cycad seeds by prolonged washing in water, teachers are told:

> • Cycasin consists of an innocuous sugar part (glucose) that is chemically bound to the active toxic substance methylazoxymethanol (MMA), and in a chemical reaction with water (called hydrdolysis), cycasin is broken up into these two parts. (Sambono 2021, p.8)

All of this is fine, and would be useful lead-ins to the relevant science, especially for schools with even small numbers of First Nation students. But the article's conclusion is contentious:

> • How and why First Nations Australians applied heat-lithic treatment to siliceous rocks provides a cultural context to explore how First Nations Australians have long worked scientifically through making astute observations and use of trial and error in development of tool manufacturing processes. (Sambono 2021, p.9)

Does making astute observations and using trial and error constitute science? Does it suffice for a culture having a science in the same sense that classical physics or modern genetics is a science? Joseph Needham, famously wrote in his 24-volume study of *Science and Civilisation in China* (Needham 1954-2004) that though China had unmatched technologies, two-thousand years or more of recorded observations; and trial and error procedures across a multitude of domestic, commercial, and industrial practices including pottery, ceramics, iron making, canal building and much more – China had no science. It had advanced technology but not science (Needham 1969, chap.1). For Needham science was defined by:

> The application of mathematical hypotheses to Nature, the full understanding and use of the experimental method, the distinction between primary and secondary qualities, the geometrization of space, and the acceptance of the mechanical model of reality. Hypotheses of primitive or medieval type distinguish themselves quite clearly from those of modern type. Their intrinsic and essential vagueness always made them incapable of proof or disproof, and they were prone to combine in fanciful systems of gnostic correlation. (Needham 1969, p.15)

[51] Jonathan Rauch has detailed much of this incompatibility in his recent *The Constitution of Knowledge* (Rauch 2021).

With good reason, Simon Winchester's biography of Needham was titled: *The Man Who Loved China* (Winchester 2008). He was a member of the Royal Society and his clear-headed, informed, publicly-stated views on Chinese science were never thought to be grounds for revoking his membership.

There are cultural, ethical, and political reasons for the teaching and learning of appropriate ethnosciences. And perhaps, as in the case of New Zealand, legal reasons. There the 1840 Treaty of Waitangi, signed between the British Crown and Māori chieftains, required that the new country 'maintain Māori culture and beliefs' (Palmer 2008). But these reasons are all independent of the scientificity, or otherwise, of Māori or any other ethnoscience. The placement of ethnosciences in the school or university science programme depends upon confusing the first sets of reasons with scientificity. Indigenous knowledge systems, or more loosely ways of knowing, can be respected, or even championed, without them needing to be called 'science' or deemed the equivalent of 'orthodox' science.

The Editorial of the South Australian thematic issue reproduces the Australian Curriculum Corporation's claim that:

> Studies of Aboriginal cultures and Torres Strait Islander cultures in the Science curriculum will show students and teachers that there are different concepts of science and ways of knowing the world. (Australian Curriculum Corporation 1996, p.15)

Any anthropological/sociological/historical study confirms that there are myriad concepts of science and ways of knowing the world. But are they all science? Should they be funded as science? And should they be taught as science in a science programme as distinct from a social science programme? Are a group of children passing a ball around, playing rugby? Are another group making noise, making music? Rugby involves passing a ball and music involves making noise, but these necessary conditions are not sufficient. Making them so, undermines language, communication and research. All answer to the posed questions will depend on philosophical positions and arguments which will need to be articulated.

On these matters, including the current New Zealand debate, in 2001, the New Zealand Waitangi Tribunal determined:

> (1) Mātauranga Māori belongs to Iwi [Māori nation] and should remain under Māori control.
> (3) Mātauranga Māori is different to science and should not be confused with it.
> (4) Māori participation in science and technology should be encouraged but it is not a goal which is directly linked to Mātauranga Māori.

Charbel El-Hani, a Brazilian biologist and philosopher of science who for decades has worked with a NE Brazilian traditional fishing community documenting their native knowledge and practices, comprehensively addressed this matter in a paper aptly titled 'Valuing indigenous knowledge: To call it "science" will not help' (El-Hani & de Ferreira Bandeira 2008). The 2,000+ signatories to the 'Against the Professors' letter would have done well to have read the paper.

Constructivism provides a readymade, and irresistible, philosophical argument for the inclusion of ethnoscience in science programmes. But too often educators supporting constructivist philosophy have not looked around the corner to see what might be coming to science programmes once these premises are accepted: astrology, creation science, National Socialist science, Maoist science, Christian Science, and so on down the list.

Post-Truth Condition

The very same arguments are replayed in debates about education in a post-truth world (McIntyre 2018). One extensively documented review of 'Post-truth Education' published in a special thematic issue of *Educational Psychologist* on the topic (2020, vol.55 no.3) identifies a number of factors that have contributed to the post-truth condition, and concludes:

> These trends jointly create a climate in which intellectual values such as truth, accuracy, fair-mindedness, and open-mindedness have become harder to pursue and achieve. Although none of these phenomena are historically new, their current scope and scale may be more extreme than before (Kienhues, Lucks & Bromme 2020).

It is noteworthy that constructivism was not among the trends identified as leading to post-truthism. But as has been pointed out here, constructivist philosophy, when taken seriously, leads immediately to post-truthism: If there is no independent, objective world, and if we cannot have knowledge of it anyway, then there is no truth as classically understood. These implications and problems were pointed out by early critics of constructivism. In different guises they are being re-run in current indigenous science and post-truth era debates.

Michael Devitt, formerly a Sydney philosopher, made a prescient appraisal when, thirty years ago, constructivism was at its height:

> I have a candidate for *the* most dangerous contemporary intellectual tendency, it is ... constructivism. Constructivism is a combination of two Kantian ideas with twentieth-century relativism. The two Kantian ideas are, first, that we make the known world by imposing concepts, and, second, that the independent world is (at most) a mere 'thing-in-itself' forever beyond our ken. ... [considering] its role in France, in the social sciences, in literature departments, and in some largely well- meaning, but confused, political movements [it] has led to a veritable epidemic of 'world-making'. Constructivism attacks the immune system that saves us from silliness. (Devitt 1991, p.ix)

Devitt did not mention Education among the domains harmed, if not laid waste, by constructivism but, as documented above, he could have.

Conclusion

It is telling that the once loud voices that trumpeted constructivist philosophy as the 'new best thing' and rejoiced in it winning 'the paradigm war' in science education – are so quiet in the Covid era. Doubtless this is because it is clear to everyone that the virus actually exists and cannot just be thought away, as it could be if ontological idealism were true. And also, because scientists are epistemological realists who by patient, collaborative, objective, international cooperation are step-by-step gaining knowledge of Covid-19 origins, composition, transmission mechanisms, and mutations; and are proposing effective pharmacological (vaccines) and non-pharmacological (social distancing, mask wearing) measures for its mitigation. Any gainsaying of this would bring ridicule upon an academic. No one wants reminding that they once said that all of this effective scientific work would be fanciful, exploitive, ideological and delusional. And probably 'phallogocentric' to boot.

In the aftermath of the 2001 World Trade Center attack, the United States government was moved to establish a 9/11 Commission to understand and comprehend how such an unthinkable thing, of such magnitude, organisation sophistication, and impact, could happen; and what lessons about government and social institutions could be learnt.[52] After the 6 January 2021 storming of the US Congress a comparable January 6 Commission has been established. In both cases the commissions were intended to shed light on how the unexpected situations came to be: What constellation of distant and proximate causes was responsible for the events?

Perhaps a comparable Education Commission into the science education embrace of constructivism is warranted. This essay has documented just some of the central philosophical failures of constructivism; failures that, unless corrected, diminish confidence and trust in science and, doubtless, diminish confidence in and funding for science education research. The US National Research Council addressed some of these matters in its 2002 report *Scientific Research in Education* (Shavelson & Towne 2002). How such flawed central philosophical positions came to be adopted, and championed, by the foremost scholars in science education and taught to generations of students is a topic worthy of a Commission of Inquiry. And this leaves aside the now exhaustively documented failures of constructive pedagogy which is something that also warrants commission-like investigation.[53]

In 2001 there was a very sympathetic, uncritical joint UNESCO-IBE (International Bureau of Education) report on *Constructivism and Education* (Ducret 2001). Twenty-years later, perhaps another less sympathetic and more critical report, though with an adjusted title, *Revisiting*

[52] The Commission Report is available HERE.
[53] This literature is canvassed in Matthews 2021, pp.169-173.

Constructivism and Education could be commissioned. It could augment the UNESCO-IBE 2019 *Future of Education* report.[54]

Assuredly one of the recommendations of any such commission would be provision for some exposure to history and philosophy of science for those teaching and researching in science education (Matthews 2020). A minimum of such training would have helped avoid the shallow, ill-conceived, and damaging idealist ontological and relativist epistemological positions that that were the hallmark of high-tide constructivism.

Conflict of Interest Statement. The author attests that there are no financial or commercial considerations that are relevant to the researching and writing of this paper. There is no conflict of interest.

References

Agazzi, E. (ed.): 2017, *Varieties of Scientific Realism: Objectivity and Truth in Science*, Springer, Dordrecht.

Agazzi, E. & Pauri, M. (eds.): 2000, *The Reality of the Unobservable: Observability, Unobservability and Their Imapact on the Issue of Scientific Realism*, Kluwer Academic Publishers, Dordrecht.

[54] See UNESCO site HERE.

Aikenhead, G.S.: 1996, 'Cultural Assimilation in Science Classrooms: Border Crossings and Other Solutions', *Studies in Science Education* 7, 1-52.
Aikenhead, G.S.: 1997, 'Towards a First Nations Cross-Cultural Science and Technology Curriculum', *Science Education* 81(2), 217-238.
Alters, B.J. & Alters, S.M.: 2001, *Defending Evolution: A Guide to the Creation/Evolution Controversy*, Jones and Bartlett Publishers, Sudbury, MA.
Ashton, P.T.: 1992, 'Editorial', *Journal of Teacher Education* 43(5), 322.
Barrow, R.: 2020, 'The Decline of Philosophy in Educational Study and Why it Matters'. In A.D. Colgan & B. Maxwell (eds.) *The Importance of Philosophy in Teacher Education: Mapping the Decline and Its Consequences*, Routledge, New York, pp.15-24.
Bell, B.F.: 1991, 'A Constructivist View of Learning and the Draft Forms 1-5 Science Syllabus', *SAME Papers 1991*, 154-180.
Bentley, M.L.: 1998, 'Constructivism as a Referent for Reforming Science Education'. In M. Larochelle, N. Bednarz & J. Garrison (eds.), *Constructivism and Education*, Cambridge University Press, pp.233-249.
Bernal, J.D.: 1954/1965, *Science in History*, 4 vols., (3rd edition), C.A Watts, London.
Bird, A.: 2000, *Thomas Kuhn*, Princeton University Press, Princeton.
Bird, A.: 2012, '*The Structure of Scientific Revolutions* and its Significance: An essay review of the 50th anniversary edition' *The British Journal for the Philosophy of Science* 63(4) 859-883.
Boden, M.: 2010, 'Against Constructivism', *Constructivist Foundations* 6(1), 84-89
Boudry, M. & Pigliucci, M. (eds): 2017, *Science Unlimited? The Challenges of Scientism*, University of Chicago Press, Chicago.
Brickhouse, N.W.: 2001, 'Embodying Science: A Feminist Perspective on Learning', *Journal of Research in Science Teaching* 38(3), 282-295.
Brink, J. van den: 1991, 'Didactic Constructivism', In E.von Glasersfeld (ed.) *Radical Constructivism in Mathematics Education*, Kluwer, Dordrecht, pp. 195-227.
Broughton, D. & McBreen, K.: 2015, 'Mātauranga Māori, Tino Rangatiratanga and the Future of New Zealand Science', *Journal of the Royal Society of New Zealand*. 45: 83-88. doi:10.1080/03036758.2015.1011171
Brown, J.R.: 2001, *Who Rules in Science: An Opinionated Guide to the Science Wars*, Harvard University Press, Cambridge MA.
Bunge, M.: 1986, 'In defence of realism and scientism', *Annals of Theoretical Psychology*, 4, 23-26.
Bunge, M.: 2016, *Between Two Worlds: Memoirs of a Philosopher-Scientist*, Springer, Dordrecht.
Bybee, R.W.: 1987, 'Science education and the science-technology-society (S-T-S) theme', *Science Education* 71(5), 667-683.
Carey, S.: 1986, 'Cognitive Psychology and Science Education', *American Psychologist* 41, 1123-1130.
Cheung, K.C. & Taylor, R.: 1991, 'Towards a Humanistic Constructivist Model of Science Learning: Changing Perspectives and Research Implications', *Journal of Curriculum Studies* 23(1), 21-40.
Colgan, A.D. & Maxwell, B. (eds.): 2020, *The Importance of Philosophy in TeacherEducation*, Routledge, New York.
Colson, P., Rolain, J.-M., Lagier, J.-C., Brouqui, P., & Raoult, D.: 2020, 'Chloroquine and hydroxychloroquine as available weapons to fight COVID-19. *International Journal of Antimicrobial Agents, 55*(4),

Confrey, J.: 1990, 'What Constructivism Implies for Teaching'. In R. Davis, C. Maher, & N. Noddings (eds.) *Constructivist Views on the Teaching and Learning of Mathematics*, National Council of Teachers of Mathematics, Reston, VA., pp.107-124.

Davis, B. & Sumara, D.: 2003, 'Constructivist Discourses and the Field of Education: Problems and Possibilities', *Educational Theory* **52**(4), 409-428.

Davis, N.T.B., McCarty, J., Shaw, K.L., & Sidani-Tabbaa, A.: 1993, 'Transitions from Objectivism to Constructivism in Science Education', *International Journal of Science Education* 15, 627-636.

Denzin, N.K. & Lincoln, Y.S. (eds.): 2005, *The Sage Handbook of Qualitative Research*, Thousand Oaks, CA.

Devitt, M.: 1991, *Realism & Truth*, 2nd ed., Basil Blackwell, Oxford.

Devlin, W.J. & Bokulich, A. (eds.): 2015, *Kuhn's Structure of Scientific Revolutions – 50 Years On*, Springer, Dordrecht.

Driver R. & Bell B.: 1985, Students thinking and the learning of science: a constructivist view. *School Science Review* 67(240), 445-456.

Driver, R. & Oldham, V.: 1986, 'A Consructivist Approach to Curriculum Development in Science', *Studies in Science Education* 13, 105-122.

Driver, R. Guesne, E. & Tiberghien, A. (eds.): 1985, *Children's Ideas in Science*, Open University Press, Milton Keynes.

Driver, R.: 1988, 'A Constructivist Approach to Curriculum Development'. In P. Fensham (ed.) *Development and Dilemmas in Science Education*, Falmer Press, New York, pp.133-149.

Ducret, J.-J.(ed.): 2001 *Constructivism and Education*, UNESCO-International Bureau of Education, Geneva, [*Prospects* 31(2)].

Duit, R. 2009, *Bibliography – STCSE*, http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html

Duit, R.: 1993, `The Constructivist View: A Fashionable and Fruitful Paradigm for Science Education Research and Practice'. In L.P. Steffe (ed.) *Epistemological Foundations of Mathematical Experience*, Springer-Verlag, New York.

Duit, R.: 1996, 'Constructivism', *Revista Investigações em Ensino de Ciências* (IENCI), vol.1 no.1.

Edis, T. & BouJaoude, S.: 2014, 'Rejecting Materialism: Responses to Modern Science in the Muslim Middle East'. In M.R. Matthews (ed.) *International Handbook of Research in History, Philosophy and Science Teaching*, Springer, Dordrecht, pp. 1663-1691.

Eijck, van M. & Roth W.-M.: 2007, 'Keeping the Local Local: Recalibrating the Status of Science and Traditional Ecological Knowledge (TEK) in Education', *Science Education* 91, 926-947.

El-Hani, C.N. & de Ferreira Bandeira, F.P.S.: 2008, 'Valuing indigenous knowledge: To call it "science" will not help', *Cultural Studies of Science Education* 3, 751-779.

Fensham, P.J.: 1992, 'Science and Technology'. In P.W. Jackson (ed.), *Handbook of Research on Curriculum*, Macmillan, New York, pp.789-829.

Fensham, P.J.: 2004, *Defining an Identity: The Evolution of Science Education as a Field of Research*, Kluwer Academic Publishers, Dordrecht.

Finkel, L.: 2018, 'Infusing social justice into the science classroom: Building a social justice movement in science education', *The Journal of Educational Foundations* 31(1-2), 38-56.

Fleer, M.: 1999, 'Children's Alternative Views: Alternative to What?', *International Journal of Science Education* 21(2), 119-135.

Fleer, M., & Robbins, J.: 2003, '"Hit and run research" with "hit and miss" results in early childhood science education', *Research in Science Education* 33(4), 405-431.

Fleury, S.C.: 1998, 'Social Studies, Trivial Constructivism, and the Politics of Social Knowledge'. In M. Larochelle, N. Bednarz & J. Garrison (eds.), *Constructivism and Education*, Cambridge University Press, pp. 156-172.

Flick, L.B. & Lederman, N.G. (eds.): 2004, *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education*, Kluwer, Dordrecht.

Fosnot, C.T. (ed.): 2005, *Constructivism: Theory, Perspectives, and Practice*, 2nd Edition, Teachers College Press, New York.

Fosnot, C.T.: 1993, 'Rethinking Science Education: A Defense of Piagetian Constructivism', *Journal of Research in Science Teaching* 30(9), 1189-1201.

Frow, J. & Morris, M. (eds.): 1993, *Australian Cultural Studies: A Reader*, Allen & Unwin, Sydney.

Gagné, R.M.: 1965, *The Conditions of Learning*, Holt, Rinehart & Winston, New York.

Gallagher, J.J.: 1971, 'A broader base for science education', *Science Education, 55*, 329–338.

Gilbert, J.K. & Swift, D.J.: 1985, 'Towards a Lakatosian Analysis of the Piagetian and Alternative Conceptions Research Programs', *Science Education* 69(5), 681-696.

Gilbert, J.K. & Watts, D.M.: 1983, 'Concepts, Misconceptions & Alternative Conceptions: Changing Perspectives in Science Education', *Studies in Science Education* 10, 61-98.

Glasersfeld, E. von: 1984, 'An Introduction to Radical Constructivism'. In P. Watzlawick *The Invented Reality*, W.W. Norton & Co., New York, pp. 17-40.

Glasersfeld, E. von: 1987, *Construction of Knowledge*, Intersystems Publications, Salinas CA.

Glasersfeld, E. von: 1989, 'Cognition, Construction of Knowledge and Teaching', *Synthese* 80(1), 121-140.

Glasersfeld, E. von: 1995, *Radical Constructivism. A Way of Knowing and Learning*, The Falmer Press, London.

Golinski, J.: 2012, 'Thomas Kuhn and Interdisciplinary Conversation: Why Historians and Philosophers of Science Stopped Talking to One Another'. In S. Mauskopf & T. Schmaltz (eds.) *Integrating History and Philosophy of Science*, Springer, Dordrecht, pp.13-28.

Good, R., Wandersee, J. & St. Julien, J.: 1993, 'Cautionary Notes on the Appeal of the New "Ism" (Constructivism) in Science Education'. In K. Tobin (ed.) *Constructivism in Science and Mathematics Education*, AAAS, Washington DC, pp.71-90.

Gross, P.R., Levitt, N. & Lewis, M.W. (eds.): 1996, *The Flight from Science and Reason*, New York Academy of Sciences, New York, (distributed by Johns Hopkins University Press, Baltimore).

Haack, S.: 2012, 'Six Signs of Scientism', *Logos & Episteme* 3, 75-95.

Hamlyn, D.W.: 1967, 'The Logical and Psychological Aspects of Learning'. In R.S. Peters (ed.) *The Concept of Education*, Routledge & Kegan Paul, London, pp.24-43.

Hamlyn, D.W.: 1973, 'Human Learning'. In R.S. Peters (ed.), *The Philosophy of Education*, Oxford University Press, Oxford, pp.178-194.

Hamlyn, D.W.: 1978, *Experience and the Growth of Understanding*, Routledge & Kegan Paul, London.

Hansson, L. & Yacoubian, H.A.: 2020, 'Nature of Science for Social Justice: Why, What and How?'. In L. Hansson & H.A. Yacoubian (eds.) *Nature of Science for Social Justice*, Springer, Dordrecht, pp.1-21.

Helm, H. & Novak, J.D. (eds.): 1983, *Proceedings of the International Seminar on Misconceptions in Science & Mathematics*, Education Department, Cornell University, Ithaca.

Hikuroa, D.: 2017, 'Mātauranga Māori- the ūkaipō of knowledge in New Zealand', *Journal of the Royal Society of New Zealand*, 47(1), 5-10. http://dx.doi.org/10.1080/03036758.2016.1252407

Horwich, P. (ed.): 1993, *World Changes: Thomas Kuhn and the Nature of Science*, Bradford Books, Cambridge, MA.

Hoyningen-Huene, P.: 1993, *Reconstructing Scientific Revolutions: Thomas S. Kuhn's Philosophy of Science*, University of Chicago Press, Chicago.

Hoyningen-Huene, P.: 2015, ´Kuhn's Development Before and After *Structure'*. In W.J. Devlin & A. Bokulich (eds.) *Kuhn's Structure of Scientific Revolutions – 50 Years On*, Dordrecht, Springer, pp.135-152.

Inhelder, B. & Piaget, J.: 1958, *The Growth of Logical Thinking*, Basic Books, New York. (French original, 1955).

Irzik, G. & Kurtulmus, F.: 2019, 'What is Epistemic Public Trust in Science?', *Brit. Jrn. Philos. Sc.* 70, 1145-1166.

Jenkins, E.W.: 2000, 'Research in science education: time for a health check?' *Studies in Science Education*, 35, 1–26.

Kienhues, D., Jucks, R., & Bromme, R.: 2020, Sealing the gateways for post-truthism: Re-establishing the epistemic authority of science' *Educational Psychologist 55*(3), 144–154.

Kitchener, R.F.: 1986, *Piaget's Theory of Knowledge: Genetic Epistemology and Scientific Reason*, Yale University Press, New Haven.

Kitchener, R.F.: 1992, `Piaget's Genetic Epistemology: Epistemological Implications for Science Teaching'. In R.A. Duschl & R.J. Hamilton (eds.) *Philosophy of Science, Cognitive Psychology, and Educational Theory and Practice*, State University of New York Press, Albany, pp.116-146.

Kuhn, T.S.: 1970, *The Structure of Scientific Revolutions* (2nd edition), Chicago University Press, Chicago. (First edition, 1962).

Kuhn, T.S.: 1991/2000, 'The Trouble with Historical Philosophy of Science', The Robert and Maurine Rothschild Lecture, Department of History of Science, Harvard University. In J. Conant & J. Haugeland (eds.) *The Road Since Structure: Thomas S. Kuhn*, University of Chicago Press, Chicago, pp.105-120.

Laudan, L.: 1982: 'Science at the Bar-Causes for Concern', *Science, Technology, & Human Values* 41, 16-19.

Lawson, A.E.: 1985, 'A Review of Research on Formal Reasoning and Science Teaching', *Journal of Research in Science Teaching* 22(7), 569-618.

Lemke, J.L.: 2001, 'Articulating Communities: Sociocultural Perspectives on Science Education', *Journal of Research in Science Teaching* 38(3), 296-316.

Leplin, J. (ed.): 1984, *Scientific Realism*, University of California Press, Berkeley.

Lincoln, Y.S. & Guba, E.G.: 1985, *Naturalistic Inquiry*, Sage Publications, Newbury Park, CA.

Loving, C.C. & Cobern, W.A.: 2000, 'Invoking Thomas Kuhn: What Citation Analysis Reveals for Science Education', *Science & Education* 9(1-2), 187-206.

Magoon, A.J.: 1977, `Constructivist Approaches in Educational Research', *Review of Educational Research* 47(4), 651-693.

Matthews, M.R.: 1995, *Challenging New Zealand Science Education*, Dunmore Press, Palmerston North.

Matthews, M.R.: 2000, 'Constructivism in Science and Mathematics Education'. In D.C. Phillips (ed.) *National Society for the Study of Education 99th Yearbook*, National Society for the Study of Education, Chicago, pp. 161-192.

Matthews, M.R.: 2004, 'Thomas Kuhn and Science Education: What Lessons can be Learnt?' *Science Education* 88(1), 90-118.

Matthews, M.R.: 2015, *Science Teaching: The Contribution of History and Philosophy of Science: 20th Anniversary Revised and Enlarged Edition*, Routledge, New York. Matthews, M.R.: 2019a, *Feng Shui: Teaching About Science and Pseudoscience*, Springer, Dordrecht.

Matthews, M.R.: 2019b, 'Mario Bunge and the Enlightenment Tradition in Education'. In M.R. Matthews (ed.) *Mario Bunge: A Centenary Festschrift*, Springer, Dordrecht, 645-682.

Matthews, M.R.: 2020, 'The Contribution of Philosophy to Science Teacher Education'. In A.D. Colgan & B. Maxwell (eds), *The Importance of Philosophical Thinking in Teacher Education*, Routledge, New York, pp.121-142.

Matthews, M.R.: 2021, 'Philosophical Problems with Constructivism: Some Considerations for Student-Centered Teaching and Learning'. In S. Hoidn & M. Klemenčič (eds.) *The Routledge International Handbook of Student-Centered Learning and Teaching in Higher Education*, Routledge, New York, pp.47-64.

Maxwell, N.: 2014, 'Unification and Revolution: A Paradigm for Paradigms', *Journal for General Philosophy of Science*, vol. 45, 133-149.

McIntyre, L.C.: 2018, *Post-truth*, MIT Press, Cambridge, MA.

McIntyre, L.C.: 2019, *The Scientific Attitude: Defending Science from Denial, Fraud, and Pseudoscience*, MIT Press, Cambridge, MA.

McIntyre, L.C.: 2021, *How to Talk to a Science Denier*, MIT Press, Cambridge, MA.

Merton, R.K.: 1942/1973, 'The Normative Structure of Science'. In his *The Sociology of Science: Theoretical and Empirical Investigations* (N.W. Storer, ed.), University of Chicago Press, Chicago, 1973, pp. 267-280.

Morf, A.: 1998, 'An Epistemology for Didactics: Speculations on Situating a Concept'. In M. Larochelle, N. Bednarz & J. Garrison (eds.), *Constructivism and Education*, Cambridge University Press, pp. 29-42.

Moshman, D.: 'Pluralist Rational Constructivism', *Issues in Education*, 3(2), 229-234. Munby, H.: 1982, *What is Scientific Thinking?* Science Council of Canada, Ottawa.

Nadeau, R. & Destautels, J.: 1984, *Epistemology and the Teaching of Science*, Science Council of Canada, Ottawa.

Nanda, M.: 2003, *Prophets Facing Backward. Postmodern Critiques of Science and Hindu Nationalism in India*, Rutgers University Press.

Nattress, N.: 2007, 'AIDS Denialism versus Science', *Skeptical Inquirer* 31, 31-37.

Needham, J.: 1969, *The Grand Titration: Science and Society in East and West*, Allen & Unwin, London.

Needham, J. & others: 1954-2004, *Science and Civilisation in China*, 24 vols., Cambridge University Press, Cambridge.

Newton-Smith, W.H.: 1981, *The Rationality of Science*, Routledge, & Kegan-Paul, Boston.

Nickles, T. (eds.): 2003, *Thomas Kuhn*, Cambridge University Press, New York.

Nola, R.: 1997, 'Constructivism in Science and in Science Education: A Philosophical Critique', *Science & Education* 6(1-2), 55-83.

Nola, R.: 2000, 'Saving Kuhn from the Sociologists of Science', *Science & Education* 9(1-2), 77-90.

Nola, R.: 2003, *Rescuing Reason: A Critique of Anti-Rationalist Views of Science and Knowledge*, Kluwer Academic Publishers, Dordrecht.

Nola, R., Clements, K., Cooper, G., Corballis, M., Elliffe, D., Werry, J. & Rata, E.: 2021, 'In Defence of Science', *Listener*, July 31.

Novak J.D.: 1977a, An alternative to Piagetian psychology for science and mathematics education. *Science Education* 61(4), 453-477.

Novak J.D.: 1977b, *A Theory of Education*, Cornell University Press, Ithaca, NY.

Novak, J.D. (ed.): 1987, *Misconceptions and Educational Strategies in Science and Mathematics*, 3 vols., Cornell University, Ithaca, NY.

Novak, J.D.: 2018, *A Search to Create a Science of Education: The Life of an Ivy League Professor, Business Consultant, and Research Scientist*, Institute for Human and Machine Cognition.
Oreskes, N.: 2020, *Why Trust Science?* Princeton University Press, Princeton.
Oreskes, N. & Conway, E.M.: 2010, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury Press, New York.
Overton, W.R.: 1982/1988, 'United States District Court Opinion *McLean v. Arkansas'.* In M. Ruse (ed.) *But Is It Science? The Philosophical Question in the Creation/Evolution Controversy*, Prometheus Books, Buffalo, pp.307-331.
Palmer, M.: 2008, *The Treaty of Waitangi in New Zealand's Law and Constitution*, Victoria University of Wellington Press, Wellington.
Pennock, R., & Ruse, M. (eds.): 2008. *But is it Science? The Philosophical Question in the Creation/Evolution Controversy* (Second Edition). Buffalo, N.Y.: Prometheus.
Pépin, Y.: 1998, 'Practical Knowledge and School Knowledge: A Constructivist Representation of Education'. In M. Larochelle, N. Bednarz & J. Garrison (eds.), *Constructivism and Education*, Cambridge University Press, pp.173-192.
Peters, M.A.:2020, 'Anti-scientism, technoscience and philosophy of technology: Wittgenstein and Lyotard', *Educational Philosophy and Theory* 52(12), 1225-1232
Phillips, D.C.: 1995, 'The Good, the Bad and the Ugly: The Many Faces of Constructivism', *Educational Researcher* 24(7), 5-12.
Phillips, D.C.: 1997, 'Coming to Terms with Radical Social Constructivisms', *Science & Education* 6(1-2), 85-104. Reprinted in M.R. Matthews (ed.) *Constructivism in Science Education: A Philosophical Examination*, Kluwer Academic Publishers, Dordrecht, pp. 139-158.
Ratcliffe, M. & Grace, M.: 2003, *Science education for citizenship. Teaching socio-scientific issues*, Open University Press Maidenhead, UK.
Rauch, J.: 2021, *The Constitution of Knowledge: A Defense of Truth*, Brookings Institution Press, Washington DC.
Roth, M.-W.: 1999, 'Authentic School Science: Intellectual Traditions'. In R. McCormick & C. Paechter (eds.), *Learning and Knowledge*, Sage Publications, London, pp.6-20.
Roth, W.-M.: 2006, *Learning Science: A Singular Plural Perspective*, Sense Publishers, Rotterdam.
Roth, M-W. & Roychoudhury, A.: 1994, 'Physics Students' Epistemologies and Views about Knowing and Learning', *Journal of Research in Science Teaching* 31(1), 5-30.
Roth, W.-M.& Tobin, K.: 2007, 'Introduction: Gendered Identities'. In W.-M. Roth & K. Tobin (eds) *Science, Learning, Identity. Sociocultural and Cultural-Historical Perspectives*, Sense Publishers, Rotterdam, pp.99-102.
Ruse, M. (ed.): 1988, *But Is It Science? The Philosophical Question in the Creation/Evolution Controversy*, Prometheus Books, Albany, NY.
Ruse, M.: 2000, *The Evolution Wars: A Guide to the Debates*, ABC-CLIO, Santa Barbara, CA.
Sadler, T. D. (ed.): 2011, *Socio-scientific issues in the classroom: Teaching, learning and research*, Springer, Dordrecht.
Safford, T.G., Whitmore, E.H. & Hamilton, L.C.: 2021, 'Follow the scientists? How beliefs about the practice of science shaped COVID-19 views', *Journal of Science Communication* 20(7), 1-19.
Sambono, J.: 2021, 'The Aboriginal and Torres Strait Islander Histories and Cultures Cross-curriculum Priority: Cultural responsiveness in science education', *SASTA Journal* No.1, pp.4-13.
Scheffler, I.: 1966, *Science and Subjectivity*, 1st edition, Hackett, Indianapolis.
Shapere, D.: 1964, `The Structure of Scientific Revolutions', *Philosophical Review* 73, 383-394.

Shavelson, R.J. & Towne, L. (eds.): 2002, *Scientific Research in Education*, National Academy Press, Washington DC.

Shimony, A.: 1976, 'Comments on Two Epistemological Theses of Thomas Kuhn'. In R.S. Cohen, P.K. Feyerabend & M.W. Wartofsky (eds.) *Essays in Memory of Imre Lakatos*, Reidel, Dordrecht, pps.569-588.

Shrady, N.: 2008, *The Last Day: Wrath, Ruin & Reason in The Great Lisbon Earthquake of 1755*, Penguin, Harmondsworth, Middlesex.

Slezak, P.: 2000, 'A Critique of Radical Social Constructivism'. In D.C. Phillips (ed.) *Constructivism in Education: 99th Yearbook of the National Society for the Study of Education*, NSSE, Chicago, pp. 91-126.

Smith, G. H.: 1992, 'Kura Kaupapa Maori Schooling: Implications for the Teaching of Science in New Zealand', unpublished paper, Education Department, University of Auckland.

Snowden, F.M.: 2019, *Epidemics and Society: From the Black Death to the Present*, Yale University Press, New Haven, CT.

Solomon, J. & Aikenhead, G.S. (eds.): 1994, *STS Education: International Perspectives on Reform*, Teachers College Press, New York.

Staver, J.: 1998, 'Constructivism: Sound Theory for Explicating the Practice of Science and Science Teaching', *Journal of Research in Science Teaching* 35(5), 501-520.

Stegmüller, W.: 1976, *The Structure and Dynamics of Theories*, Springer, New York.

Stewart, G.T.: 2019, Mātauranga and Pūtaiao: The question of 'Māori science'. *New Zealand Science Review*, *75*(4), 65-68.

Stove, D.C.: 1982, *Popper and After: Four Modern Irrationalists*, Oxford, Pergamon Press.

Suchting, W.A.: 1992, 'Constructivism Deconstructed', *Science & Education* 1(3), 223-254. Reprinted in M.R. Matthews (ed.) *Constructivism in Science Education: A Philosophical Examination*, Kluwer Academic Publishers, Dordrecht, (1998), pp.61-92.

Suppe, F.(ed.): 1977, *The Structure of Scientific Theories*, University of Illinois Press, Urbana.

Thoresen, C.E. (ed.): 1973, *Behavior Modification in Education: The Seventy-second Yearbook of the National Society for the Study of Education*, University of Chicago Press, Chicago.

Tobin, K. & Tippins, D.: 1993, 'Constructivism as a Referent for Teaching and Learning'. In K. Tobin (ed.) *The Practice of Constructivism in Science and Mathematics Education*, AAAS Press, Washington DC., pp.3-21.

Tobin, K. (ed.): 1993, *The Practice of Constructivism in Science and Mathematics Education*, AAAS Press, Washington DC.

Tobin, K.: 1991, 'Constructivist Perspectives on Research in Science Education', paper presented at the annual meeting of the National Association for Research in Science Teaching, Lake Geneva, Wisconsin.

Tobin, K.: 2000, 'Constructivism in Science Education: Moving On'. In D.C. Phillips (ed.) *Constructivism in Education'*, National Society for the Study of Education, Chicago, pp.227-253.

Tobin, K.: 2007, 'The Revolution that was Constructivism'. In M. Larochelle (ed.), *Key Works in Radical Constructivism: Ernst von Glasersfeld*, Sense Publishers, Rotterdam, pp.291-297.

Tobin, K.: 2015, 'Connecting science education to a world in crisis', *Asia-Pacific Science Education*, 1:2, (doi:10.1186/s41029-015-0003-z)

Vygotsky, L.S.: 1962, *Thought and Language*, MIT Press, Cambridge.

Vygotsky, L.S.: 1978, *Mind in Society: The Development of Higher Psychological Processes*, Harvard University Press, Cambridge.

Wheatley, G.H.: 1991, 'Constructivist Perspectives on Science and Mathematics Learning', *Science Education* 75(1), 9-22.

Wilholt, T.: 2016, 'Epistemic Trust in Science', *Brit. Journ. Philos. Science* 64 233-53

Winchester, S.: 2008, *The Man Who Loved China: The Fantastic Story of the Eccentric Scientist who Unlocked the Mysteries of the Middle Kingdom*, HarperCollins, New York.

Woolgar, S.: 1986, 'On the Alleged Distinction between Discourse and *Praxis'*, *Social Studies of Science* 16, 309-317.

Yeany, R.H.: 1991, 'A Unifying Theme in Science Education?', *NARST News* **33**(2), 1-3. Yong, E.: 2021, 'The Covid-19 Manhattan Project', *The Atlantic*, Jan./Feb.

Zeidler, D.L. & Sadler, T.D. (eds.): 2008, 'Social and Ethical Issues in Science Education', thematic issue of *Science & Education* 17(8-9).