M.R. Matthews (ed.) *Mario Bunge: A Centenary Festschrift*, Springer, 2019.

Chapter 36

Mario Bunge and the Enlightenment Project in Science Education

Michael R. Matthews[1]

36.1 Introduction

The unifying theme of Bunge's life and research is the constant and vigorous advancement of the eighteenth-century Enlightenment project; and energetic criticism of cultural and academic movements that reject the principles of the project or devalue its historical and contemporary value.[2] Bunge is unashamedly a defender of the Enlightenment, while over the past half-century, many intellectuals, academics, educators, and social critics have either rejected it outright (postmodernists) or compromised its core to such an extent that it can barely give direction to the kinds of personal, philosophical, political or educational issues that historically it had so clearly and usefully addressed (multiculturalists). For many feminists, including educators, the very expression 'the Enlightenment' is derogatory and its advancement is thought misguided, misogynist and mistaken.

The practice of enlightened education has been a constant in Bunge's life since his founding in 1940 of a workers' school, (the *Universidad Obrera Argentina*) in Buenos Aires, and the writing of his first book, *Temas de Educación Popular* [Themes in Popular Education] (Bunge 1943).[3] As with the founding figures of the historical Enlightenment, Bunge saw that education had to be *critical, applied*, and promote *rationality* and a scientific habit of mind.

For much of the nineteenth and early-twentieth centuries support for the Enlightenment was the norm for most progressive thinkers; over the past half-century this has changed. With the rise of Romanticism, Feminist epistemology, Critical Theory, Postmodernism and Multiculturalism the repute of the Enlightenment waned. Its fundamental universalism in science and ethics is rejected. Many now regard it as the enabler of colonialism, racism, high-tech warfare, environmental despoliation and degradation of traditional cultures. Defence or rejection of the Enlightenment project has been a position-marker in major cultural and educational debates of the past half-century, such as: postmodernism, feminism, scientism, the Science Wars, multiculturalism, the appraisal of Western Civilization programmes in universities, constructivism in philosophy and education, promotion and state-support of alternative medicine, human rights across cultures, globalization, and so on down to state-sanctioned compulsory vaccination and water fluoridation.[4] In each case, commitment to the project leads in one direction, whilst rejection

[1] School of Education, University of New South Wales, Sydney, Australia
Email: m.matthews@unsw.edu.au

[2] For his explicit endorsement of the Enlightenment project see Bunge (1994, reproduced in 1999, chap.7).

[3] For the titles of the 15 chapters of this 99-page book, see Appendix A.

[4] For accounts of the counter-Enlightenment tradition, see at least McMahon (2001) and Sternhell (2010).

leads to another. Understandably these debates have spawned an enormous, and often vituperative, literature that has moved well beyond the academy and into popular culture.[5]

36.2 The Counter-Enlightenment in Education

The Enlightenment project is widely rejected in education. Consider some claims advanced by contemporary influential science educators.

> For some, 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).

Others maintain that science is:

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

Contributors to a major science education handbook hold that:

> ..one of the first places where critical inquirers might look for oppression is positivist (or modernist) science …modernist science is committed to expansionism or growth …modernist science is committed to the production of profit and measurement ...modernist science is committed to the preservation of bureaucratic structures … Science is a force of domination not because of its intrinsic truthfulness, but because of the social authority (power) that it brings with it. (Steinberg & Kincheloe 2012, pp.1487-88)

A proponent of constructivism, and former editor of a major research journal in science education, relates that:

> …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)

A hugely published researcher and former president of the National Association for Research in Science Teaching contends:

> 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.1)

A much-awarded science educator maintains:

---

[5] See for example Andersen (2017), Brown (2001), Gross, Levitt & Lewis (1996), Koertge (1998), and Pinker (2018),

> …. 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)

A feminist science educator asserts:

> Scientific knowledge, like other forms of knowledge, is gendered. 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)

It is easy to multiply such examples. Opening any science education journal or book provides them in abundance. They give a sense of what is at stake; a sense of how philosophical positions have repercussions in educational policy, pedagogy and teacher training. The Enlightenment tradition simply rejects these claims and consequently curriculum development, pedagogy, and teacher education programmes predicated upon them. All of the foregoing claims are ill-informed and unsupportable,[6] but their rejection requires entering into philosophical argument and hopefully dialogue.[7] Bunge's corpus of work, with its richness, detail and clarity, make it a valuable resource for this engagement.

36.3 The Historical Enlightenment and the Enlightenment Project

It is important to make a distinction between the Enlightenment (noun) and the Enlightenment project (adjective). The historical Enlightenment occurred in Europe during the 'long' eighteenth century that stretched between the 'Glorious' English Revolution of 1688 and the French Revolution of 1789. By contrast the Enlightenment project, or the tradition to which it gave rise, has continued to the present day.[8] This chapter will adopt the convention of using the upper case 'Enlightenment' to refer to the eighteenth-century European events, debates, campaigns, and defining texts; and the 'Enlightenment project' to refer to the subsequent elucidation, elaboration, refinement, adjustment, and historically-informed defence of its basic commitments.

As well as the Enlightenment project there are also, lower case and plural, enlightenment projects. Europe did not have a monopoly on enlightenment principles; those principles so powerfully and clearly enunciated by different European writers, are also found, to one degree or another, in most other cultural traditions, perhaps most visibly in Islamic, Hindu and Chinese traditions. Divorced from, and independent of eighteenth-century Europe, such writers are contributing to an enlightenment project, but not to *the* Enlightenment project. Assuredly both upper and lower-case projects can learn from each other: Asia can learn from Europe, and Europe can learn from Asia and other cultures where enlightenment projects have flourished.

---

[6] Arguments for this harsh appraisal can be found in Matthews (2015, chap.8).

[7] For excellent critiques of the philosophical foundations of such constructivist and postmodernist writing in education, see: McCarthy (2018), Schulz (2007), and contributions to Matthews (1998).

[8] Among many high-quality books on the historical Enlightenment see: Anchor (1967), Ferrone (2015), Fitzpatrick et al (2007), Gay (1966), Himmelfarb (2004), Israel (2001, 2006, 2011), Pagden (2013) and Porter (2000).

In China, for instance, both the 'Hundred Days Reform' of 1898 and the 'May Fourth Movement' of 1919 were animated both by European Enlightenment convictions, and by Chinese neo-Confucian convictions (Spence 1982, Tang 2015). In the Muslim world, the Arab Spring of 2011 was fuelled by natural anger and resentment, but it was also informed by both European Enlightenment arguments and arguments from the Islamic tradition. Ditto the incipient Saudi 'revolution' of 2018 begun by brave women demanding, and getting, the right to drive cars. Their appeals were part Western and part Islamic. In India Bhimrao Ramji Ambedkar's heroic mobilisation of the 'untouchables' and their campaign to end discrimination and oppression, was informed by Enlightenment sources and also by the secular Buddhist tradition (Matthews 2015, pp.48-50, Mukherjee, 2009). The Enlightenment project does not have a monopoly on enlightenment projects; the latter take place in all societies, but nowhere with the same comprehensive tool-kit of formulated arguments.

One of the first uses of the expression 'Enlightenment project' is in Alasdair McIntyre's *After Virtue* (McIntyre 1981); it occurs in the headings of three chapters. McIntyre decries the project, with Chapter 5 titled 'Why the Enlightenment Project of Justifying Morality Had to Fail'. He writes: 'The Enlightenment is consequently the period *par excellence* in which most intellectuals lack self-knowledge …in which the blind acclaim their own vision … ' (McIntyre 1981, p.78). His basic claim is that the science-based, anti-teleological outlook of the Enlightenment cannot deal with the fundamentals of human living, namely intentional, ethical life and moral decision making. Aristotle could ground ethics rationally and ontologically because of his notion of 'embodied' natures that realize themselves towards their own 'perfection' in natural circumstances. But when Enlightenment philosophers rejected Aristotle, they lost an objective, rooted-in-nature moral compass. McIntyre's critique was continued in his *Whose Justice? Which Rationality?* (McIntyre 1988) where he rejects the Enlightenment's commitment to rationality in the singular as distinct from the plural rationalities.

Variants of McIntyre's arguments had been advanced by many in the nineteenth century Romantic reaction to the Enlightenment. And numerous epistemological and political arguments have been advanced through the twentieth century, with Horkheimer and Adorno's 1944 critique perhaps being the most influential (Horkheimer & Adorno 1944/1972). Kuhnian relativism, postmodernism and 'critical theory', have fuelled contemporary rejection of the project.[9]

It needs also to be appreciated that the singular term, *the* Enlightenment hides the reality that there were different national centres, each with their own religious, political and philosophical issues; and produced their own literatures, in their own time frames.[10] The most significant national centres being England,[11] Scotland,[12] France,[13] Italy,[14] Germany,[15] Holland,[16] and America.[17] The Enlightenment came late and shone weakly in Catholic Spain and Austria, and did not shine at all in the Papal States. Climactic events such as the decade-

[9] See Berlin (1980), fleischacker (2013, Pt.4) and Garrard (2006).
[10] Individual chapters in Porter & Teich (1981) are devoted to the Enlightenment in England, Scotland, France, Netherlands, Switzerland, Italy, Germany (Catholic and Protestant), Austria, Bohemia, Sweden, Russia and America. These chapters can be consulted in conjunction with the following national references.
[11] See Porter (2000).
[12] See Herman (2001).
[13] See Artz (1968) and Fitzpatrick (2007).
[14] See Venturi (1972).
[15] See Clark (1999).
[16] See Dunthorne (2007), Schama (1981) and contributions to van Bunge (2003).
[17] See Cassara (1988), Commager (1977), Ferguson (1997), Koch (1961, 1965), and May (1976).

long French Revolution (1789-99) had different impacts on Enlightenment thought in different areas of Europe.[18]

The Enlightenment was not constituted by static collection of authoritative texts providing timeless, non-contextual answers to political, social, religious, philosophical or scientific questions. In Kant's canonical 1784 essay 'What is Enlightenment?' he writes:[19]

> Enlightenment is man's release from his self-incurred tutelage. Tutelage is man's inability to make use of his understanding without direction from another. Self-incurred is this tutelage when its cause lies not in lack of reason but in lack of resolution and courage to sue it without direction from another. *Sapere aude!* 'Have courage to use your own reason' – that is the motto of enlightenment. (Kant 1784/1995, p.1)

A few years later in the Preface to the first edition of his *Critique of Pure Reason*, Kant enunciates the defining feature of eighteenth-century Enlightenment thinking, namely that it was critical and self-correcting:

> Our age is, in especial degree, the age of criticism, and to criticism everything must submit. Religion through its sanctity, and law-giving through its majesty, may seek to exempt themselves from it. But they then awaken just suspicion, and cannot claim the sincere respect which reason accords only to that which has been able to sustain the test of free and open examination. (Kant 1787/1933, p.9)

The canonical texts were not exempt from criticism. Such criticism including adjustment in the light of social upheavals such as the French and American revolutions, the experience of European colonisation, and scientific accomplishments in fields such as electricity and chemistry - all fuelled the Enlightenment project.

The Enlightenment was at odds with ahistoric fundamentalisms of all kinds. There was, with some debate around the edges,[20] an identifiable canon of texts, but these did not constitute a scripture.[21] The texts did not become authoritative in virtue of being canonical; being in a recognised canon made them influential, but not authoritative. Unlike fundamentalism in religion, politics, and 'party' or institutionalised philosophy, a characteristic of Enlightenment analyses and debates is that they are not settled by quoting texts or reference to official interpreters. To the extent that scientific, political, religious or ethical debates are settled by authority, there is a corresponding departure from the ethos of the Enlightenment. All competent contributors to the Enlightenment project take the view that philosophical, political, or ethical positions are in the canon because they are correct, they are not correct because they are in the canon. This is the same attitude as taken by competent theologians about scriptural positions.

The seventeenth-century's new science - or 'natural philosophy' as it was then called, - of Galileo, Descartes, Huygens, Boyle and Newton caused a massive change not

---

[18] See contributions to Church (1974).

[19] Kant's 1784 essay, and the essay 'What is Enlightenment?' by Moses Mendelssohn to which Kant was responding, are contained in the Schmidt anthology (Schmidt 1996). Also included are 20+ eighteenth century contributions to the 'What is Enlightenment?' debate, and a dozen twentieth-century studies of the issue. Kant's essay, and its reception over the past two centuries, is well treated in Fleischacker (2013).

[20] Jonathan Israel (Israel 2006, p.867) identifies and discusses seventy individual contributors to the formation of Enlightenment thought. Choosing who, 250 years later, might be included in the Enlightenment canon has its own problems.

[21] Among numerous anthologies of Enlightenment texts, see: Eliot & Stern (1979), Gay (1973), Hyland et al. (2003), and Kramnick (1995).

just in the science of the time, but in contemporary European philosophy.[22] This in turn had enduring repercussions for religion, ethics, politics, economics, law, literature, and culture.[23] The new science was instrumental in the birth of the modern world; it was the seed of which the Enlightenment was the fruit. It had a defining influence on eighteenth-century Enlightenment thinkers including: John Locke (1632-1704), Baruch Spinoza (1632-1677), Voltaire (1694-1778), Benjamin Franklin (1706-1790), Julien de la Mettrie (1709-1751), David Hume (1711-1776), Denis Diderot (1713-1784), Jean D'Alembert (1717-1783), Nicolas de Condorcet (1743-1794), Claude Adrien Helvétius (1715-1771), Immanuel Kant (1724-1804), Joseph Priestley (1733-1804) and Thomas Jefferson (1743-1826).

David Hume, in a much-quoted passage, captured the esteem and repute in which Newton was held - at least by the English - when he wrote in his *History of England*:

> In Newton this island may boast of having produced the greatest and rarest genius that ever rose for the ornament and instruction of the species. Cautious in admitting no principles but such as were founded on experiment, but resolute to adopt every such principle, however new or unusual. (Hume 1754-62/1879, vol.6, p.344)

Later in the same paragraph, Hume make a far more consequential claim, one that has echoed through philosophy in the subsequent centuries, and that bears upon one of the most contested of Enlightenment principles. He writes:

> While Newton seemed to draw off the veil from some of the mysteries of nature, he showed at the same time the imperfections of the mechanical philosophy, and thereby restored her ultimate secrets to that obscurity in which they ever did *and ever will* remain. (Hume 1754-62/1879, vol.6, p.344, emphasis added)

This is Hume the positivist and sceptic speaking. He enunciates the sceptical position concerning knowledge of nature's 'ultimate' constituency and composition. Hume's scepticism famously extended to all things not immediately perceivable or for which there are no sense impressions, including causal powers beyond constant conjunctions, angels, spirits, grace, miracles, Aristotelian forms, and so on. Enlightenment philosophers, of whom Hume was one of the greatest, divided on this epistemological principle of whether 'ultimate' or 'unseen' reality was knowable. There was a strong sceptical strain in the Enlightenment.[24] However nearly all believed that by adherence to the Newtonian method, as variously understood,[25] the empirical world, including importantly, the social world, could be known.

This conviction was led from the top. Newton in his *Opticks* said: 'If natural philosophy in all its Parts, by pursuing this Method, shall at length be perfected, the Bounds of Moral Philosophy will be also enlarged' (Newton 1730/1979, p.405). David Hume echoed this expectation with the subtitle of his famous *Treatise on Human Nature* which reads, *Being an Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects*.[26] In the

---

[22] For studies of the Scientific Revolution, see: Lindberg & Westman (1990), Osler (2000), and Wootton (2015).

[23] On the theme of science and the Enlightenment, see: Hankins (1985), Matthews (1989) and O'Hara (2010, chap.7).

[24] See Garrett (2007) and contributions to Charles & Smith (2013).

[25] There was contemporary debate about just what was the method, what it allowed and did not allow, and what was its legitimate domain. For accounts of Newton's method, see Cohen (1980), Harper (2011) and contributions to Butts & Davis (1970).

[26] At the time, 'moral subjects and philosophy included present-day history, social sciences, politics, economics and ethics.

preface he says he is following the philosophers of England who have 'began to put the science of man on a new footing' (Hume 1739/1888, p.xxi). The Marquis de Condorcet (1743-1794), a leading *philosophe* of the French Enlightenment said in his 1782 acceptance speech at the French Academy that: 'the moral [social] sciences' would eventually 'follow the same methods, acquire an equally exact and precise language, attain the same degree of certainty' as the natural sciences (Condorcet 1976, p.6).

The epistemological division highlighted by Hume was about the knowability of the 'unseen' world of mechanisms and constituents; what today would be called the 'theoretical' or 'metaphysical' domain. This was the eighteenth-century debate about realism versus positivism/instrumentalism/empiricism; a debate which is on-going.[27] The debate continues within the Enlightenment project. Most adherents are realists, but no less a figure than Ernst Mach was a combative instrumentalist concerning theoretical terms in science. And there were 'in-house' disputes about the applicability of the Newtonian method to religious, scriptural and ethical questions. This prefigured contemporary debate about the pros and cons of 'Scientism'.

Nevertheless, despite geographic spread, local variations, and internal disputes over particular commitments, there are identifiable Enlightenment principles. Although there is some scatter, noise, localisation, and a few parochial outliers – philosophical lines of best fit can be ascertained for the Enlightenment package.

36.4 Bunge and Others on Enlightenment Principles

The Enlightenment party was a very mixed and heterogeneous group; it was a very Broad Church. Politically there were republicans, monarchists, constitutional monarchists and proponents of benevolent despotism; religiously there were atheists, Deists, Unitarians, Christians of varying kinds, and Jews; and among the religious, some were devout while others were cynical, supporting religion solely for its socially cohesive function; ontologically there were dualists, monists, materialists, and physicalists; epistemologically there were sceptics, fallibilists, and 'certainists'; culturally there were preservers and innovators, agitators and conformists. And as well as the well-known religious, politically conservative, and reactionary critics of the time, the Enlightenment had its own internal critics.[28] It was an enormously rich age; in Isaiah Berlin's estimation:

> The intellectual power, honesty, lucidity, courage and disinterested love of the truth of the most gifted thinkers of the eighteenth century remain to this day without parallel. Their age is one of the best and most hopeful episodes in the life of mankind. (Berlin 1956, p.29)

Despite the heterogeneity, enough commonalities can be discerned to justify the gathering of so many individuals and texts into the Enlightenment family. Jonathan Israel, perhaps the foremost contemporary Enlightenment scholar, is prepared to tentatively assert that the European Enlightenment was a:

> single highly integrated intellectual and cultural movement, displaying differences in timing, no doubt, but for the most part preoccupied not only with the same intellectual problems but often even the very same books and insights everywhere from Portugal to Russia and from

[27] See contributions to Agazzi (2017), Cohen, Hilpinen & Renzong (1996), and Leplin (1984). The debate and literature is reviewed in Matthews (2015, chap.9).

[28] For instance, the German Christian Erhard, wrote in 1789: 'Damned be the Enlightenment which exchanges blind trust in itself for blind trust in others' (Knudsen 1996, p.270). This charge of blind trust, self-deception, if not arrogance, has been echoed in the following centuries by countless critics.

> Ireland to Sicily. Arguably indeed, no major cultural transformation in Europe, since the fall of the Roman Empire, displayed anything comparable to the impressive cohesion of European intellectual culture in the late seventeenth and early eighteenth century. (Israel 2001, p.v)

The historical, philosophical, and educational task is to delineate just what were the commonalities, the guiding principles, that identify the Enlightenment family.

Bunge identifies the core principles of the historical Enlightenment as:

1. Trust in reason.
2. Rejection of myth, superstition, and generally groundless belief or dogma.
3. Free inquiry and secularism.
4. Naturalism, in particular materialism, as opposed to supernaturalism.
5. Scientism or the adoption of the scientific approach to the study of society as well as nature.
6. Utilitarianism in ethics, as opposed to both religious morality and secular deontologism.
7. Respect for praxis, especially craftmanship and industry.
8. Modernism, progressivism, and trust in the future.
9. Individualism together with libertarianism, egalitarianism (to some degree or other), and political democracy (though not yet for women or slaves).
10. Universalism or cosmopolitanism, for example, human rights and education for all 'free men'. (Bunge 1999, p.131)

As a contribution to the Enlightenment project, each of these principles need to be connected to Enlightenment texts or sources, they need to be sufficiently elaborated for philosophical and policy purposes, and they need to be defended, and suitably adjusted or abandoned, if convincing contrary arguments are advanced.

Bunge's foregoing selection and distillation of the principles can profitably be compared to or triangulated with that of others. Carl Becker, a critic of the Enlightenment, in his 1932 *The Heavenly City of the Eighteenth-Century Philosophers* identified its four essential commitments as:

> (1) man is not natively depraved; (2) the end of life is life itself, the good life on earth instead of the beatific life after death; (3) man is capable, guided solely by the light of reason and experience, of perfecting the good life on earth; and (4) the first and essential condition of the good life on earth is the freeing of men's minds from the bonds of ignorance and superstition, and of their bodies from the arbitrary oppression of the constituted social authorities. (Becker 1932, pp.102-3)

The physicist and philosopher Abner Shimony, in his 1996 Presidential Address – 'Some Historical and Philosophical Reflections on Science and Enlightenment' - to the US Philosophy of Science Association identified the core commitments of the historical Enlightenment as:

1. On matters of fact, whether particular or general, there is objective truth or falsity.
2. There is a universal human nature (except for abnormalities) in all places and times.
3. One aspect of this universal human nature is that the cognitive faculties of individual normal, human beings suffice in principle for determining the truth or falsity of propositions concerning matters of fact, though training and removal of superstitions, dogmas, etc. are needed for full realization of what is possible in principle.

4. The authority of socially-established experts and of social institutions, including those which claim divine sanction, is subordinate to judgments by natural human faculties.
5. As a corollary, no social institution has the right to control inquiry, or the communication of the results of inquiry, or the critical examination of claims to knowledge.
6. The basic natural sciences, particularly the physical sciences, provide exemplary instances of reliable methods of inquiry and reliable general results concerning matters of fact.
7. In particular, natural theology, essentially employing the methods of the natural sciences, is the primary mode of theological inquiry.
8. A corollary of the existence of a universal human nature is a universality of human goals.
9. Another corollary is that the basis for ethics is to be found in the constitution of every normal being, though there is disagreement concerning the exact character of this basis; among the prescriptions of the naturally-based ethics are universal benevolence towards human beings and condemnation of punishment and constraint beyond what is needed for the common good.
10. Human cognitive faculties are capable in principle of devising good solutions to practical human social and political problems. (Shimony 1997, pp.S2-3)

It is useful to divide the personalities, ideas and movements into 'moderate' and 'radical' Enlightenments. The former include Locke, Rousseau, Voltaire and Kant; the latter Spinoza, Diderot, Holbach and Helvétius. The moderate Enlightenment favoured Reason, but not too much; it wanted clear evidence-based thinking, but mostly for science; it wanted social improvement but not political disruption; it denied the 'divine right' of kings, but not kingship; it wanted intelligent and non-superstitious religion, but not atheism.

Jonathan Israel has provided the most extensive and detailed study (800 pps) of the radical Enlightenment. He sees its fundamental principles as:

1. Adoption of philosophical (mathematical-historical) reason as the only and exclusive criterion of what is true.
2. Rejection of all supernatural agency, magic, disembodied spirits, and divine providence.
3. Equality of all mankind (racial and sexual).
4. Secular 'universalism' in ethics anchored in equality and chiefly stressing equity, justice, and charity.
5. Comprehensive toleration and freedom of thought based on independent critical thinking.
6. Personal liberty of lifestyle and sexual conduct between consenting adults, safe-guarding the dignity and freedom of the unmarried and homosexuals.
7. Freedom of expression, political criticism, and the press, in the public sphere.
8. Democratic republicanism as the most legitimate form of politics. (Israel 2006, p.866)

While there are other 'summations' of the Enlightenment,[29] the historian Philipp Blom writes: 'What makes the thinking of the radical Enlightenment so essential today is its power, its simplicity, and its moral courage' (Blom 2010, p.xvi). Bunge concurs with this estimation. In particular he affirms that the method of natural science needs be utilised in social science, that ethical principles cannot come from without, and there can be neither

[29] Kieran O'Hara lists six: 'new sources of authority, confidence and optimism, scepticism, universal reason, self-interest, elitism' (O'Hara 2010, chap.1). The Appendix of Commager (1977) provides a good distillation of the thinking and commitments of the *Philosophes*.

knowledge of the supernatural realm nor reason to believe there is such. But as with all serious advocates of the Enlightenment, he is not uncritical:

> Of course, the Enlightenment did not do everything for us: no single social movement can do everything for posterity – there is no end to history. For instance, the Enlightenment did not foresee the abuses of industrialization, it failed to stress the need for peace, it exaggerated individualism, it extolled competition at the expense of cooperation, it did not go far enough in social reform, and it did not care much for women or for the underdeveloped peoples. However, the Enlightenment did perfect, praise, and diffuse the main conceptual and moral tools for advancing beyond itself. (Bunge 1999, p.142)

These and other such corrections in the light of historical developments and philosophical critiques, are constitutive of the Enlightenment project; it is an intrinsically self-correcting enterprise. Corrections do not mean abandonment. Whilst recognising shortfalls in the Enlightenment project, Bunge correctly maintains that:

> we all … are children of the Enlightenment: we all enjoy the benefits of secularism, free inquiry, rationality, objectivity, individual freedoms, and progress (in some respects). … And this, the freedom to create, debate, and diffuse new ideas, is what the Enlightenment was all about. (Bunge 2000, p.231)

Bunge is politically and intellectually pitted against all closed, authoritarian regimes, states and ideologies. He abhors, along with all liberals, censorship of scholarly work as is routinely practiced in China, most if not all Islamic states, Egypt, Turkey, and until recently all countries where the Catholic church exercised political power.

36.5 Education and the Enlightenment Project

It is unfortunate that education is not separately delineated in the foregoing 'fundamentals' lists. It deserves to be.

All eighteenth-century English, French and German Enlightenment figures saw education as essential for the reformation of their society and for the more radical thinkers, the creation of a new society. Locke,[30] Spinoza,[31] Priestley,[32] Rousseau,[33] Helvétius,[34] Kant,[35] all wrote works on education.[36] They all rejected religious and philosophical views that saw humans as essentially corrupted, Fallen, and incapable of learning; they were all committed to the improvement of life and society, to the possibility of progress; and to the efficacy of reason in ordering personal and national affairs. What enabled all of this was education. The Enlightenment education project has two major strands, they addressed two kinds of questions: philosophical and pedagogical.

The philosophical questions were to what extent and age should education be conducted? Who should control education – the State, churches, or parents? How should education be funded? Should education be classical or utilitarian? What role should the Church or churches play in education? Should religious teaching be allowed in state schools? What should be the content, curriculum, or programme of education? Should the state

---

[30] Locke (1693/1968) in Axtell (1968). See also Schouls (1992) and Tarcov (1989).
[31] Spinoza (1677/1910). See also Puolimatka (2001).
[32] Priestley (1765/1965; 1791).
[33] Rousseau (1762/1991). See also Trachtenberg (1993).
[34] Helvétius (1772/1810).
[35] Kant (1803/1899).
[36] See Parry (2008).

support private or religious schooling? In the pedagogical strand the questions were: What are the best methods of education? Are there natural or constitutional barriers to learning? Are learning difficulties remediable? What are the gains and losses of child-centered teaching? The philosophical and pedagogical questions prompted lively debate. Answering the questions became part of the Enlightenment project. Some participants, for example Condorcet, contributed more to the philosophical issues, others, for example Rousseau, contributed more to the pedagogical issues, some, for example Dewey and Mach, contributed to both.

John Locke, Newton's self-described 'underlabourer' opens his hugely influential 1693 *Some Thoughts Concerning Education* with two central planks of the Enlightenment's educational programme.[37] First:

> A Sound Mind in a sound Body, is a short, but full Description of a Happy State in this World: He that has these Two, has little more to wish for; and he that wants either of them, will be but little the better for any thing else. (Locke 1693/1968, p.114)

And second:

> I think I may say, that for all the Men we meet with, Nine Parts of Ten are what they are, Good or Evil, useful or not, by their Education. (Locke 1693/1968, p.114)

Eighty years later, Helvétius captured the importance of education to Enlightenment thinkers, and to their policies for the remaking of society, when he wrote:

> If I can demonstrate that man is, in fact, nothing more than the product of his education, I shall doubtless reveal an important truth to the nations. They will learn that they have in their hands the instrument of their greatness and their felicity, and that to be happy and powerful, it is only a matter of perfecting the science of education. (Helvétius 1772/1810, chap.1, 3; in Parry 2007, p.230)

There was then, as now, dispute over what constituted the 'science of education'. John Locke (1632-1704), Jean-Jacques Rousseau (1712-1778), Joseph Priestley (1733-1804), and Heinrich Pestalozzi (1746-1827) were the most prominent contributors to the formation of a hoped-for educational science. Locke's empiricism, which linked concepts to experience and more specifically sensation, was developed as a guiding educational psychology or theory of learning. Such a psychology of learning provided an easy passage through to child-centred, experiential pedagogy.

In an essay 'Of Study' written in 1677 Locke expresses: 'The end of study is knowledge, and the end of knowledge practice or communication' (Axtell 1968, p.406). To a degree he anticipates Kant's century-later, 1784 'dare to think for yourself' maxim when he writes:

> He that distrusts his own judgement in everything, and thinks his understanding not to be relied on in the search for truth, cuts off his own legs that he may be carried up and down by others, and makes himself a ridiculous dependence upon the knowledge of others, which can be possibly of no use to him; for I can no more know anything by another man's understanding than I can see by another man's eyes. (Axtell 1968, p.419)

---

[37] The book is of 200-odd pages, covering 215 sections. In English there were 40 printings of it as a separate book between 1693 and 1964. In French there were 23 translations and printings between 1695 and 1966. And there were American, German, Dutch, Spanish, Italian, Polish, Rumanian and Swedish printings. (Axtell 1968, pp.98-104).

The Enlightenment commitment to education was manifest in the writings and practice of the two foremost scientist/statesmen of early America: Benjamin Franklin and Thomas Jefferson. As Governor of Virginia, Jefferson moved to establish a whole system of elementary and county-based secondary schooling. He reformed and reorganised the College of William and Mary, and when his reforms were frustrated, he moved to establish, and largely designed, the University of Virginia in Charlottesville. In a 1786 letter, 'A Crusade Against Ignorance', Jefferson writes of the constitution of the colony, that:

> I think by far the most important bill in our whole code is that for the diffusion of knowledge among the people. No other sure foundation can be devised for the preservation of freedom, and happiness. … Preach, my dear Sir, a crusade against ignorance; establish and improve the law for educating the common people. (Koch 1965, pp.311-12)

He was animated to distance the American colonies from the European countries of their parentage where:

> ignorance, superstition, poverty and oppression of body and mind in every form, are so firmly settled on the mass of the people, that their redemption from them can never be hoped. … If all the sovereigns of Europe were to set themselves to work to emancipate the minds of their subjects from their present ignorance and prejudices, and that as zealously as they now endeavour the contrary, a thousand years would not place them on that high ground on which our common people are now setting out. (Koch 1965, pp.311-12)

Benjamin Rush, a signatory to the Declaration of Independence, and conscious advocate of the Enlightenment project, wrote in his 1786 *Plan for the Establishment of Public Schools and the Diffusion of Knowledge in Pennsylvania* that:

> The golden age, so much celebrated by the poets, is already within reach; legislatures need only to establish proper modes and places of education in every part of the state. (Ferguson 1997, p.153)

Although Enlightenment thinkers were dedicated to education, they differed over the reach and form of that education; in particular over the appropriate education of peasants in Europe and the working classes in Britain. There was an elitist and conservative strand in the Enlightenment; one that saw the best education as fitting a person to their 'station in society'. Locke's *Thoughts Concerning Education* could have been titled *Thoughts Concerning a Gentleman's Education* as he consciously acknowledged in the closing sentences of the book:

> I have touch'd little more than those Heads [topics], which I judged necessary for the Breeding of a young Gentleman of his Condition in general; and have now published these my occasional Thoughts with this Hope, That though this be far from being a compleat Treatise on this Subject, or such, as that everyone may find, what will just fit his Child in it, yet it may give some small light to those … that dare venture to consult their own Reason, in the Education of their Children, rather than wholly to rely upon Old Custom. (Locke 1693/1968, p.325)

In Germany, Adolf Freiherr von Knigge (1752-1796), a leader of the 'radical' Illuminati, wrote in 1788:

> That one now gradually attempts to motivate the peasant to abandon many of his inherited prejudices in the methods of planting and indeed in the management of his household, that

> one hopes through purposeful schooling to destroy foolish fancies, stupid superstitions, and belief in ghosts, witches and similar matters, and that one now teaches the peasant to read, write, and calculate well – all this is indeed commendable and useful. But to give them all sorts of books, stories, and fables, to accustom them to transporting themselves into a world of ideas, to open their eyes to their own impoverished condition which cannot be improved, to make them discontented with their lot through too much enlightenment, to transform them into philosophers who blather about the uneven division of earthly goods – that is truly worthless. (Knudsen 1996, p.276)

Two years later in Germany Johann Ludwig Ewald wrote in his *On Popular Enlightenment: Its Limits and Advantages:*

> I would be very much misunderstood if one were to believe I intended to acquaint the peasant systematically with the full extent of these [new] sciences. That is neither possible nor useful. The slumbering mental capacities of these crude natural men could not comprehend such matters, and even if one were to do everything to awaken them, such learning would be neither intelligible nor useful to them. (Knudsen 1996, p.276)

This politically conservative strand of educational thought occurred in all national Enlightenment traditions. But it was criticised internally for conflicting with the Enlightenment principle of equality which commonly translated into 'equality opportunity' and 'non-discrimination' policies in education. This was a slow process that worked itself out at different rates in different countries. This was all a part of the Enlightenment project.

In England, The Cavalier (Royalist) Parliament had passed the Corporation Act in 1661 and the Act of Uniformity in 1662. These Acts prohibited dissenters or 'nonconformists' (Presbyterians, Anabaptists, and later Methodists and Unitarians) from enrolling in Cambridge and Oxford which were then the only universities in England. The same strictures applied to Roman Catholics, Jews, Muslims and and of course Atheists.

In 1687, the year of completion of the *Principia*, the Catholic King James II asked Cambridge University to confer a degree upon a Benedictine monk and exempt him from taking the usual oath to uphold the Anglican faith. No less a figure than Isaac Newton was a leader of the successful fight against this proposal (Brooke 1991, p.159).[38]

A similar history and struggles played out in all countries where Enlightenment writings and thought was found. In France, in 1687, the year of publication of Newton's *Principia*, the Edict of Nantes, which had given some measure of freedom and relief to Huguenots, was revoked by the Sun King, Louis XIV, and overnight one million French Protestants were made outlaws in their own country. Protestant services were banned, with those found taking part in them sent for life to the galleys as slaves; Protestants were banned from all government and educational employment; only Catholic marriages were recognised, so Protestant wives became concubines and Protestant children were made illegitimate and unable to inherit property; hundreds of protestant clergy were hanged. It is estimated that perhaps 200-500,000 Huguenots fled France for other lands (Goubert 1972, p.160). Louis proudly boasted that he had rid France of heresy. He ruled till his death in 1715, being succeeded to the throne by his five-year old grandson, Louis XV who ruled for a further 59 years till 1774, in turn being followed on the throne by Louis XVI who was guillotined in 1793 in the latter days of the French Revolution. There was no national system of education, all schools were private and under the control of local priests with natural philosophy

[38] Testifying to the slowness of educational reform, women were not granted full and equal rights at Cambridge until 1948.

(science) barely taught; *colléges* were under the control of either the Jesuit or Oratorian orders, and devoted almost entirely to theology, law and classics. One estimate is that through most of the eighteenth century, till the First Republic, fully eighty percent of the French population could neither read nor write, and no one saw this as a problem (Schapiro 1963, p.197). This was the *ancien régime* against which Enlightenment thought struggled for a century, and then more through to modern day France.

Through the reign of LouisXV Jean D'Alembert (1717-83) the encyclopedist, Louis René La Chalotais (1701-85) the jurist, and Rolland d'Erceville (1730-1794) the educator, wrote articles, pamphlets and reports decrying the backward looking, classical-language obsessed, useless French education of the schools and *colléges.*[39] In a 1768 report to parliament, *Plan d'Education*, d'Erceville maintained:

> Each one ought to have the opportunity of receiving that education most suited to him; not every kind of soil responds to the same care and yields the same product; every mind does not require the same degree of culture nor do all men have the same needs or abilities; it is in relation to these abilities and needs that public education should be organised. (Kandel 1930, p.184)

These were Enlightenment-inspired, pre-revolutionary interventions. With the French Revolution, many Enlightenment outsiders became policy-making insiders (Church 1974). Charles Maurice de Talleyrand-Périgord (1754-1838) in a 1791 Report to the National Assembly wrote:

> Instruction has in general the aim of perfecting man at all ages and to help ceaselessly to promote the advantage of each, and the benefit of society as a whole through enlightenment and experiment and to combat the errors of preceding generations. (Kandel 1930, p.186)

Nicolas de Condorcet (1743-1794) was the most thorough, consistent, and influential advocate of Enlightenment education in eighteenth-century France. His justly famous 400-page comprehensive *Report on Education* presented to the Legislative Assembly in 1792 is a landmark document in the history of education.[40] It has five philosophical papers on education and detailed curricula for all subjects in all schools from elementary (*petites écoles*) to university. Its opening sentence is: 'Public education is a duty that society owes to all citizens'. This was, and has remained, a rallying call of the Enlightenment education project; it assuredly is one of the 'hard core' defining principles of the project.

Condorcet elaborated an entire far-sighted Enlightenment education scheme, that though proposed 250 years ago, is strikingly modern and contemporary. His *Report* proposed, among other things: state-funding of all education and a four-tier system of schools culminating in university, compulsory elementary education for girls as well as boys, co-education, teaching mathematics and sciences from the elementary level, banning religious teaching in state schools, the teaching of non-religious based civics and ethics courses. Many other 'progressive' and 'liberal' reforms were proposed. Secondary schools were to teach many varied courses including pure and applied mathematics, experimental physics and chemistry, national and international history, logic, political constitutions, political economy, music and dancing. Indicative of the new way of thinking ushered in by the Enlightenment

---

[39] The educational writings and assembly reports of La Chalotais, Turgot, Diderot, and Condorcet are translated and published in English in Fontainerie (1932).

[40] A 50-page portion of the lengthy text is in Fontainerie (1932). Reisner, an education historian, said of the Report that: 'Probably no finer ideal of education in a national state has ever been set forth' (Reisner 1930, p.147).

was the directive that the Constitution and the Declaration of Rights were to be taught as factual historical documents and so to be scrutinized, not adulated. Condorcet said the schools should avoid nationalism and patriotic excesses. The *Report* instituted a programme of competitive state scholarships (*élèves de la patrie*) to allow children of the poor to progress through boarding schools to the highest levels; it proposed appropriate adult education for farmers, workers and mothers; it made the teaching service independent of both the Church and the State having its own regulator and making its own regulations.[41]

By a decree of 1795 a system of central schools (*écoles centrales*) was established throughout France, one for each national department. Each school was required to have a public library, a garden, a natural history cabinet, and a laboratory for physics and chemistry.

Sadly, Condorcet suffered the same fate as Lavoisier. With a change of power in the revolutionary assembly, he was arrested and killed in prison. But his *Report* had been published and it was partly implemented in the brief years of the First Republic and Napoleon's rule. All its policies and programmes were shelved at the Bourbon Restoration. But progressively it was implemented through the later nineteenth century in France. Whilst *Report* was a center-piece in the struggle between clericalism and secularism in nineteenth-century France, it was taken as a model for many other national and provincial systems right through the twentieth century.[42]

Condorcet in his influential *Sketch for a Historical Picture of the Progress of the Human Mind* (Condorcet 1795/1955) had given an early Enlightenment justification for social science, or the scientific study of society:

> The sole foundation for belief in the natural sciences is this idea, that the general laws directing the phenomena of the universe, known or unknown, are necessary and constant – why should this principle be any less true for the development of the intellectual and moral faculties of man than for the operations of nature. (Condorcet, 1795/1955, p.173)

He thought that the impact of education could be charted, and appropriate 'experiments' or innovations, could be exported or generalised. If something worked in one department, it should work in another. In the following decades, especially during Napoleon's reign, there was intense debate and politicking about the curriculum, administration and control of the newly-established school system. The idea of a central state-controlled system was opposed by liberals and the Catholic Church. During the Restoration (1814-30) the forces of Reaction rolled back most of the foregoing Enlightenment-motivated educational reforms. Edmond About (1828-85) writing of his own Restoration-Era college education said:

> The serious studies in our day consisted in translating French into Greek and Latin and vice-versa, in handling a given subject in French or Latin and an elegant trifling in Latin verse. … While the exact sciences it was good form to ignore unless one expected to enter St. Cyr and the *Ecole Polytechnique*. (Kandel 1930, p.195)

In England, schooling was not much different. The philosopher C.E.M. Joad (1891-1953) typifies the circumstance some fifty years after About's lament about French education:

> I left my public school in 1910, an intelligent young barbarian. … My acquaintance with the physical sciences was confined to their smells. I had never been in a laboratory; I did not know what an element was or a compound. Of biology I was no less ignorant. I knew

[41] Condorcet's education writings are discussed in Schapiro (1963, chap.11).
[42] See Kandel (1930, chap.VI).

> vaguely that the first Chapter of Genesis was not quite true, but I did not know why. Evolution was only a name to me and I had never heard of Darwin. (Joad 1935, p.9)

The foregoing pages give an indication of the centrality of education both for the Enlightenment and the Enlightenment project. They suffice to show that there were educational debates and disagreements among contributors to the project. Importantly, and obviously, the Enlightenment tradition had no monopoly on the promotion of enlightened education. Arguments for practicality, for modernity, for inclusion of local and national histories, for modern languages, for teaching mathematics and natural science, for curbing the educational power of State and Church, and so on - were made both inside and outside the Enlightenment tradition. Education was a natural sphere for 'popular front' campaigns. Proponents of Enlightenment education shared much with advocates of Liberal Education in the Anglo-American world[43] and with champions of *Bildung* in the Germanic and continental world.[44]

What distinguished Enlightenment-inspired educational proposals and programmes is their insistence on state responsibility for universal education (yet leaving open the question of State control of education),[45] the valuation of natural science, their efforts to have pupils appreciate the method of science, and to see its application to personal, social and cultural problems. Four examples of contributors to the educational strand of the Enlightenment project will be sketched so as to better appreciate these claims: Joseph Priestley, a Christian clergyman of the eighteenth century; Ernst Mach, a scientist, public figure and atheist of the nineteenth century; and Philipp Frank and Herbert Feigl, two scientist/philosophers of the twentieth century.

36.6 Joseph Priestley: An Eighteenth-Century Contributor to the Enlightenment Education Project

Joseph Priestley was born in Yorkshire in 1733 and died in Pennsylvania in 1804; his life spaned the core years of the European Enlightenment in which he played a significant role. He was an enormously gifted person, a polymath who made original and lasting contributions across a wide range of subjects. He wrote over two hundred books, pamphlets, and articles in history of science (most importantly of electricity and optics), political theory, theology, biblical criticism, theory of language, philosophy of education, and rhetoric; as well chemistry for which he is now best known.[46].

He was not just knowledgeable in many fields: there was an explicit interconnectedness to all his intellectual activity. For Priestley knowledge was not compartmentalised: his epistemology (sensationalism) related to his ontology (materialism),

---

[43] Thomas Huxley's 'A Liberal Education; and Where to Find It', an address given at the 1868 opening of the South London Working Men's College, shows the overlap between nineteenth-century Enlightenment education and liberal education (Huxley 1868/1964). The alliance between Philipp Frank and James Conant in the 1950s and '60s in the USA is an instructive twentieth-century example (Reisch 2017). Liberal education values the appreciation and transmission of knowledge; so also Enlightenment education.

[44] See Lövlie & Standish (2002).

[45] Joseph Priestley and fellow Dissenters wanted state support but absolutely opposed state control of education. The reconciliation of support with denial of control is a recurring question in the Enlightenment education tradition.

[46] Two definitive studies of Priestley are by Robert Schofield (1997, 2004). The latter contains a full bibliographic listing of his many books, pamphlets and articles. See also contributions to Anderson & Lawrence (1987), Birch & Lee (2007), Rivers & Wykes (2008), and Schwartz & McEvoy (1990).

both related to his theology (Unitarianism) and to his psychology (Associationism); and these all bore upon his political and social theory (Liberalism). As with Mario Bunge two centuries later, Priestley was consciously a *synoptic* or *systemic* thinker: all components of knowledge (and political and personal life as a whole) had to relate together consistently.

Modern appreciation of Priestley has been blighted by the harsh and unfair judgement of Thomas Kuhn made in his best-selling *Structure of Scientific Revolutions* (Kuhn 1970). In a famous passage Kuhn writes of the irrationality of paradigm change in science and of old paradigms just dying out until 'at last only a few elderly hold-outs remain'. He then singularly names Priestley as an example 'of the man who continues to resist after his whole profession has been converted' and adds that such a man 'has *ipso facto* ceased to be a scientist' (Kuhn 1970, p.159).

This outrageous charge 'blackened' Priestley's reputation in the academic world; Kuhn's has become the widely-accepted obituary for Priestley – the stubborn old man who held on to belief in a peculiar phlogiston substance and who resisted the dawning bright light of Lavoisierian chemistry. Pleasingly, some historians and philosophers have provided extensive studies that refute Kuhn's caricature of Priestley, but unfortunately their work is not translated into 20+ languages, nor set as class reading in countless thousands of courses and not read by millions.

A more generous and accurate assessment of Priestley was given by Frederic Harrison in his Introduction to a nineteenth-century edition of Priestley's *Scientific Correspondence*, as follows:

> If we choose one man as a type of the intellectual energy of the eighteenth century, we could hardly find a better than Joseph Priestley, though his was not the greatest mind of the century. His versatility, eagerness, activity, and humanity; the immense range of his curiosity in all things, physical, moral, or social; his place in science, in theology, in philosophy, and in politics; his peculiar relation to the Revolution, and the pathetic story of his unmerited sufferings, may make him the hero of the eighteenth century. (Bolton 1892, Introduction)

Priestley shared the Enlightenment conviction that a good education would benefit individuals and their societies. As he wrote in *The Proper Objects of Education*:

> All great improvements in the state of society ever have been, and ever must be … the result of the most peaceable but assiduous endeavours in pursuing the slowest of all processes – that of enlightening the minds of men. (Priestley 1791)

While many advocated and wrote about better and more widespread education Priestley was of the minority who practised what the Enlightenment preached: he had a life-long engagement in schooling, teaching and learning. Priestley's educational views were part of his overall systematic position: his theology, philosophy, epistemology, psychology, social theory and science were all parts of a coherent whole. He was under impressed with the state of English education, in particular education in natural philosophy, or science.

> I am sorry to have occasion to observe, that natural science is very little, if at all, the object of *education* in this country, in which many individuals have distinguished themselves so much by their application to it. And I would observe that, if we wish to lay a good foundation for a philosophical taste, and philosophical pursuits, persons should be accustomed to the sight of experiments, and processes, in *early life*. They should, more especially, be early initiated in the theory and practice of *investigation*, by which many of the old discoveries may be made to be really *their own*; on which account they will be much more valued by them. (Priestley (Priestley 1790, p.xxix)

This is one of the first endorsements of inquiry teaching, and more specifically of historical-investigative teaching – following in the experimental footsteps of those who have gone before.[47] This is in part why he wrote the first history of Optics (Priestley 1772)[48] and of Electricity (Priestley, 1767/1775)[49]. His assumption was that the habits and skills acquired in investigating nature – observing, hypothesising, seeking evidence for and against, experiments with controls - would flow on to the investigation of other matters: religion, revelation, politics, church history and so on. For Priestley, and a good many of the Enlightenment philosophers, science would be:

> the means, under God, of extirpating all error and prejudice, and of putting an end to all undue and usurped authority in the business of religion, as well as of science'. (Priestley 1775-77, Vol.I, p.xiv)

Priestley had a good critical education at the Dissenting Academy at Daventry where he was exposed to lively debate and argument on all subjects. After ministry at Nantwich, he went on to teach at the famed Warrington Academy where he introduced physics and chemistry to the curriculum. The dissenting academies were a response by the non-conformist churches to the Anglican Church's monopoly on English school and university education; students of any faith, or no faith, could enrol. Robert Merton has been one of many to draw attention to the role of these Dissenting Academies in fostering and promoting science in England (Merton 1938/1970, p.119). One commentator has said:

> It is in Non-conformist England, the England excluded from the national universities, in industrial England with its new centres of population and civilisation that we must seek the institutions which gave birth to the utilitarian and scientific culture of the new era. (Halevy, quoted in Brooke 1987, p.11)

An historian of education has opined:

> Warrington Academy, was for 30 years arguably the finest educational establishment in the world, largely due to the input and influence of Joseph Priestley. (Rose 2007, p.235)

This is a case where a significant part of the Enlightenment project, namely education was advanced by others, namely Christian believers. Newton at Cambridge inspired the Dissenters, but the Dissenters (and Catholics, Jews, Muslims and atheists) were forbidden to enrol there. In contrast, the Enlightenment's 'Free Inquiry' was the entrenched motto of the Dissenting Academies.[50]

In 1758 at age 25 years Priestley took a pastor's position at Nantwich in Cheshire. While there he established a school with 30 boys and, in a separate room, six girls. He taught in the school for three years, six days a week, from 7am to 4pm, teaching Latin, Greek, English grammar and geography. In addition, he taught some Natural Philosophy and purchased an air pump and an electrical machine and instructed his pupils in their use. Priestley may well have been the first person to teach laboratory science to schoolchildren.

---

[47] On the tradition of historical-investigative teaching of science, see Heering & Höttecke (2014).
[48] For the next 150 years this was the only English-language history of Optics.
[49] This authoritative work led to productive correspondence with Franklin, Volta and many others; it was instrumental in the birth of electrical science.
[50] On the contribution of the Dissenting Academies to English education and culture see Smith (1954), Wykes (1996).

As well as some three decades of direct engagement in teaching, Priestley wrote a number of influential works on the theory and practice of education. His most famous work - *An Essay on a Course of Liberal Education for Civil and Active Life* (Priestley 1765/1965) - was written and published while teaching at Warrington Academy. It originally appeared as a pamphlet then it became a 25-page Preface to his *Lectures on History and General Policy* (Priestley 1788). In this incarnation it had 16 printings and was translated into Dutch (1793) and French (1798). In the American edition of 1803 Priestley adds a note to the above text:

> Since this was written, which is near forty years ago, few persons have had more to do in the business of education than myself; and what I then planned in theory has been carried into execution by myself and others, with, I believe, universal approbation. (Passmore 1965, p.289)

This theme of connecting theory to practice runs through all Priestley's work, including his opposition to Lavoisier's new oxygen theory. Although he is neither a harbinger of Marxism nor a premature Positivist, Priestley was always suspicious of theory that ran too far in front of practice, or removed itself too far from the facts of the matter; for him, to use a later phrase, 'theory had to be proved in practice'. Priestley advocated a coordinated curriculum, saying that:

> When subjects which have a connection are explained in a regular system, every article is placed where most light is reflected upon it from the neighbouring subjects. (Passmore 1965, p.293)

He advocated a structured and guided curriculum:

> The plainest things are discussed in the first place, and are made to serve as axioms, and the foundation of those which are treated of afterwards. Without this regular method of studying the elements of any science, it seems impossible ever to gain a clear and comprehensive view of it. (Passmore 1965, p.293)

He stresses that liberal education for civil and active life needs to promote the understanding of the principles of subject matter, by saying:

> A man who has been used to go only in one beaten track and who has had no idea given him of any other … Will be wholly at a loss when it happens that that track can no longer be used; while a person who has a general idea of the whole course of the country may be able to strike out another and perhaps a better road than the former. (Passmore 1965, p.295)

As a teacher at the Dissenting Academy at Warrington Priestley insisted on students asking and answering questions, he promoted free engagement with all subjects including Divinity, he ensured that authorities on both sides of controversial issues be read and quoted. One of his Warrington students recalled that:

> At the conclusion of his lecture, he always encouraged his students to express their sentiments relative to the subject of it, and to urge any objections to what he had delivered, without reserve. It pleased him when anyone commenced such a conversation. … His object … was to encourage the students to examine and decide for themselves, uninfluenced by the sentiments of any other persons. (Rutt 1817-32, vol.1, p.50. In Lindsay 1970, p.15)

Priestley had some confidence that an educational regime such as he proposed and enacted, would result in the betterment of society. He said 'I cannot help flattering myself that were the studies I have here recommended generally introduced into places of liberal education, the consequences might be happy for this country in some future period' (Passmore 1965, p.301). This was the *reformist* Priestley. But, with reason, he was also regarded as a *revolutionary*. His understanding of the flow-on effects of scientific investigation and of the flow-on effects of the acquisition of its associated mental and character dispositions led him in a sermon on 'The Importance and Extent of Free Inquiry', to proclaim from his Birmingham pulpit:

> We are as it were, laying gunpowder, grain by grain, under the old building of error and superstition, which a single spark may hereafter inflame, so as to produce an instantaneous explosion; in consequence of which that edifice, the erection of which has been the work of ages, may be overturned in a moment and so effectually as that same foundation can never be built again. (Priestley 1785)

With Britain having just been defeated in the American Revolution (1775-1783) and with the first stirrings of the French Revolution (1787-1789) being felt in all European states and kingdoms, such words were not judicious. They led to his sobriquet 'Gunpowder Joe' and in 1791 to an enraged 'King and Church' mob ransacking his home, library and laboratory and his flight from Yorkshire to America.

Through Priestley's personal friendships with Benjamin Franklin, George Washington, John Adams and Thomas Jefferson, and the admiration they all had for him, there was a direct impact of Enlightenment ideas on late colonial and early independent US public life and education.[51]

Thomas Huxley (1825-1895), perhaps the most lucid and effective champion of Enlightenment causes and Enlightenment education in nineteenth-century England,[52] gave a speech in 1874 at the unveiling of Priestley's statue in Leeds. He said that Priestley was in large measure responsible for the intellectual/cultural advances that nineteenth century Britain had made over that of the eighteenth century :

> Reason has asserted and exercised her primacy over all provinces of human activity; that ecclesiastical authority has been relegated to its proper place; that the good of the governed has been finally recognized as the end of government, and the complete responsibility of the governors to the people as its means; and that the dependence of natural phenomena in general on the laws of action of what we call matter has become an axiom. (Huxley 1874/1964, p.38-9)

36.7 Ernst Mach: A Nineteenth-Century Contributor to the Enlightenment Education Project

Ernst Mach (1838-1916), was one of the great philosopher-scientists of the late nineteenth and early twentieth centuries; and was major contributor to the Enlightenment project in education. Unfortunately, his contribution to education has been almost entirely ignored in the English-speaking world.[53] This is a pity, because current trends in the practice and theory

[51] For Priestley's impact in early America, see Davenport (1990), D'Elia (1990), and Graham (2008),
[52] See Desmond (1994) and Jensen (1991).
[53] John Bradley, the English chemist and educator, organized his chemistry instruction on Machian principles (Bradley 1963-68), and he wrote a useful book on Mach's philosophy of science (Bradley 1971). Mach the educator is discussed in Matthews (1990, 2015 pp.33-37). The most comprehensive and best documented discussion of the subject is Siemsen (2014).

of science education are in many respects repeating Mach's century-old arguments concerning the purposes and aims of science teaching, the nature of understanding, and the best ways to promote the learning of science. An obituary of a century ago, did draw attention to Mach the educator:

> It is Mach the *educationalist* whom we must here bring to the attention of our readers, particularly the younger ones, and not as someone who has passed on, but as a man whose seed is destined to put down ever further roots in physics teaching, and, with that, in all teaching about real things, and to fructify the whole spirit of this teaching. (Höfler 1916, W. A. Suchting trans.)

Mach was fluent in most European languages, an enthusiast of Greek and Latin classics, a physicist who made significant contributions to such diverse fields as electricity, gas dynamics, thermodynamics, optics, energy theory and mechanics; a historian and philosopher of science, a psychologist, Rector of the German University in Prague, a member of the Upper House of the Austrian Parliament and a writer of lucid prose. He was a person of strong character and convictions, a socialist and outspoken liberal-humanist in the centre of the archconservative Catholic Austro-Hungarian Empire. Einstein said of him that 'he peered into the world with the inquisitive eyes of a carefree child taking delight in the understanding of relationships' (Hiebert 1976, p.xxi). Mach made scientific and philosophical contributions across the whole temporal span from Darwin to Einstein. The first of Mach's five hundred publications was in 1859, the year of Darwin's *The Origin of Species*; his last work was published five years after his death in 1921, the year of Einstein's *Relativity: The Special and General Theory.*[54]

Mach's understanding of science and philosophy bore upon his educational ideas. He was influenced by the ideas of the German philosopher-psychologist-educationalist Johann Friedrich Herbart. He applied Herbart's ideas in his first teaching assignment 'Physics for Medical Students', and in the text he wrote arising from this course (*Compendium of Physics for Medical Students* Mach 1863). Mach's concern here was with 'economy of thought', with getting across the general outline of the conceptual modes of physics, and with overcoming the compartmentalism of physics.

Psychology was a long-standing interest of Mach's. At fifteen years of age Mach had read Kant's *Prologomena* and signalled his subsequent positivist commitments – 'The superfluity of the role of the "thing-in-itself" suddenly dawned upon me' (Blackmore 1972, p.11). His teaching was the occasion to unite pedagogical, psychological and scientific concerns. The first of his many science textbooks for school students, published in 1886, was widely used and went through several editions. Indeed, most of the major figures in European physics at the beginning of the twentieth century learnt science from Mach's school texts. These texts provided a logical and historical introduction to science, they sought to present students with the 'most naive, simple, and classical observations and thoughts from which great scientists have built physics' (Pyenson 1983, p.34). Whilst at Prague he taught courses on 'School Physics Teaching'. In 1887 Mach founded and co-edited the world's second-published science education journal - *Zeitschrift für den Physikalischen und Chemischen Unterricht* (*Journal of Instruction in Physics and Chemistry*). He contributed regularly to this journal until a stroke forced his retirement in 1898.

Mach did not write any systematic work on educational theory or practice; his ideas are scattered throughout his texts and journal articles. However, there are three lectures where he addressed pedagogical issues. One of these is perhaps his most systematic

---

[54] An excellent documentary source of Mach's bountiful influence in science, philosophy and beyond is Blackmore, Itagaki & Tanaka (2001).

treatment of education in general and science education in particular – 'On Instruction in the Classics and the Mathematico-Physical Sciences' (Mach 1886/1986), translated in his *Popular Scientific Lectures*. His other chief pedagogical papers are 'On Instruction in Heat Theory' (1887), and 'On the Psychological and Logical Moment in Scientific Instruction' (1890),[55] in volumes one and four respectively of his *Zeitschrift*.

As well as intellectual and practical interests in education, Mach had a notable Enlightenment-inspired political involvement in educational reform. The best of the Enlightenment thinkers connected thought to action. As Marx a century later would say, the point of philosophising was to change the world, not just to think about the world. Mach addressed teacher organizations, spoke in the Austrian Parliament on the need for school curricular change, and was active in the struggles to transform the entrenched German gymnasium pattern of separating schools for language and classics from those for science and mathematics. Mach championed the creation of the new *Einheitsschule* where integrated education in the humanities and the sciences could occur. There have been few scientists who have displayed such a wide-ranging interest in both formal (school) and informal (the reading public) education. Mach's relative neglect by English-speaking science educators is unfortunate.

Well-founded curricular and pedagogical proposals in school science are based upon two foundations: views about the nature and scope of science, and views about the nature and practice of education. The Enlightenment project has contributed to both. There are of course other matters to be considered in drawing up curricula - political, social and psychological, to name just the obvious ones. But what one thinks, explicitly or implicitly, about the philosophy of science and about the philosophy of education will largely determine the form of the science curriculum. Mach's suggestions for the conduct of science education stem in part from his theory of science and his Herbartian theory of education. Some of the major themes of Mach's philosophy of science (his view of the nature of science) are the following:

- Scientific theory is an intellectual construction for economizing thought and thereby conjoining experiences.
- Science is fallible; it does not provide absolute truths.
- Science is a historically conditioned intellectual activity.
- Scientific theory can only be understood if its historical development is understood.

Mach's educational ideas are fairly simple and uncontroversial:

- Begin instruction with concrete materials and thoroughly familiarize students with the phenomena discussed.
- Aim for understanding and comprehension of the subject matter.
- Teach little, but teach it well.
- Follow the historical order of development of a subject.
- Tailor teaching to the intellectual level and capacity of students.
- Address the philosophical questions that science entails and which gave rise to science.
- Show that just as individual ideas can be improved, so also scientific ideas have constantly been, and will continue to be, overhauled and improved.
- Engage the mind of the learner.

---

[55] This last paper has recently, for the first time, been translated and published in English (Mach 1890/2018). Hayo Siemsen was translator and editor, who sadly died prematurely in 2018.

Although a pre-eminent theorist, and concerned with economy of thought in education, Mach firmly believed that abstractions in the science classroom should, as Hegel said of philosophy, take flight only at dusk: 'Young students should not be spoiled by premature abstraction, but should be made acquainted with their material from living pictures of it before they are made to work with it by purely ratiocinative methods' (Mach 1886/1986, p.4). This Enlightenment conviction goes all the way back to John Locke and beyond. A simple point, usually observed in its breach, as Arnold Arons has lamented:

> As physics teaching now stands, there is a serious imbalance in which there is an overabundance of numerical problems using formulae in canned and inflexible examples and a very great lack of phenomenological thinking and reasoning. (Arons 1988, p.18)

Another of Mach's concerns was the tendency to overfill the curriculum. For him the principal aims of education were to develop understanding, strengthen reason and promote imagination. A bloated curriculum counteracted these aims:

> I know nothing more terrible than the poor creatures who have learned too much. What they have acquired is a spider's web of thoughts too weak to furnish sure supports, but complicated enough to produce confusion. (Mach 1886/1986, p.367)

One hundred years later this lament is still being voiced about the USA's 'one mile wide and one inch deep' curricula.

Mach believed in presenting science historically, or as he put it, teaching should follow the genetic approach:

> every young student could come into living contact with and pursue to their ultimate logical consequences merely a *few* mathematical or scientific discoveries. Such selections would be mainly and naturally associated with selections from the great scientific classics. A few powerful and lucid ideas could thus be made to take root in the mind and receive thorough elaboration. (Mach 1886/1986, p.368)

Mach's major textbooks on mechanics (1883), heat (1869) and optics (1922) all follow the genetic method of exposition. This was Priestley's method, and it is partly why Priestley wrote his histories. Mach realised that the logic of a subject was not necessarily the logic of its presentation - a point known to most school teachers, if not to administrators. The logic of a discipline and the logic of its pedagogy are not identical, as Mach's contemporary and fellow positivist Pierre Duhem also maintained:

> The legitimate, sure, and fruitful method of preparing a student to receive a physical hypothesis is the historical method . . . that is the best way, surely even the only way, to give those studying physics a correct and clear view of the very complex and living organisation of this science. (Duhem 1906/1954, p.268)

36.8 Philipp Frank and Herbert Feigl: Two Twentieth-Century Contributors to the Enlightenment Education Project

The two European émigré positivist philosophers Philipp Frank and Herbert Feigl flesh out more of the Enlightenment education project, specifically its implications for science education. Their writings and activities also show the large commonality between the Enlightenment project and the project of Liberal Education. Many things are shared, but the

former has an intrinsic commitment to social and cultural change that is not intrinsic to the latter.

Philipp Frank (1884-1966) was born in Vienna in 1884 and died in Cambridge Massachusetts in 1966. In 1907 he received his doctorate in theoretical physics at the University of Vienna where he studied under Ludwig Boltzmann. Frank's first paper, published in 1907 at the age of 23 years – 'Experience and the Law of Causality' (Frank 1907/1949) – characterized his subsequent philosophical concern: namely prolonged and informed philosophical reflection on the structures, methodology and history of science. The meetings of the Vienna Circle that he instigated set the style of his subsequent intellectual career: there was a seriousness of purpose coupled with a genuine open-mindedness towards different opinions and traditions:

> This apparent internal discrepancy [in the group] provided us, however, with a certain breadth of approach by which we were able to have helpful discussions with followers of various philosophical opinions. Among the participants in our discussions were, for instance, several advocates of Catholic philosophy. Some of them were Thomists, some were rather adherents of a romantic mysticism. Discussions about the Old and New Testaments, the Jewish Talmud, St. Augustine, and the medieval schoolmen were frequent in our group. Otto Neurath even enrolled for one year in the Divinity School and won an award for the best paper on moral theology. This shows the high degree of our interest in the cultural background of philosophic theories and our belief in the necessity of an open mind which would enable us to discuss our problems with people of divergent opinions. (Frank 1949, pp.1-2)

Frank published two explicitly educational papers: 'Science Teaching and the Humanities' (Frank 1950b) and 'The Place of Philosophy of Science in the Curriculum of the Physics Student' (Frank 1947/1950). He regretted that the 'result of conventional science teaching has not been a critically minded type of scientist, but just the opposite' (Frank 1947/1950, p.230). In part this regret is because 'the science student who has received the traditional, purely technical instruction in his field is extremely gullible when he is faced with pseudophilosophic and pseudoreligious interpretations that fill somehow the gap left by his science courses' (Frank 1947/1950, p.230). As a consequence, 'This failure prevents the science graduate playing in our cultural and public life the great part that is assigned to him by the ever-mounting technical importance of science to human society' (Frank 1947/1950, p.231).

It is of course the history and philosophy of science that makes good these shortfalls; or rather, for Frank, just philosophy of science because this indeed consists of two inseparable components, 'logico-empirical analysis' and 'socio-psychologic' analysis (Frank 1947/1950, p.248). The first is conceptual or semantic analysis, the second is careful historical analysis. He says that 'This analysis is the chief subject that we have to teach to science students in order to fill the gaps left by traditional science teaching' (Frank 1947/1950, p.245).

Frank is an advocate of liberal education, affirming that a variety of subject matters should be mastered, and that as much as possible relations between the subjects should be brought out. He believes that humanities can be taught from *within* science, saying that:

> The student of science will get the habit of looking at social and religious problems from the interior of his own field and entering the domain of the humanities by a wide-open door … there is no better way to understand the philosophic basis of political and religious creeds than by their connection with science. (Frank 1950, p.281)

Herbert Feigl was born in 1902 in Reichenberg then in Austria-Hungary, a part of the Sudetenland which subsequently was incorporated in Czechoslovakia. He died in Minneapolis in 1988. At age 16 he read an article on the theory of special relativity and set about trying, without success, to refute it. He said that the attempt resulted in him learning a lot of mathematics and physics. At age 20 he went to the University of Vienna to study philosophy with Moritz Schlick (and additionally to study mathematics, physics and psychology). He was a founding member of the Vienna Circle established by Schlick in 1924 as a weekly evening discussion group, and he remained a member of the Circle until his emigration to the US in 1930. In 1927, Feigl presented his doctoral thesis on 'Chance and Law: An Epistemological Investigation of Induction and Probability in the Natural Sciences'. In the US he worked with Percy Bridgman at Harvard on the foundations of physics including the topic of operational definitions of theoretical terms. In 1940 he was appointed professor of philosophy at the University of Minnesota; in 1953 he established the Minnesota Center for the Philosophy of Science, a centre that would make a significant contribution to the articulation and spread of logical empiricist philosophy in the US and worldwide, especially through contributions to the many volumes of *Minnesota Studies in Philosophy of Science.*

Feigl published one explicitly educational paper: 'Aims of Education for Our Age of Science: Reflections of a Logical Empiricist' (Feigl 1955). Feigl regarded promotion of individual autonomy as the prime educational achievement:

> As long as education promotes the formation of intelligence and character in a manner that allows for free learning, rational choices, and critical reflection, human beings so educated will have an excellent opportunity for being masters of their own activities and achievements. (Feigl 1955, p.322)

This is almost, and not accidently, a verbatim repetition of the opening sentences of Kant's 1784 'What is Enlightenment?' quoted earlier in this chapter. Not surprisingly, Feigl advocates teaching science in a historically and philosophically informed manner, saying:

> It is my impression that the teaching of science could be made ever so much more attractive, enjoyable, and generally profitable by the sort of approach that is more frequently practiced in the arts and the humanities. The dull and dry-as-dust science courses can be replaced by an exciting intellectual adventure if the students are permitted to see the scientific enterprise in broader perspective. Preoccupation with the purely practical values of applied science has overshadowed the intellectual and cultural values of the quest for knowledge. (Feigl 1955, p.337)

And further, he embraces the orthodox liberal education position wherein: 'training in the sciences and in the scientific attitude should, of course, be combined with studies in history, literature, and the arts' (Feigl 1955, p.338). As important as science is, it is not the only thing that Feigl treasures:

> I consider truly great music the supreme achievement of the human spirit...I am inclined to think that music expresses (even more than poetry) what is inexpressible in cognitive and especially in scientific language. (Cohen 1981, p.5)

Feigl has a robust account of values and recognizes that they are an intrinsic part of education; that they mould and direct educational processes and are crucial to the establishment of educational aims. Feigl has an even more robust account of rationality and its place in education. He believes that the classical Aristotelean conception of man as

rational animal 'may still be a good beginning' (Feigl 1955, p.335), and then explicates the idea for education, stressing that rationality covers at least six virtues of thought and conduct:

- clarity of thought (the meaningful use of language and avoidance of gratuitous perplexities);
- consistency of reasoning (conformity with the principles of formal logic);
- reliability of knowledge claims (wherever the evidence is too weak, belief should be withheld);
- objectivity of knowledge claims (knowledge claims should be testable by anyone sufficiently equipped with intelligence and competence);
- rationality of purposive behaviour (maximum positive outcomes are to be gained at the cost of minimum negative outcomes);
- moral rationality (adherence to principles of justice, equity or impartiality, and abstention from coercion and violence in the settlement of conflicts of interest. (Feigl 1955, pp.335-336ff)

Frank and Feigl made an indirect, but nevertheless significant, contribution to US and international physics education through their Harvard collaboration with physicist-philosopher-historian Gerald Holton who oversaw the much-used and influential *Harvard Project Physics Course* (Holton 1978). Holton's articulation of the philosophy of the course, and the course's structure, resonates with Enlightenment themes. Discrete topics in physics are linked to each other, to topics in other sciences, to mathematics, to philosophy, literature, and so on. Knowledge is a tapestry and should be presented as such to students. He distinguishes scientific training from scientific education, a distinction made by Mach and most other proponents of enlightened education. For Holton:

> Training is achieved by imparting the most efficient skill for a scientific purpose. Education is achieved by imparting a point of view that allows generalization and application in a wide variety of circumstances in one's later life. (Holton 1978, p.298)

36.9 Conclusion

Modern science is based on Enlightenment-grounded commitments: the importance of evidence; rejection of simple authority, especially non-scientific authority, as the arbiter of knowledge claims; a preparedness to change opinions and theories; a fundamental openness to participation in science regardless of gender, class, race or religion; recognizing the inter-dependence of disciplines; and pursuing knowledge for advancement of personal and social welfare. All of this needs to be manifest in science education, along with a willingness to resist the imposition of political, religious and ideological pressures on curriculum development, textbook choice and pedagogy.

These commitments are mostly made without awareness of their Enlightenment roots. It is important for educators to connect these contemporary commitments with their historical scientific-philosophical base; and to be aware of the trajectories and philosophical-political-religious buffeting that the commitments have experienced over time. If the past is known, it can be learnt from; and teachers can develop a sense of belonging to an open-minded, critical, scholarly tradition, and hopefully defend it. Some in this tradition take their inspiration from the Enlightenment, others from other sources. Defense of the tradition requires serious philosophical work. Questions of epistemology concerning the objective knowability of the world, questions of ontology concerning the constitution of the world, specifically regarding methodological and ontological naturalism, questions of methodology concerning theory

appraisal and evaluation, and the limits, if any, of scientism, questions of ethics concerning the role of values in science - all need to be fleshed out, and Enlightenment answers defended against their many critics

The Enlightenment education tradition has been advanced by numerous individuals. Just some – Priestley, Mach, Frank and Feigl – have been elaborated upon here. Other Anglo-Americans that warrant elaboration are Thomas Huxley, Frederick Westaway, John Dewey, and Gerald Holton. And there are numerous European, Latin American, and Asian contributors to the project. They all have a commitment to some constellation of the core Enlightenment principles that have been detailed above. The tradition is characterised by valuing the cultural importance of science; [56] by commitment to the growth of knowledge of the natural and social worlds; the diffusion of this knowledge by both formal and informal education; the utilisation of knowledge for the amelioration of social and cultural problems; and for the flourishing of personal life. For this to happen, the history and philosophy of science needs to be absorbed as science is taught, and more especially where science teachers are trained.[57]

That Enlightenment banner continues to be carried by Mario Bunge. He champions Enlightenment principles, adjusts them, and adds to them. In Latin America of the mid- and late twentieth century, he was one of the outstanding Enlightenment figures, and has been the same in the wider international academic community.

References

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

Aikenhead, G.S.: 1997, 'Towards a First Nations Cross-Cultural Science and Technology Curriculum', *Science Education* 81(2), 217-238.

Anchor, R.: 1967, *The Enlightenment Tradition*, University of California Press, Berkeley.

Andersen, K.: 2017, *Fantasyland: How America Went Haywire, A 500-Year History*, Penguin, London.

Anderson, R.G.W. & Lawrence, C. (eds.): 1987, *Science, Medicine and Dissent: Joseph Priestley (1733-1804)*, Wellcome Trust, London,

Arons, A.B.: 1988, 'Historical and Philosophical Perspectives Attainable in Introductory Physics Courses', *Educational Philosophy and Theory* 20(2), 13-23.

Artz, F.B.: 1968, *The Enlightenment in France,* Kent State University Press, Oberlin, OH.

Axtell, J.L. (ed.): 1968, *The Educational Writings of John Locke*, Cambridge University Press, Cambridge.

Becker, C.: 1932/1960, *The Heavenly City of the Eighteenth-Century Philosophers*, Yale University Press, New Haven.

Berlin, I. (ed.): 1956, *The Age of Enlightenment*: *The Eighteenth-Century Philosophers,* Mentor Books, New York.

Berlin, I.: 1980, 'The Counter-Enlightenment'. In H. Hardy (ed.) *Against the Current*, Viking, New York, pp. 1-24.

Birch, J.S. & Lee, J. (eds.): 2007, *Joseph Priestley. A Celebration of His Life and Legacy*, Scotforth Books, Lancaster.

[56] Wallis Suchting provides a rewarding discussion of the cultural significance of science (Suchting 1994).

[57] The argument is developed, and literature canvassed, throughout Matthews (2015).

Blackmore, J.T., Itagaki, R. & Tanaka, S.: 2001, 'Alois Höfler: Polymath', *Ernst Mach's Vienna 1895-1930*, Kluwer Academic Publishers, Dordrecht.
Blackmore, J.T.: 1972, *Ernst Mach: His Work, Life and Influence*, University of California Press, Berkeley.
Blom, P.: 2010, *A Wicked Company: The Forgotten Radicalism of the European Enlightenment*, Basic Books, New York.
Bolton, H.C. (ed.): 1892, *Scientific Correspondence of Joseph Priestley*, New York.
Bradley, J.: 1963-68, `A Scheme for the Teaching of Chemistry by the Historical Method', *School Science Review* 44, 549-553; 45, 364-368; 46, 126-133; 47, 65-71, 702-710; 48, 467-474; 49, 142-150; 454-460.
Bradley, J.: 1971, *Mach's Philosophy of Science*, London.
Brickhouse, N.W.: 2001, 'Embodying Science: A Feminist Perspective on Learning', *Journal of Research in Science Teaching* 38(3), 282-295.
Brooke, J.H.: 1987, 'Joseph Priestley (1733-1804) and William Whewell (1794-1866): Apologists and Historians of Science. A Tale of Two Stereotypes'. In R.G.W. Anderson & C. Lawrence (eds.) *Science, Medicine, and Dissent: Joseph Priestley (1733-1804)*, Wellcome Trust & Science Museum, London, pp.11-27.
Brooke, J.H.: 1991, *Science and Religion: Some Historical Perspectives*, Cambridge, Cambridge University Press.
Brown, J.R.: 2001, *Who Rules in Science: An Opinionated Guide to the Science Wars*, Harvard University Press, Cambridge MA.
Bunge, M.: 1943, *Temas de educación popular*, El Ateneo, Buenos Aires.
Bunge, M.: 1994, 'Counter-Enlightenment in Contemporary Social Studies'. In P. Kurtz & T.J. Madigan (eds.) *Challenges to the Enlightenment: In Defense of Reason and Science*, Prometheus Books, Buffalo, NY, pp.25-42.
Bunge, M.: 1999, *The Sociology-Philosophy Connection*, Transaction Publishers, New Brunswick, NJ.
Bunge, M.: 2000, *Social Science under Debate: A Philosophical Perspective*, Toronto: University of Toronto Press.
Butts, R.E. & Davis, J.W. (eds.): 1970, *The Methodological Heritage of Newton*, University of Toronto Press, Toronto.
Cassara, E.: 1988, *The Enlightenment in America*, University Press of America, Lanham.
Charles, S. & Smith, P.J. (eds.): 2013, *Scepticism in the Eighteenth Century: Enlightenment, Lumières, Aufklärung*, Springer, Dordrecht.
Church, W.F. (ed.): 1974, *The Influence of the Enlightenment on the French Revolution*, 2nd edition, D.C. Heath & Co., Lexington, MA.
Clark, W.: 1999, 'The Death of Metaphysics in Enlightened Prussia'. In Clark, W., Golinksi, J. & Schaffer, S. (eds): 1999, *The Sciences in Enlightened Europe*, University of Chicago Press, Chicago, pp.423-473.
Cohen, I.B.: 1980, *The Newtonian Revolution*, Cambridge University Press, Cambridge.
Cohen, R.S. (ed.): 1981, *Inquiries and Provocations: Selected Writings of Herbert Feigl 1929-1974*, Reidel, Dordrecht.
Cohen, R.S., Hilpinen, R. & Renzong, Q. (eds.): 1996, *Realism and Anti-Realism in the Philosophy of Science: Beijing International Conference, 1992*, Kluwer Academic Publishers, Dordrecht.
Commager, H.S.: 1977, *The Empire of Reason: How Europe Imagined and America Realized the Enlightenment*, Doubleday, New York.
Condorcet, N.: 1795/1955, *Sketch for a Historical Picture of the Progress of the Human Mind*, (June Barraclough, trans.), Noonday Press, New York.
Condorcet, N.: 1976, *Selected Writings,* K.M. Baker (ed.), Bobbs-Merrill, Indianapolis, IN.

D'Elia, D.J.: 1990, 'Joseph Priestley and His American Contemporaries'. In A.R. Schwartz & J.G. McEvoy (eds.), *Motion Towards Perfection: The Acheivements of Joseph Priestley*, Skinner House Books, Boston, pp.237-250.
Davenport, D.A.: 1990, 'Joseph Priestley in America: 1794-1804'. In A.R. Schwartz & J.G. McEvoy (eds.), *Motion Towards Perfection: The Acheivements of Joseph Priestley*, Skinner House Books, Boston, pp.219-236.
Desmond, A.: 1994, *Huxley: From Devil's Disciple to Evolution's High Priest*, Basic Books, New York.
Duhem, P.: 1906/1954, *The Aim and Structure of Physical Theory*, trans. P.P. Wiener, Princeton University Press, Princeton.
Dunthorne, H.: 2007, 'The Dutch Republic: "That mother nation of liberty"'. In M. Fitzpatrick, P, Jones, C. Knellwolf & I. McCalman (eds.), *The Enlightenment World*, Routledge, London, pp.87-103.
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.
Eliot, S. & Stern, B. (eds.): 1979, *The Age of Enlightenment: An Anthology of Eighteenth Century Texts,* Ward Lock Educational, East Grinsted.
Feigl, H.: 1955, 'Aims of Education for Our Age of Science: Reflections of a Logical Empiricist'. In N.B Henry (ed.), *Modern Philosophies and Education: The Fifty-fourth Yearbook of the National Society for the Study of Education*, University of Chicago Press, Chicago, pp. 304-341. Reprinted in *Science & Education* 13(1-2), 2004.
Ferguson, R.A.: 1997**,** *The American Enlightenment, 1750-1820***,** Harvard University Press, Cambridge.
Ferrone, V.: 2015, *The Enlightenment. History of an Idea*, Princeton University Press, Princeton, NJ (orig Italian, 2010)
Fitzpatrick, M., Jones, P., Knellwolf, C. & McCalman, I. (eds.): 2007, *The Enlightenment World*, Routledge, London.
Fitzpatrick, M.: 2007, 'The Age of Louis XIV and early Enlightenment in France'. In M. Fitzpatrick, P, Jones, C. Knellwolf & I. McCalman (eds.), *The Enlightenment World*, Routledge, London, pp.134-155.
Fleischacker, S.: 2013, *What is Enlightenment?*, Routledge, New York.
Fontainerie, F. de la (ed.): 1932, *French Liberalism and Education in the Eighteenth Century*, McGraw-Hill, New York.
Frank, P.: 1907/1949, 'Experience and the Law of Causality'. In his *Between Physics and Philosophy*, Harvard University Press, Cambridge MA, pp.53-60.
Frank, P.: 1947/1950, 'The Place of Philosophy of Science in the Curriculum of the Physics Student'. In his *Modern Science and Philosophy*, Harvard University Press, Harvard, pp.228-259.
Frank, P.: 1950a, *Modern Science and Its Philosophy*, Harvard University Press, Cambridge, MA.
Frank, P.: 1950b, 'Science Teaching and the Humanities'. In his *Modern Science and Its Philosophy*, Harvard University Press, Cambridge, MA, pp.260-285.
Garrard, G.: 2006, *Counter-Enlightenment: From the eighteenth century to the present*, Routledge, London.
Garrett, A.: 2007, 'Enquiry, scepticism and Enlightenment'. In M. Fitzpatrick, P, Jones, C. Knellwolf & I. McCalman (eds.), *The Enlightenment World*, Routledge, London, pp.57-64.

Gay, P. (ed.): 1973, *The Enlightenment: A Comprehensive Anthology*, Simon & Schuster, New York.
Gay, P.: 1966, *The Enlightenment: An Interpretation*, 2-vols., New York.
Goubert, P.: 1972, *Louis XIV and the Twenty Million Frenchmen*, Vintage Books, New York.
Graham, J.: 2008, 'Joseph Priestley in America'. In I. Rivers & D.L. Wykes (eds.), *Joseph Priestley: Scientist, Philosopher, and Theologian*, Oxford University Press, Oxford, pp.203-230.
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).
Hankins, T.L.: 1985, *Science and the Enlightenment*, Cambridge University Press, Cambridge.
Harper, W.L.: 2011, *Isaac Newton's Scientific Method: Turning Data into Evidence about Gravity and Cosmology*, Oxford University Press, Oxford.
Heering, P. & Höttecke, D.: 2014, 'Historical-Investigative Approaches in Science Teaching'. In M.R. Matthews (ed.) *International Handbook of Research in History, Philosophy and Science Teaching*, Springer, Dordrecht, pp. 1473-1502.
Helvétius, C.A.: 1772/1810, *A treatise on man; his intellectual faculties and his education*, (trans. W. Hooper), Venor, Hood & Sharpe, London. Original *De l'homme, de ses facultés intellectuelles et de son education* (1772).
Herman, A.: 2001, *The Scottish Enlightenment: The Scot's Invention of the Modern World*, Harper, London.
Hiebert, E.N.: 1976, `Introduction'. In E. Mach *Knowledge and Error*, Reidel, Dordrecht.
Himmelfarb, G.: 2004, *The Roads to Modernity. The British, French, and American Enlightenments*, Alfred A. Knopf, New York.
Höfler, A.: 1916, 'Obituary for Mach', *Zeitschrift für den physikalischen und chemischen Unterricht*, 29 (57, March)
Holton, G.: 1978, 'On the Educational Philosophy of the Project Physics Course'. In his *The Scientific Imagination: Case Studies*, Cambridge University Press, Cambridge, pp.284-298.
Horkheimer, M. & Adorno, T.W.: 1944/1972, *Dialectic of Enlightenment*, Herder and Herder, New York.
Hume, D.: 1739/1888, *A Treatise of Human Nature: Being an Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects*, Clarendon Press, Oxford.
Hume, D.: 1754-62/1879, *The History of England: From the Invasion of Julius Caesar to the Revolution in 1688* (6 volumes), Harper & Brothers, New York.
Huxley, T.H.: 1868/1964, 'A Liberal Education; and Where to Find It'. In his *Science & Education*, Appleton, New York, 1897 (orig. 1885). Reprinted with Introduction by C. Winick, Citadel Press, New York, 1964, pp.72-100.
Huxley, T.H.: 1874/1964, 'Joseph Priestley'. In his *Science & Education*, Appleton, New York, 1897 (orig. 1885). Reprinted with Introduction by C. Winick, Citadel Press, New York, 1964, pp.9-39.
Hyland, P., Gomez, O. & Greensides, F. (eds.): 2003, *The Enlightenment: A Source Book and Reader*, Routledge, New York.
Israel, J.I.: 2001, *Radical Enlightenment: Philosophy and the Making of Modernity 1650-1750*, Oxford University Press, Oxford.
Israel, J.I.: 2006, *Enlightenment Contested: Philosophy, Modernity, and the Emancipation of Man 1670-1752,* Oxford University Press, Oxford.
Israel, J.I.: 2011, *Democratic Enlightenment: Philosophy, Revolution, and Human Rights, 1750-1790,* Oxford University Press, Oxford.

Jensen, J.V.: 1991, *Thomas Henry Huxley: communicating for science*, University of Delaware Press, Newark NJ.
Joad, C.E.M.: 1935, *The Book of Joad: A belligerent Autobiography*, Faber & Faber, London.
Kandel, I.L.: 1930, *History of Secondary Education: A Study in the Development of Liberal Education*, Houghton Mifflin Company, Boston.
Kant, I.: 1784/1995, 'An Answer to the Question: What is Enlightenment?' In I. Kramnick (ed.) *The Portable Enlightenment Reader*, Penguin, London, pp.1-7.
Kant, I.: 1787/1933, *Critique of Pure Reason*, 2nd edit., N.K. Smith (trans.), Macmillan, London. (First edition, 1781).
Kant, I.: 1803/1899, *Kant on Education* (trans. Annette Churton), Kegan Paul, London.
Knudsen, J.B.: 1996, 'On Enlightenment for the Common Man'. In J. Schmidt (ed.), *What is Enlightenment? Eighteenth-Century Answers and Twentieth-Century Questions*, University of California Press, Berkeley, pp.270-290.
Koch, A. (ed.): 1965, *The American Enlightenment: The Shaping of the American Experiment and a Free Society*, George Braziller, New York
Koch, A.: 1961, *Power, Morals, and the Founding Fathers: Essays in the Interpretation of the American Enlightenment*, Cornell University Press, Ithaca NY.
Koertge, N. (ed.): 1998, *A House Built on Sand: Exposing Postmodern Myths about Science*, Oxford University Press, New York.
Kramnick, I. (ed.): 1995, *The Portable Enlightment Reader*, Penguin Books, New York.
Leplin, J. (ed.): 1984, *Scientific Realism*, University of California Press, Berkeley.
Lindberg, D.C. & Westman, R.S. (eds.): 1990, *Reappraisals of the Scientific Revolution*, Cambridge University Press, Cambridge.
Lindsay, J.: 1970, 'Introduction'. In *Autobiography of Joseph Priestley*, Adams & Dart, Bath, pp.11-66.
Locke, J.: 1693/1968, *Some Thoughts Concerning Education*. In J.L. Axtell (ed.) *The Educational Writings of John Locke*, Cambridge University Press, Cambridge, pp.114-325.
Lövlie, L., & Standish, P.: 2002, *Bildung* and the idea of a liberal education, *Journal of Philosophy of Education*, 36, 317-340.
McCarthy, C.L.: 2018, 'Cultural Studies of Science Education: An Appraisal'. In M.R. Matthews (ed.) *History, Philosophy and Science Teaching: New Perspectives*, Springer, Dordrecht, pp.99-136.
Mach, E.: 1863, *Compendium de Physik für Mediciner,* Braumüller, Vienna.
Mach, E.: 1886/1986, 'On Instruction in the Classics and the Sciences'. In his *Popular Scientific Lectures*, Open Court Publishing Company, La Salle, pp. 338-374.
Mach, E.: 1890/2018, 'Über das psychologische und logische Moment im naturawissenschaftlichen unterricht', *Zeitschrift für den physikalischen und chemischen Unterricht* 4, 1-5. 'About the Psychological and Logical Moment in Natural Science Teaching' Hayo Siemsen (trans.). In M.R. Matthews (ed) *History, Philosophy and Science Teaching: New Perspectives*, Springer, Dordrecht, pp.195-200.
Matthews, M.R. (ed.): 1989, *The Scientific Background to Modern Philosophy*, Hackett Publishing Company, Indianapolis.
Matthews, M.R. (ed.): 1998, *Constructivism and Science Education: A Philosophical Examination*, Kluwer Academic Publishers, Dordrecht.
Matthews, M.R.: 1990, 'Ernst Mach and Contemporary Science Education Reforms', *International Journal of Science Education* 12(3), 317-325.
Matthews, M.R.: 2015, *Science Teaching: The Contribution of History and Philosophy of Science: 20th Anniversary Revised and Enlarged Edition*, Routledge, New York.

May, H.F.: 1976, *The Enlightenment in America*, Oxford University Press, New York.
McIntyre, A.: 1981, *After Virtue: A Study in Moral Theory*, University of Notre Dame Press, Notre Dame IN.
McIntyre, A.: 1988, *Whose Justice? Which Rationality?* Duckworth, London.
McMahon, D.M.: 2001, *Enemies of the Enlightenment: The French counter-Enlightenment and the making of modernity,* Oxford University Press, New York.
Merton, R.K.: 1938/1970, *Science, Technology and Society in Seventeenth Century England*, Harper & Row, New York.
Mukherjee, A.P.: 2009, 'B.R. Ambedkar, John Dewey, and the Meaning of Democracy', *New Literary History* 40(2), 345-370.
Newton, I.: 1730/1979, *Opticks or A Treatise of the Reflections, Refractions, Inflections & Colours of Light*, Dover Publications, New York.
O'Hara, K.: 2010, *The Enlightenment: A Beginner's Guide*, Oneworldpublications, Oxford.
Osler, M.J. (ed.): 2000, *Rethinking the Scientific Revolution*, Cambridge University Press, Cambridge. S500/510
Pagden, A.: 2013, *The Enlightenment and Why It still Matters*, Oxford University Press, Oxford.
Parry, G.: 2007, 'Education and the Reproduction of the Enlightenment'. In M. Fitzpatrick, P. Jones, C. Knellwolf & I. McCalman (eds), *The Enlightenment World*, Routledge, London, pp.217-233.
Passmore, J.A. (ed.): 1965, *Priestley's Writings on Philosophy, Science and Politics*, Collier Macmillan, London.
Pinker, S.: 2018, *Enlightenment Now: The Case for Reason, Science, Humanism, and Progress*, Viking, New York.
Porter, R. & Teich, M. (eds.): 1981, *The Enlightenment in National Context*, Cambridge University Press, Cambridge.
Porter, R.: 2000, *The Enlightenment: Britain and the Creation of the Modern World*, Penguin Books, London.
Priestley, 1790, *Experiments and Observations on Different Kinds of Air, and other branches of Natural Philosophy, connected with the Subject .. Being the former Six Volumes abridged and methodized*, 3 vols., J. Johnson, Birmingham.
Priestley, J.: 1775, *The Discovery of Oxygen. Part 1. Experiments by Joseph Priestley.* In Alembic Club Reprints No. 7. (1992). Chicago: University of Chicago Press.
Priestley, J.: 1765/1965, *An Essay on a Course of Liberal Education for Civil and Active Life*. In J.A. Passmore (ed.) *Priestley's Writings on Philosophy, Science and Politics*, Collier Macmillan, London, pp.285-304.
Priestley, J.: 1767/1775, *The History and Present State of Electricity, with Original Experiments,* second edition, J. Dodsley, J. Johnson & T. Cadell, London; 3rd edit., 1775 reprinted Johnson Reprint Corporation, New York, 1966, with Introduction by Robert E. Schofield.
Priestley, J.: 1772, *The History and Present State of the Discoveries Relating to Vision, Light, and Colours.* 2 vols., London.
Priestley, J.: 1775-77, *Experiments and Observations on Different Kinds of Air*, 2nd edition, 3 vols, J. Johnson, London. Sections of the work have been published by the Alembic Club with the title *The Discovery of Oxygen* (Edinburgh, 1961).
Priestley, J.: 1785, *The Importance and Extent of Free Inquiry in Matters of Religion*, to which is added *The Present State of Free Inquiry in this Country,* J. Johnson, Birmingham. In Rutt *Collected* Works, vol.18.
Priestley, J.: 1788, *Lectures on History and General Policy to which is prefixed, An Essasy on the Course of Liberal Educatioin for Civil and Active Life*, P. Byrne, Dublin.

Priestley, J.: 1791, 'The Proper Objects of Education'. In J.T. Rutt (ed.) *The Theological and Miscellaneous Works of Joseph Priestley* Vol.15, pp.420-440.
Puolimatka, T.: 2001, 'Spinoza's Theory of Teaching and Indoctrination', *Educational Philosophy and Theory*, 33(3-4), 397-410.
Pyenson, L.: 1983, *Neohumanism and the Persistence of Pure Mathmatics in Wilhelmian Germany*, American Philosophical Society, Philadelphia PA.
Reisch, G.A.: 2017, 'Pragmatic engagements: Philipp Frank and James Bryant Conant on science, education and democracy', *Studies in East European Thought* 69(3), 227-244.
Reisner, E.H.: 1930, *The Evolution of the Common School*, Macmillan, New York.
Rivers, I. & Wykes, D.L. (eds.):2008, *Joseph Priestley: Scientist, Philosopher, and Theologian*, Oxford University Press, Oxford.
Rose, N.F.: 2007, 'Science Education in the 18th Century'. In J.S. Birch & J. Lee (eds.), *Joseph Priestley: A Celebration of his Life and Work*, Scotchforth Books, Lancaster, pp.234-38.
Roth, M.-W.: 1999, 'Authentic School Science: Intellectual Traditions'. In R. McCormick & C. Paechter (eds.), *Learning and Knowledge*, Sage Publications, London, pp.6-20.
Rousseau, J.J.: 1762/1991, *Emile, or On Education*, (trans. Allan Bloom), Penguin, Harmondsworth.
Schama, S.: 1981, 'The Enlightenment in the Netherlands'. In R.S. Porter & M. Teich *The Enlightenment in National Context*, Cambridge University Press, Cambridge, pp.54-71.
Schapiro, J.S.: 1963, *Condorcet and the Rise of Liberalism*, Octagon Books, New York.
Schmidt, J. (ed.): 1996, *What is Enlightenment? Eighteenth-Century Answers and Twentieth-Century Questions*, University of California Press, Berkeley.
Schofield, R.E.: 1997, *The Enlightenment of Joseph Priestley: A Study of His Life and Work from 1733 to 1773*, Penn State Press, University Park, PA.
Schofield, R.E.: 2004, *The Enlightened Joseph Priestley: A Study of His Life and Work from 1773 to 1804,* Penn State Press, University Park, PA.
Schouls, P.A.: 1992, *Reasoned Freedom: John Locke and Enlightenment*, Cornell University Press, Ithaca, NY.
Schulz, R.M.: 2007, 'Lyotard, Postmodernism and Science Education: A Rejoinder to Zembylas', *Educational Philosophy and Theory, 39(6),* 633-656.
Schwartz, A.T. & McEvoy, J.G. (eds.): 1990, *Motion Toward Perfection: The Achievement of Joseph Priestley*, Skinner House Books, Boston.
Shimony, A.: 1997, 'Presidential Address: Some Historical and Philosophical Reflections on Science and Enlightenment'. In L. Darden (ed.) *Proceedings of the 1996 PSA Meeting*, S1-14.
Siemsen, H.: 2014, 'Ernst Mach: A Genetic Introduction to His Educational Theory and Pedagogy'. In M.R. Matthews (ed.) *International Handbook of Research in History, Philosophy and Science Teaching*, Springer, Dordrecht, pp.2329-2357.
Smith, J.W.A.: 1954, *The birth of modern education. The contribution of the dissenting academies 1660-1800*. Independent Press Ltd. Alec, Allenson, Inc.: Chicago, Illinois.
Spence, J.D.: 1982, *The Gate of Heavenly Peace: The Chinese and Their Revolution, 1895-1980,* Penguin, London.
Spinoza, B.: 1677/1910, *Ethics & De Intellectus Emendatione*, J.M. Dent & Sons, London.
Steinberg, S. R. & Kincheloe, J.: 2012, 'Employing the Bricolage as Critical Research in Science Education'. In B. Fraser, K. Tobin & C. McRobbie (eds), *International Handbook of Science Education*, 2nd Edition, Springer, pp.1485-1500.
Sternhell, Z: 2010, *The anti-Enlightenment tradition*, Yale University Press, New Haven, CT.

Suchting, W.A.: 1994, 'Notes on the Cultural Significance of the Sciences', *Science & Education* 3(1), 1-56.
Tang, Y.: 2015, 'The Enlightenment and Its Difficult Journey in China'. In Y. Tang, *Confucianism, Buddhism, Daoism, Christianity and Chinese Culture*, Springer, Dordrecht, pp.279-284.
Tarcov, N.: 1989, *Locke's Education for Liberty,* University of Chicago Press, Chicago.
Tobin, K.: 2015, 'Connecting science education to a world in crisis', *Asia-Pacific Science Education*, 1:2, (doi:10.1186/s41029-015-0003-z)
Trachtenberg, Z.: 1993, *Making Citizens: Rousseau's Political Theory of Culture*, Routledge, London.
Van Bunge, W. (ed.): 2003, *The Early Enlightenment in the Dutch Republic, 1650-1750*, Brill, Leiden.
Venturi, F.: 1972, *Italy and the Enlightenment: Studies in a Cosmopolitan Century*, Susan Corsi (trans.), New York University Press, New York.
Wootton, D.: 2015, *The Invention of Science: A New History of the Scientific Revolution*, Penguin Random House, London.
Wykes, D.L.: 1996, 'The Contribution of the Dissenting Academy to the Emergence of Rational Dissent'. In K. Haakonssen (ed.) *Enlightenment and Religion: Rational Dissent in Eighteenth-century Britain*, Cambridge University Press, Cambridge, pp.99-139.

Appendix A:

Mario Bunge, *Temas de Educación Popular*, Buenos Aires: El Ateneo, 1943, 99 pages, Contents

A Social problems

1. Technological education in Argentina
2 What kind of technologists should the popular universities train?
3 Women's technological education
4 Professional re-education
5 Patriotic action of the popular universities

B Didactic problems

6 Teaching the studying technique
7 Warning to the new technology teacher
8 Emulation and rivalry in the classroom
9 Commercial education in the popular universities
10 On the teaching of mathematics in technical schools

C Organization problems

11 Conditions the administration of a popular university ought to meet
12 Selection of the professoriat
13 Intervention of students and graduates in popular universities
14 Finances of the popular universities
15 Diplomas awarded by the popular universities