History and Philosophy of Science, and Science Teaching: A Personal Overview

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For much of my teaching and research life I have contributed to the 'History, Philosophy and Science Teaching' (HPS&ST) programme. After graduating in science, and doing teacher training, I began my career as a high school science teacher, and then commenced studies in history and philosophy of science (HPS), and began university teaching on the application of HPS to pedagogical, curricular and theoretical problems in science teaching. This talk is based on those contributions and personal observations.

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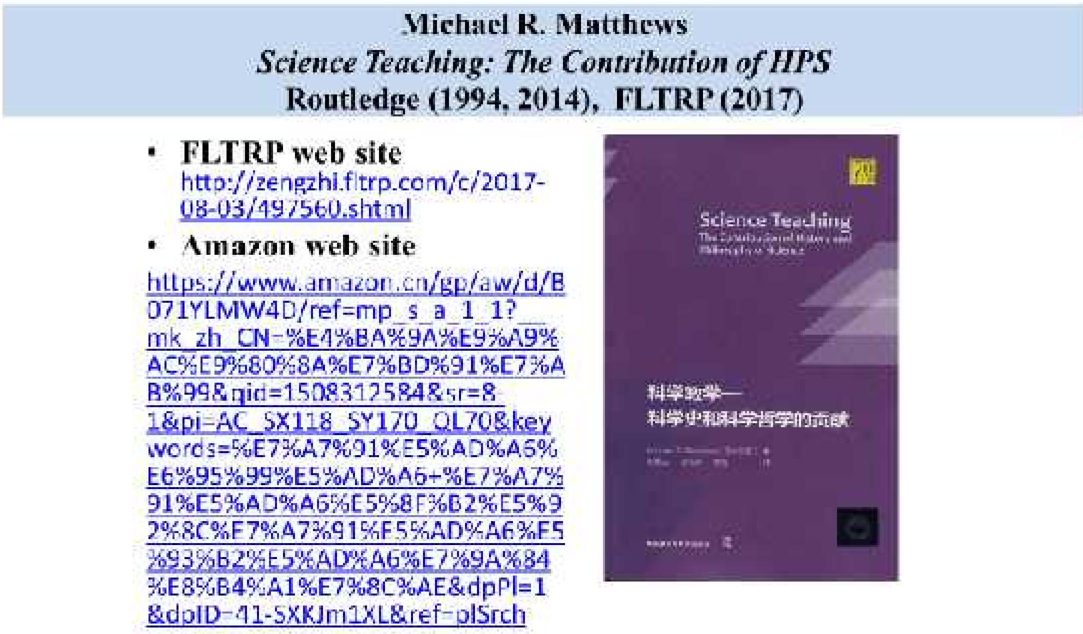

And it is my great pleasure to be able at this conference to inform you of the recently translated and published Chinese edition of my 2015 Routledge book: *Science Teaching: The Contribution of History and Philosophy of Science* (Matthews 2015). This edition has been translated by Professor Enshan Liu from Beijing Normal University, and published in 2017 by Foreign Language Teaching and Research Press in Beijing. It is available for direct sale through Amazon.

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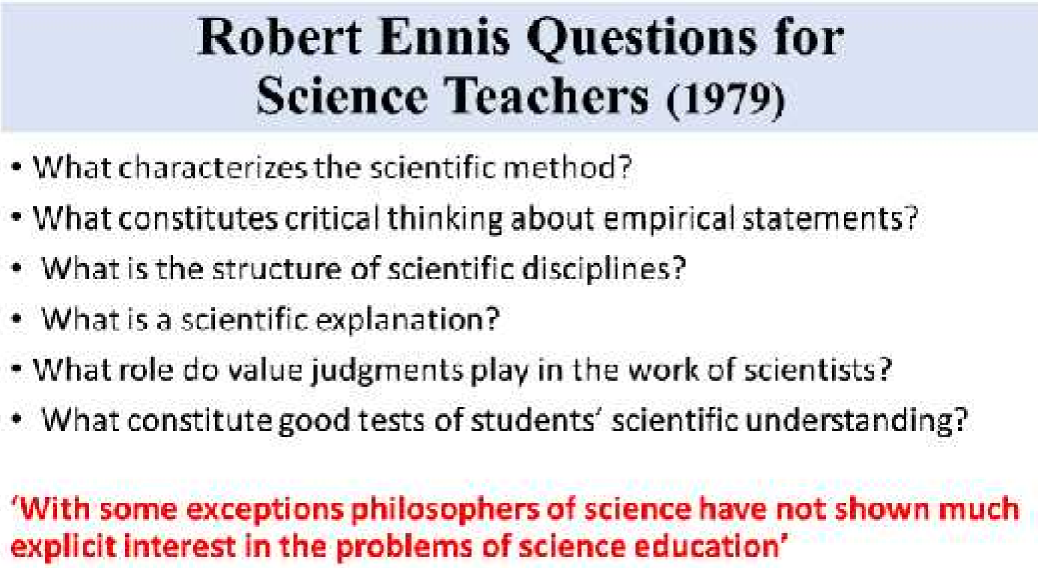

Forty years ago, Robert Ennis wrote a comprehensive review of the extant literature on philosophy of science and science teaching (Ennis 1979). His review listed six questions that science teachers constantly encounter in their classrooms and staffrooms, questions that cannot be properly illuminated without the input of philosophers and historians of science:

* What characterizes the scientific method?
* What constitutes good scientific thinking about empirical statements?
* What is the structure of scientific disciplines?
* What is a scientific explanation?
*What role do value judgments play in the work of scientists?
* What constitute good tests of students' scientific understanding?

These questions are of perennial concern to science teachers, and science teacher education programs. And of course, there are other such questions that concern all science teachers for which the input of historians and philosophers is important if not necessary. But Ennis made the melancholy observation that: 'With some exceptions philosophers of science have not shown much explicit interest in the problems of science education' (Ennis 1979, p.138).

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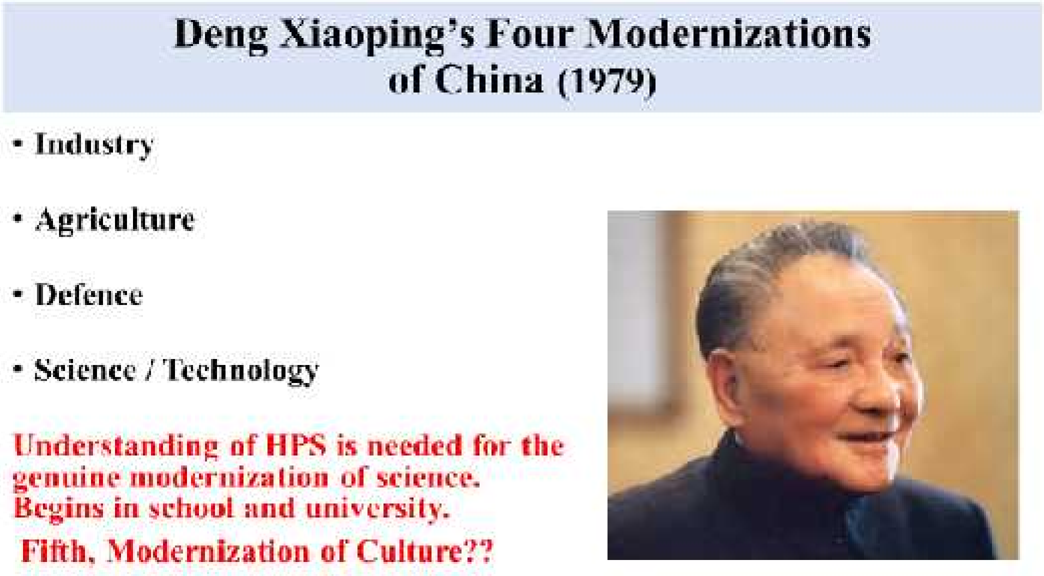

By complete coincidence, the year, 1979, that Ennis made his melancholic observation about the failure of historians and philosophers to join with science teachers in addressing common problems, was a momentus year in modern Chinese history: it marked the rehabilitation of Deng Xiaoping. At the CCP's 11th congress, Deng called for "a liberation of thoughts" and urged the party to "seek truth from facts" and abandon ideological dogma.

This marked the beginning of China's modern Economic Reform Era. It saw the commencement of his Four Modernizations' programme: Industry, Agriculture, Defence, and Science/Technology. My claim in this talk will be that the genuine modernization of science requires that the history and philosophy of science be attended to, and lessons from HPS be learnt. This should begin in school and in university science programmes.

Pleasingly, in recent decades there has been a good deal of rapprochement between the research fields of HPS and of science teaching. Both the theory of science education and, importantly, science curricula and classroom pedagogy have become more informed by the history and philosophy of science. The communities of HPS and of Education have better acknowledged how their work can be mutually beneficial for addressing theoretical, curricular and pedagogical issues in science teaching. This rapprochement has generated the contemporary 'HPS&ST research programme'.

Science, Philosophy, and the Enlightenment Project

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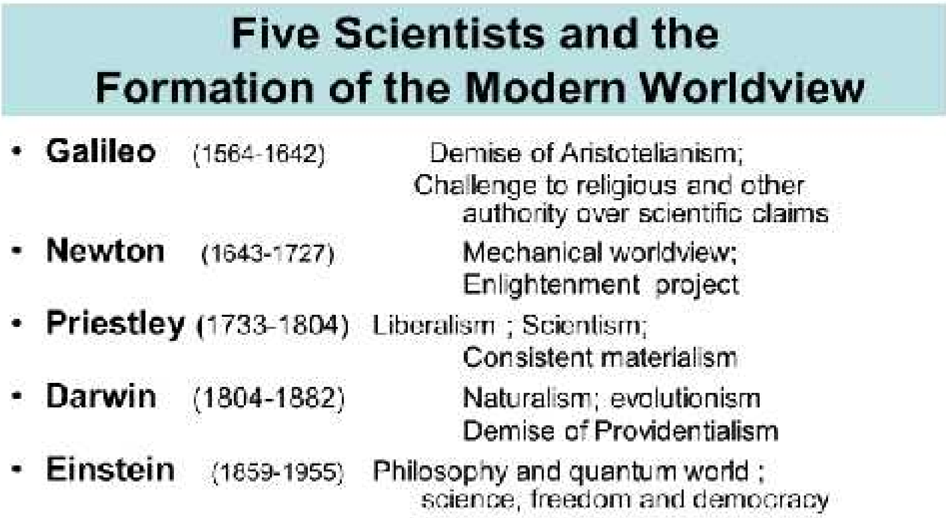

This engagement of HPS and science teaching is repeating the calls of the early modern scientists, and the European Enlightenment figures such as Isaac Newton, John Locke, Joseph Priestley and Immanuel Kant. For them, science was natural philosophy; and they all thought that good philosophy is required for the advancement of science, and conversely that confused, bad, or inadequate philosophy led to poor science. In modern terms, they believed that good *technical* science itself required attention to philosophy.

Galileo had to break with the dominating Aristotelianism of the Italian universities and Catholic Church of the late 16th century to establish his own physics and astronomy, and Newton had to break with both Aristotelianism and Cartesianism of 17th century Cambridge University to establish his own physics, which was to become the cornerstone of modern science. In turn, Kant consciously recognised the science of his day as the necessary foundation for his philosophical system, a system which many acknowledge as a pillar of modern Western philosophy.

Ernst Mach, the great 19th century German physicist and philosopher, created his Philosophical Empiricism in conjunction with his physics. Lenin famously attacked Mach and promoted Dialectical Materialism as the only philosophy consistent with science. And Dialectical Materialism, and Engel's Dialectics of Nature has had a long and powerful influence in China.

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Flow-on Hopes for the Scientific Revolution

- **Newton thought that the method he utilised would bear fruit beyond the fields of physics, astronomy and optics that he so well ploughed:**

  ***'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'* (*Optics*, p.405).**

- **Hume in the Preface to his *Treatise* says he is following the philosophers of England who have**

  ***' improvements in reason and philosophy can only be owing to a land of toleration and of liberty'* (p.xxi)**

Importantly, the 18th century Enlightenment philosophers and educators (often they were the same figures) believed that a widespread understanding and appreciation of the new science would have positive flow-on effects for society and culture; if people thought and reasoned scientifically about politics, religion, ethics, law, history, social and cultural practices then much of the discord, persecution, wars and upheaval in society would be minimized.

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Scientific Revolution and Enlightenment

The creation of civil society – the zone of relatively free exchange that lies both between and outside the state and the domestic sphere – owes a debt to science.
Experimental science requires voluntary associations and practices intended for verification by an independent audience,
however gentlemanly or oligarchic its original composition.
(Jacob 1998, p.242)

Major Enlightenment Texts

1689	Locke	*Letter Concerning Toleration*
1690	Locke	*Essay Concerning Human Understanding*
1693	Locke	*Two Treatises of Government*
1738	Voltaire	*Letters on England*
1751	Hume	*Inquiry Concerning Human Understanding*
1755	d'Alembert	*Discours preliminaire Encyclopdie*
1765	Hume	*The Natural History of Religion*
1768	Priestley	*Essay on Liberal Education*
1776	Priestley	*First Principles of Government*
1776	Gibbon	*Decline and Fall of the Roman Empire*
1784	Kant	*What is Enlightenment?*
1791	Paine	*The Rights of Man*

For the early modern scientists, both the advancement of the *New Science* – as Francis Bacon called it - and its social and cultural applications – the *Enlightenment* as it has been called - were dependent upon the science being informed by good philosophy. All the early modern scientists were natural philosophers; they recognised that they were philosophers, and as such had to be informed, critical and good philosophers. The connection between early modern science and philosophy was documented in my anthology *The Scientific Background to Modern Philosophy* (Matthews 1987).

The same argument can be made today for the practice of modern science: good science needs to be informed by good philosophy, and good philosophy - especially epistemology (what constitutes knowledge of nature) and ontology (how is nature constituted) - is in turn informed by science.

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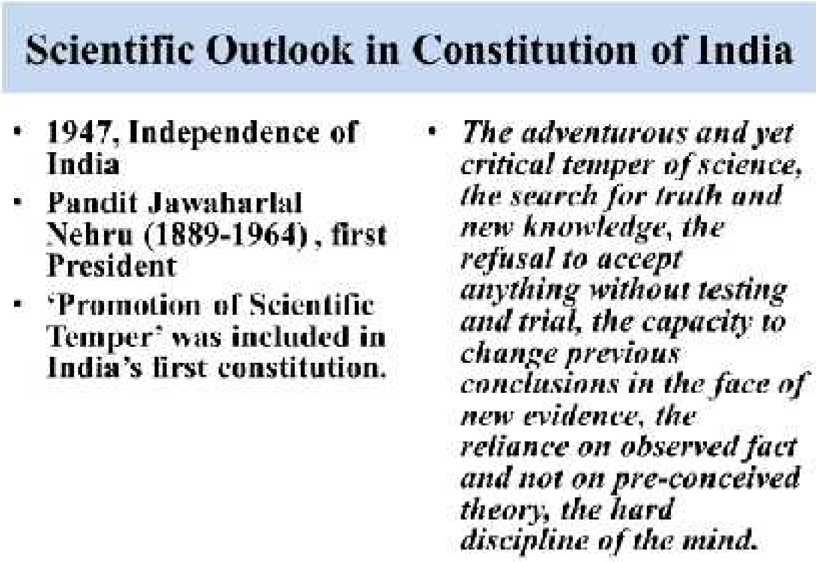

This was the Enlightenment hope: The spread of scientific thinking, or 'scientific habits of mind' as the AAAS has labelled it (AAAS 1989, chap.12), or 'scientific temper' as Pandit Jawaharlal Nehru wrote into the Indian Constitution, would not only lead to knowledge of nature, but would improve social and cultural life. Nehru argued for the constitutional recognition of Scientific Temper, and characterised it in these terms:

> The adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on pre-conceived theory, the hard discipline of the mind. (Nehru 1946/1981, p.36)

China has a very special history regarding the interplay of science and society; the freedom of individual thought and the authority of central power, whether Imperial or Communist Party. This is manifest through all Chinese history. This was so clearly manifest in Ch'en Tu-hsiu [Chen Duxiu] (1879-1942) writings and agitations in the early 20th century on 'Mr. Science and Mr. Democracy'.

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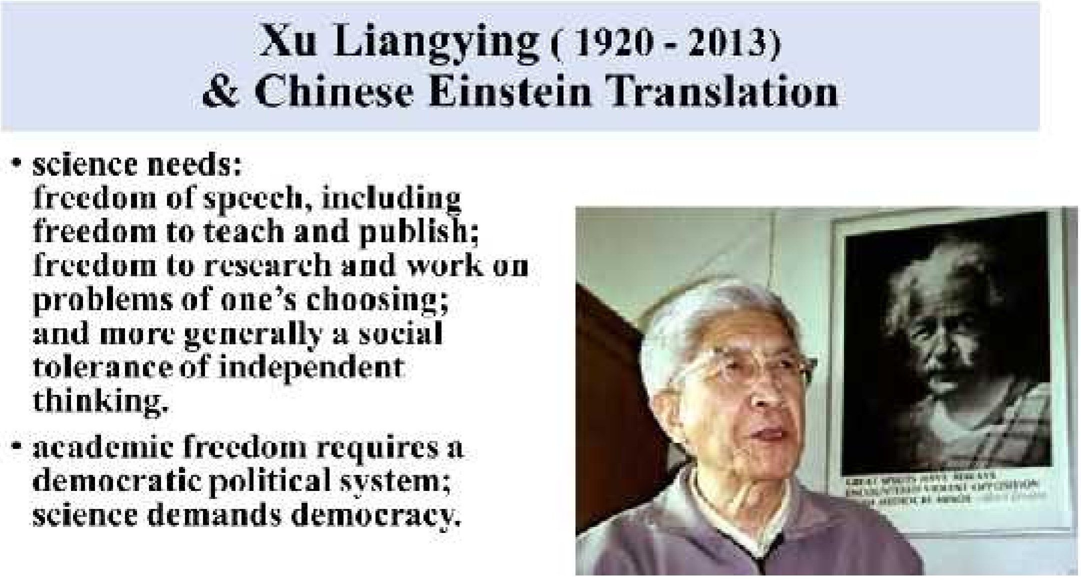

This tension between the freedom of thought required for science, and the control of central power in China, is painfully manifest in the career of Xu Liangying (1920 ~ 2013) China's foremost Einstein scholar and translator. Who some years ago I had the good fortune of hearing speak at Tsinghua University. In providing the very first Chinese translation of Einstein's *Collected Works* he repeated Einstein's insistence that science needs three kinds of freedoms: freedom of speech, including freedom to teach and publish; freedom to research and work on problems of one's choosing; and more generally a social tolerance of independent thinking.

For Einstein, and for Xu, this academic freedom requires a democratic political system; science demands democracy. When Xu moved to publish his Einstein translation in 1957, he was banished to the countryside, and there spent 20 years living as a peasant farmer. He was only rehabilitated in 1979 by Deng Xiaoping and resumed his chair of history of science at Beijing University.

A Personal Story

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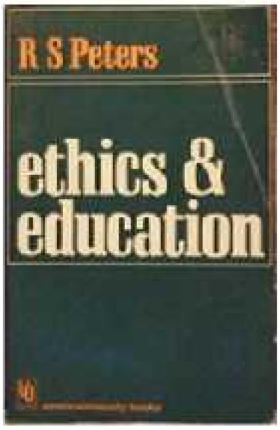
Autobiographical: Sydney University & Sydney Teachers College

Science method
& Philosophy of Education

Richard Stanley Peters



Initially I was trained in science at Sydney University, graduating in 1967. I then completed a teacher education programme that happily included a compulsory one-semester course on ‘Philosophy of Education’. This course consisted of a detailed reading and assessment of Richard Stanley Peters then just-published book *Ethics and Education* (Peters 1967). Peters was professor of philosophy and of education at the University of London.

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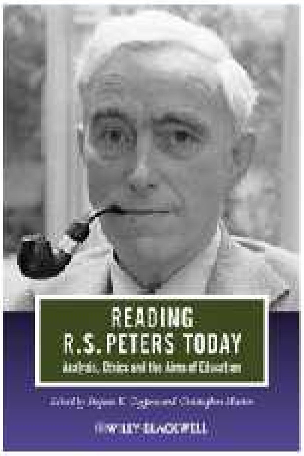
Richard Peters on Education

- Cognitive requirements
  1. intellectual breadth (not narrow or specialised)
  2. intellectual depth or understanding
- Ethical requirements
  procedures
  outcomes
- *“Nothing so practical as a good philosophy of education”*



The book’s core argument was that education, as distinct from training, or coaching or indoctrination, had both cognitive and moral dimensions. The cognitive dimension required both *depth* and *width* of understanding of subject matter. It was this early exposure to philosophy of education that set me upon the HPS&ST trajectory which has characterised my teaching and research life. For me, there was nothing so practical as a good philosophy of education.

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Lecturer in Philosophy of Education UNSW (1975-)

- Analytic philosophy of education
- Theories of knowledge and theories of learning
- Connecting philosophy to psychology for teachers
- Philosophy of education for science teachers
- Beginning of HPS & ST research

I spent some years as a high school science teacher, and then some more years as a lecturer in philosophy of education at Sydney Teachers College, before appointment to the University of New South Wales in 1975 as a lecturer in the School of Education, with responsibility for teaching philosophy to trainee science teachers. During these years I completed higher degrees in philosophy, psychology, philosophy of education, and the history and philosophy of science.

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Boston University Centre for History and Philosophy of Science (1978)

- Faculty appointed across disciplines:
- Philosophy and Physics, Philosophy and Sociology, Philosophy and Biology, Philosophy and Education, Philosophy and Mathematics, Philosophy and Theology.

These further studies included a most valuable leave period (1978) at the famous Boston University Centre for History and Philosophy of Science where it was common practice to have staff appointed across disciplines: Philosophy and Physics, Philosophy and Sociology, Philosophy and Biology, Philosophy and Education, Philosophy and Mathematics, and Philosophy and Theology. This arrangement built mutuality and close knowledge between disciplines into philosophy. Students in turn benefited from this BU arrangement.

For what it is worth, some detail of my own educational trajectory can be read in Matthews (2009) and in a 2010 interview with Yalçin Yalaki and Gültekin Çakmakci published in *The Eurasian Journal of Mathematics, Science & Technology Education* (Yalaki & Cakmaci 2010), OMIT

Editorship of *Science & Education* Journal

Through the 1980s I published different papers and books on HPS&ST, and made presentations on the subject at many HPS conferences, philosophy of education conferences, and at science education conferences.

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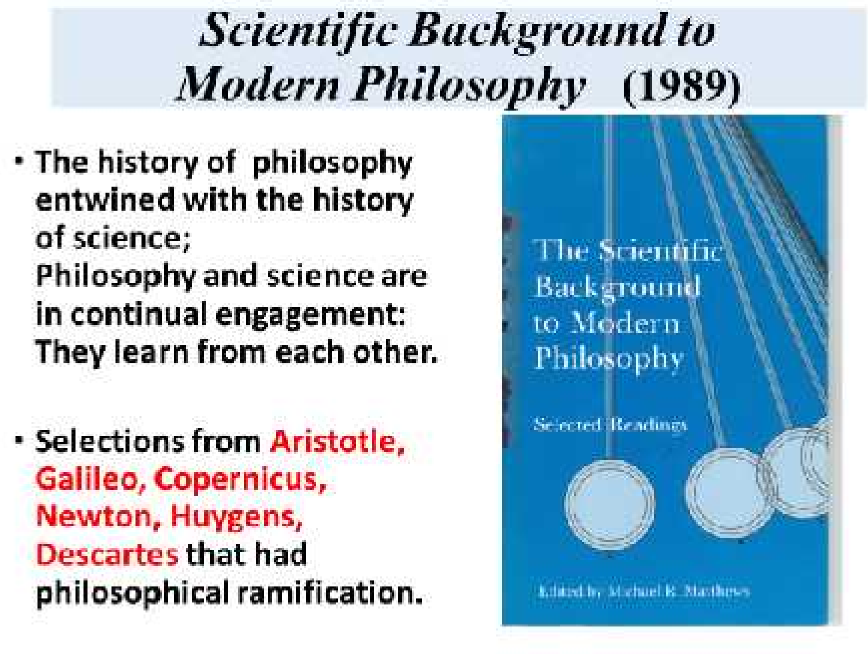

Of particular note was the publication in 1987 of my anthology *The Scientific Background to Modern Philosophy* (Matthews 1987) which provided a selection of the scientific texts of Copernicus, Galileo, Boyle, Descartes, Huygens, and Newton that influenced the well-known early modern Western philosophers. For the most part, philosophy courses dealt with these philosophers in a manner that simply left out the crucial scientific writings of the time with which they were all engaged. The book did resonate with the philosophy community as 40,000+ copies were sold in its first ten years.

The connection of this work to education was that as the above names were all found in science textbooks, and students around the world learnt something of their contributions to science, then learning something of their philosophical impacts would be of benefit to their education and to their sense of belonging to an important tradition of human thinking. Science had more significance than just learning how to make bombs or produce genetically modified foods.

This educational argument applied with even greater force to science teachers: if they are teaching about Galileo, Boyle, Huygens, Hooke, Newton and other figures of the Scientific Revolution, then they would benefit and be enhanced by knowing of the wider cultural impact of these individuals. And, of course, the very same argument applies to the cultural and philosophical impact of modern scientists whose names are etched into textbooks: Darwin, Mach, Einstein, Planck, Heisenberg, and others.

Their work impacted on philosophy, and in turn was influenced by philosophy. This symbiotic relation can be made known to students. And beyond this, teachers can be encouraged to appreciate and value the 'big cultural picture' of the subject they teach. Without science teachers, there would be no science; and the better and more informed and enthusiastic the teachers, the stronger and more appreciated the scientific tradition will be.

At the time I also published an anthology of some of the extant research literature on HPS&ST: *History, Philosophy and Science Teaching: Select Readings* (Matthews 1991). This included papers by the philosophers Ernan McMullin, Michael Martin, Jane Martin and Abner Shimony. OMIT

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In 1990, I was invited by Springer Publishers to edit their new journal *Science & Education: Contributions from History and Philosophy of Science*. The first issue of the journal appeared in 1992, and I edited the journal for its first 25 years (Matthews 2015b).

Ennis's six questions listed at the outset are perennial for science teachers, but they do not exhaust the field of HPS&ST concerns. Philosophers have usefully contributed to pedagogical problems, to curricular discussions and to debate about theoretical issues such as the following: feminist critiques of science, multiculturalism and science, evaluation of constructivist theory, environmental ethics, the nature of science, science and religion, and others.

One of the founding principles of the journal, and so of the HPS&ST programme is that these are not extracurricular or add-on questions for science teachers: philosophy of science is part of the fabric of science teaching. And students acquire or ‘pick up’ a philosophy of science from their teachers. The only issue is just how clearly this is recognised and how explicitly the philosophical questions are dealt with.

The reputation and impact of the journal grew continuously, and in just the one year, 2011, there were 108,650 article downloads from its Springer site. This is one indicator of the international interest among researchers in HPS&ST questions.

The range of connections between HPS and science education research can be seen in the titles of the thematic special issues of the journal that have been published. These include:

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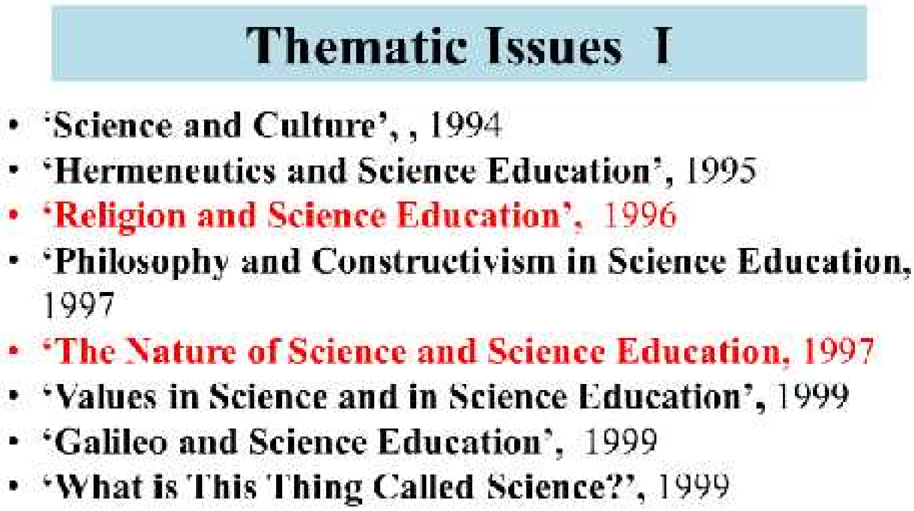

‘Science and Culture’, 3(1), 1994,
‘Hermeneutics and Science Education’, 4(2), 1995,
‘Religion and Science Education’, 5(2), 1996,
‘Philosophy and Constructivism in Science Education’, 6(1-2), 1997,
‘The Nature of Science and Science Education’, 6(4), 1997
‘Values in Science and in Science Education’, 8(1), 1999,
‘Galileo and Science Education’, 8(2), 1999,
‘What is This Thing Called Science?’, 8(4), 1999,

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'Children's Theories and Scientific Theories', 8(5), 1999,
'Thomas Kuhn and Science Education', 9(1-2), 2000,
'**Constructivism and Science Education', 9(6), 2000,**
'History, Philosophy and the Teaching of Quantum Theory', 12(2-3), 2003,
'**Science Education and Positivism: A Re-evaluation', 13(1-2), 2004,**
'Pendulum Motion: Historical, Methodological and Pedagogical Aspects', 13(1-2, 7-8), 2004,
'Science Education in Early Modern Europe', 14(3-4), 2005,
'Models in Science and in Science Education', 16(7-8), 2007,
'Teaching and Assessing the Nature of Science', 17 (2-4), 2008,

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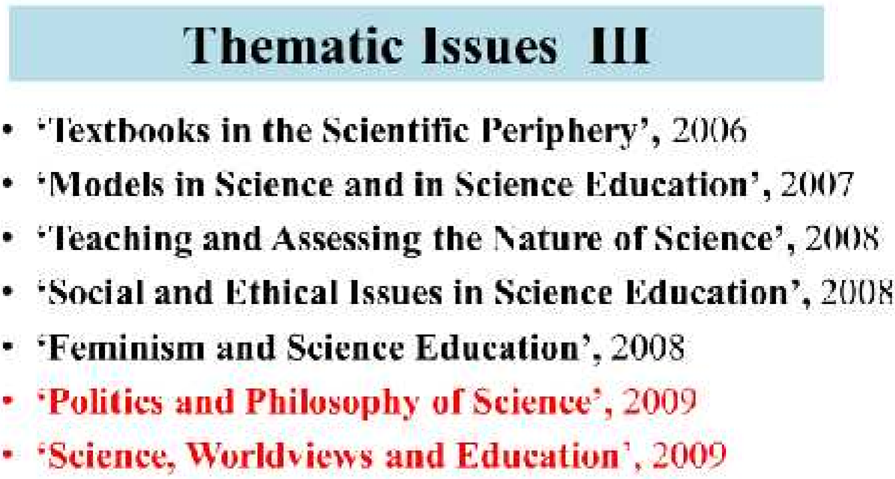

‘Social and Ethical Issues in Science Education’, 17(8-9), 2008,
‘Feminism and Science Education’, 17(10), 2008,
‘**Politics and Philosophy of Science’, 18(2), 2009,**
‘**Science, Worldviews and Education’, 18(6-7), 2009,**
‘Darwinism and Education’ 19(4-5, 6-8), 2010,

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Thematic Issues IV

- **‘Darwinism and Education’**, 2010
- **‘Science and Pseudoscience in Society and Classrooms’**, 2011
- **‘Popularising and Policing Darwinism 1859-1900’**, 2012
- **‘Mario Bunge: Evaluations of His Systematic Philosophy’**, 2012
- **‘Philosophical Considerations in the Teaching of Biology’**, 2013
- **‘Philosophical Considerations in the Teaching of Chemistry’**, *Science & Education* 2013
- **‘Commercialisation and Commodification of Science: Philosophical and Educational Issues’**, 2013

‘**Science and Pseudoscience in Society and Classrooms’ 20(5-6), 2011,**
‘Popularising and Policing Darwinism 1859-1900’, 21(7), 2012,
‘Mario Bunge: Evaluations of His Systematic Philosophy’, 21(10), 2012,
‘Philosophical Considerations in the Teaching of Biology’, 22 (1-3), 2013,
‘Philosophical Considerations in the Teaching of Chemistry’, *Science & Education* 22(7), 2013,
‘**Commercialisation and Commodification of Science’, 22(10), 2013,**
‘Philosophy and Mathematics Education’, 23(1), 2014,

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Thematic Issues V

- **'Philosophy and Mathematics Education'**, 2014
- **'Genetics and Society'**, 2014
- **'Literature and Science Education'**, 2014
- **'History of Science in Museums'**, 2014
- **'Energy Conservation: History, Philosophy and Education'**, 2014
- **'Mendel, Mendelism and Education'**, 2015
- **'Physics and Mathematics: Historical, Philosophical and Pedagogical Relations'**, 2015

'Genetics and Society', 23(2), 2014,
Energy Conservation: History, Philosophy and Education', 2014
'Literature and Science Education', 23(3), 2014,
'Mendel, Mendelism and Education', 24(1-2), 2015,
'Physics and Mathematics: Historical, Philosophical and Pedagogical Relations', 24(4-5), 2015,

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Journal Springer Site

- **http://www.springer.com/education/science+education/journal/11191**

The Contents of all the above thematic issues can be downloaded from the journal's Springer site:
http://www.springer.com/education/science+education/journal/11191

Routledge book: ***Science Teaching: The Role of History and Philosophy of Science***

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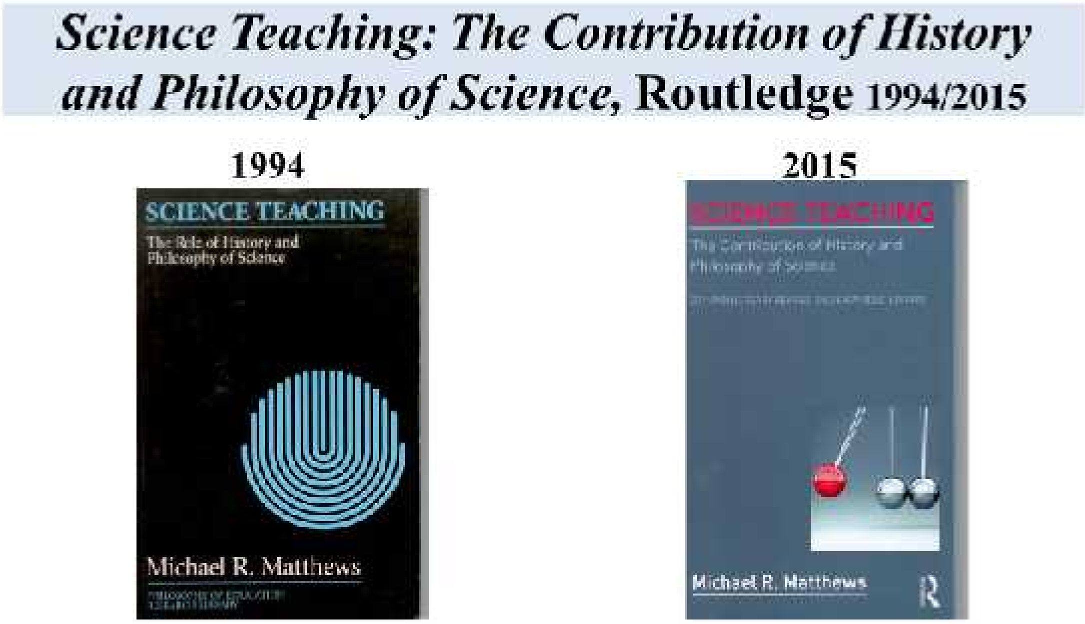

The publication history of my own book - *Science Teaching: The Role of History and Philosophy of Science* (Routledge 1994) – reflects something of the recent history of the HPS&ST research programme and perhaps is worth noting.

In early 1989 I discussed HPS&ST research with Professor Israel Scheffler at Harvard who then offered me a contract for his Routledge Philosophy of Education book series. The book's modest purpose was stated in its opening sentence:

> This book seeks to contribute to science teaching and science teacher education by bringing the history and philosophy of science and science teaching into closer contact.

It is noteworthy that the book appeared in Routledge's 'Philosophy of Education Research Library'. At the time HPS&ST was simply off the radar of science education publishing. This was clear in the content of the Robert Ennis (1979) and Richard Duschl (1986) articles mentioned above. But my book appeared at a propitious time; the HPS&ST research tide was turning. The book stayed in print, and Greek (2007) and Korean (2013) translations were published. Its 2015 Google Scholar citations (1,250) indicated wide usage; indeed, Google listed it as the most cited science education book of the period. OMIT

Routledge proposed a second, expanded, revised edition of the book, and a contract for such was signed in June 2011. The book - *Science Teaching: The Contribution of History and Philosophy of Science* – was published in 2015 (Matthews 2015a). It is no longer off the science education radar but part of Routledge's science education list (www.routledge.com/9780415519342).

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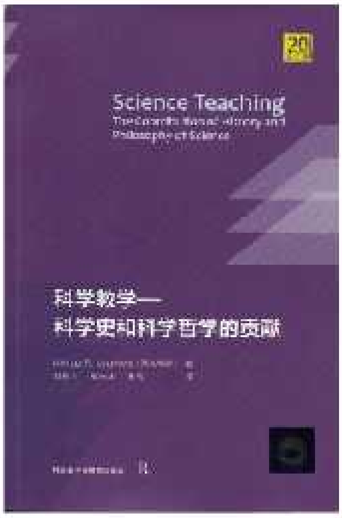
Michael R. Matthews
Science Teaching: The Contribution of HPS
Routledge (1994, 2014), FLTRP (2017)

- **FLTRP web site**
  http://zengzhi.fltrp.com/c/2017-08-03/497560.shtml
- **Amazon web site**
  https://www.amazon.cn/gp/aw/d/B071YLMW4D/ref=mp_s_a_1_1?mk_zh_CN=%E4%BA%9A%E9%A9%AC%E9%80%8A%E7%BD%91%E7%AB%99&qid=1508312584&sr=8-1&pi=AC_SX118_SY170_QL70&keywords=%E7%A7%91%E5%AD%A6%E6%95%99%E5%AD%A6+%E7%A7%91%E5%AD%A6%E5%8F%B2%E5%92%8C%E7%A7%91%E5%AD%A6%E5%93%B2%E5%AD%A6%E7%9A%84%E8%B4%A1%E7%8C%AE&dpPl=1&dpID=41-SXKJm1XL&ref=plSrch



Pleasingly there have been Greek (2007, first edition), Korean (2013, first edition), Turkish (2017), Spanish (2017) and now Chinese editions (Foreign Language Technical and Research Press, (http://en.fltrp.com/) of the book. Translation of the Chinese edition was overseen by Professor Enshan Liu from Beijing Normal University.

[25] OMIT

Book's Structure

- * Arguments for the role of HPS in science education.
- * Examining the successes and failures of previous efforts to bring HPS into closer connection with the science program.
- * Elaborating case studies where the contrast between HPS and 'professional' or 'technical' approaches to science teaching and curricula development can be evaluated.
- * Examining instances of theoretical debates in science education – constructivism, feminism, multiculturalism, worldviews, and nature of science - that can be clarified and informed by HPS.
- * Outlining the contribution that HPS can make to science teacher education.

The book's argument is that the history and philosophy of science has a significant contribution to make to three domains in science education: theoretical, curricular and pedagogical. More specifically the book contributed to HPS&ST by:

* Outlining the arguments for the role of HPS in science education.
* Reviewing the history of school science curricula in order to situate the claims of HPS-informed teaching against other approaches to science pedagogy.

* Examining the successes and failures of previous efforts to bring HPS into closer connection with the science program.
* Elaborating some case studies where the contrast between HPS and 'professional' or 'technical' approaches to science teaching and curricula development can be evaluated.
* Examining some instances of prominent theoretical debates in science education – constructivism, feminism, multiculturalism, worldviews, and nature of science - that can be clarified and informed by HPS.
* Outlining the contribution that HPS can make to science teacher education. OMIT

Springer *International Handbook of HPS&ST Research*
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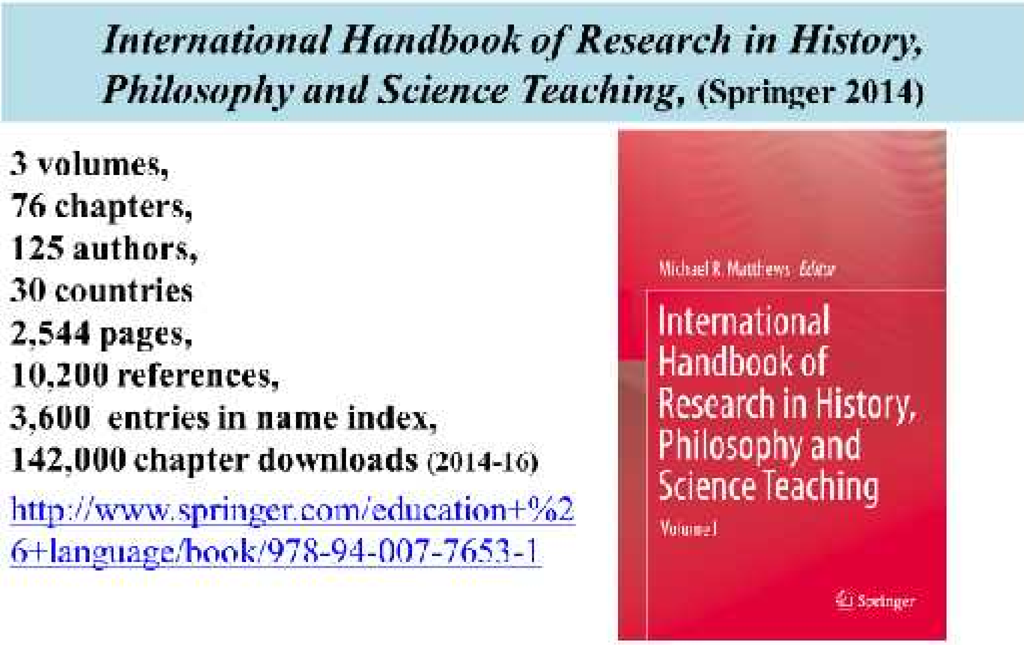

To celebrate the 25th anniversary of *Science & Education* journal, Springer commissioned me to bring together and edit an *International Handbook of Research in History, Philosophy, and Science Teaching* (Matthews 2014).

(See: http://www.springer.com/education+%26+language/book/978-94-007-7653-1)

The handbook is in 3 volumes, having 76 chapters, 2,544-pages, 10,200 references, and 3,600 entries in its Name Index. Its 125 authors come from 30 countries. In its first three years there have been 142,000+ chapter-downloads from its Springer site. This is another indicator of the international reach and impact of the HPS&ST programme.

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PART IV: BIOGRAPHICAL STUDIES (5)

ERNST MACH
FREDERICK W. WESTAWAY
ERIC J. HOLMYARD
JOHN DEWEY
JOSEPH SCHWAB

The handbook is structured in four sections: pedagogical (24 chapters), theoretical (33 chapters), national (11 chapters), and biographical (5 chapters) research. Each chapter sets the relevant literature in its historical context, and engages in an assessment of the strengths and weakness of the research addressed, and suggests potentially fruitful avenues of future research.

The contents of the handbook are as follows:

Section One: Pedagogical Studies

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Part I Physics
Pendulum Motion: A Case Study in How History and Philosophy Can Contribute to Science Education
Using History to Teach Mechanics
Teaching Optics: A Historico-Philosophical Perspective
Teaching and Learning Electricity: The Relations Between Macroscopic Level Observations and Microscopic Level Theories
The Role of History and Philosophy in Research on Teaching and Learning of Relativity
Meeting the Challenge: Quantum Physics in Introductory Physics Courses
Teaching Energy Informed by the History and Epistemology of the Concept with Implications for Teacher Education
Teaching About Thermal Phenomena and Thermodynamics: The Contribution of the History and Philosophy of Science OMIT

Part II Chemistry
Philosophy of Chemistry in Chemical Education: Recent Trends and Future Directions
The Place of the History of Chemistry in the Teaching and Learning of Chemistry
Historical Teaching of Atomic and Molecular Structure

Part III Biology

History and Philosophy of Science and the Teaching of Evolution: Students' Conceptions and Explanations
History and Philosophy of Science and the Teaching of Macroevolution
Twenty-First-Century Genetics and Genomics: Contributions of HPS-Informed Research and Pedagogy
The Contribution of History and Philosophy to the Problem of Hybrid Views About Genes in Genetics Teaching

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Cultural Studies in Science Education: Philosophical Considerations
Science Education in the Historical Study of the Sciences .

Section Three Regional Studies

Part XIII Regional Studies
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The History and Philosophy of Science in Science Curricula and Teacher Education in Canada
History and Philosophy of Science and the Teaching of Science in England
Incorporation of HPS/NOS Content in School and Teacher Education Programmes in Europe
History in Bosnia and Herzegovina Physics Textbooks for Primary School: Historical Accuracy and Cognitive Adequacy
One Country, Two Systems: Nature of Science Education in Mainland China and Hong Kong
Trends in HPS/NOS Research in Korean Science Education .
History and Philosophy of Science in Japanese Education: A Historical Overview
The History and Philosophy of Science and Their Relationship to the Teaching of Sciences in Mexico
History and Philosophy of Science in Science Education, in Brazil -
Science Teaching and Research in Argentina: The Contribution of History and Philosophy of Science

Section Four: Biographical Studies

Part XIV Biographical Studies
Ernst Mach: A Genetic Introduction to His Educational Theory and Pedagogy
Frederick W. Westaway and Science Education: An Endless Quest
E. J. Holmyard and the Historical Approach to Science Teaching
John Dewey and Science Education
Joseph J. Schwab: His Work and His Legacy

Just my own two contributions from the handbook can be pointed to in order to flesh out some of the contents:

Pedagogical Studies: Physics I

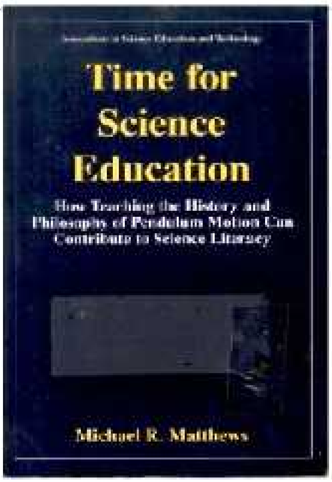
- **Pendulum Motion: A Case Study in How HPS Can Contribute to Science Education**
  Michael R. Matthews
- **Using History to Teach Mechanics**
  Colin Gauld
- **Teaching Optics: A HPS Perspective**
  Igal Galili
- **Teaching and Learning Electricity: The Relations Between Macroscopic Level Observations and Microscopic Theories**
  Jenaro Guisasola

[29]

Matthews Pendulum Books

- **13 chapters**
- **1,200 references**
- **The pendulum was foundational for the creation of modern European science.**
- **Galileo, Newton, Huygens**
- **Huygen's seconds' pendulum as international unit of length, the metre**

2000



Teaching Pendulum Motion from the Pedagogy section and Seconds Pendulum demonstration

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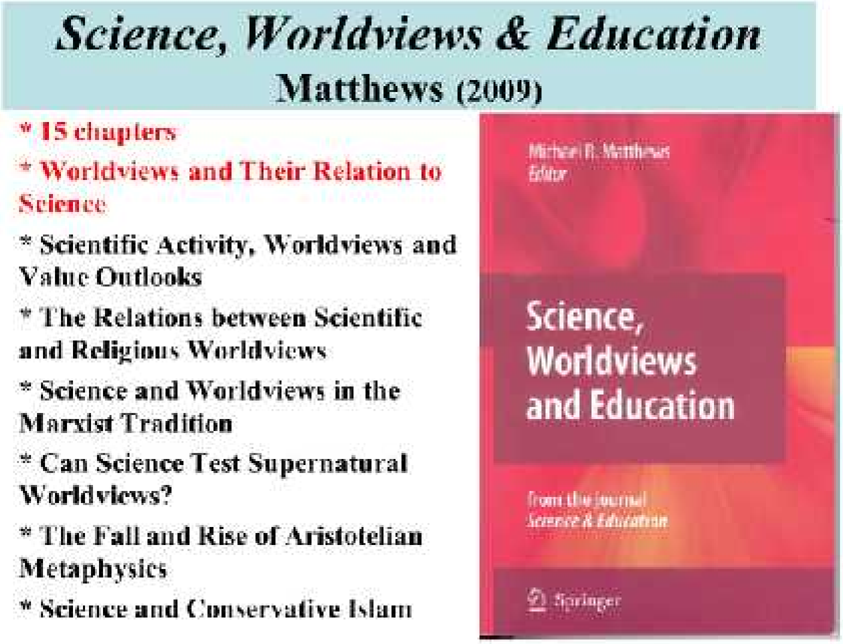

#Teaching Worldviews from the Theoretical section.

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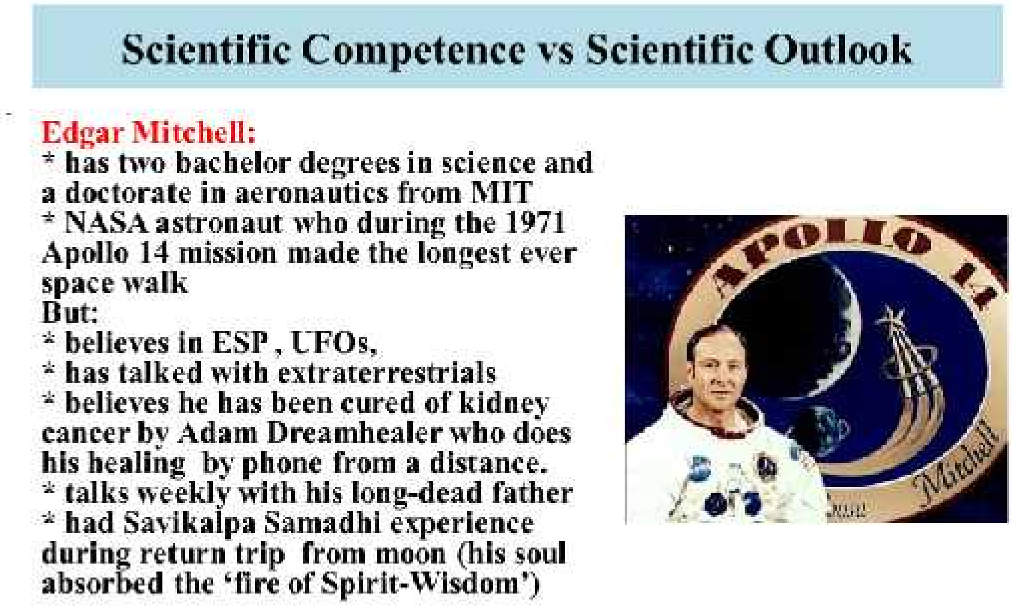

The content of both these chapters is also included in the translated *Science Teaching* book.

History, Philosophy and Technical Education

The rapprochement between HPS and science education is not only dependent on having a liberal view of science education: a good technical science education also requires some integration of history and philosophy into the program. Knowledge *of* science entails knowledge of scientific facts, laws, theories - the *products* of science; it also entails knowledge of the *processes* of science - the social, technical and intellectual ways in which science develops and tests its knowledge claims.

HPS is important for the understanding of these process skills. Technical - or 'professional' or 'disciplinary' as it is sometimes called - science education is enhanced if students know the meaning of terms that they are using; if they can think critically about texts, reports and their own scientific activity; if they know how certain evidence relates or does not relate to hypotheses being tested; if they can intelligently and carefully represent data and argue from data to phenomena; and if they can discuss, argue and advance thinking among their colleagues.

These scientific abilities are enhanced if students have read examples of sustained inquiry, clever experimentation, insightful hypotheses, and exemplary debates about hypothesis evaluation and testing.

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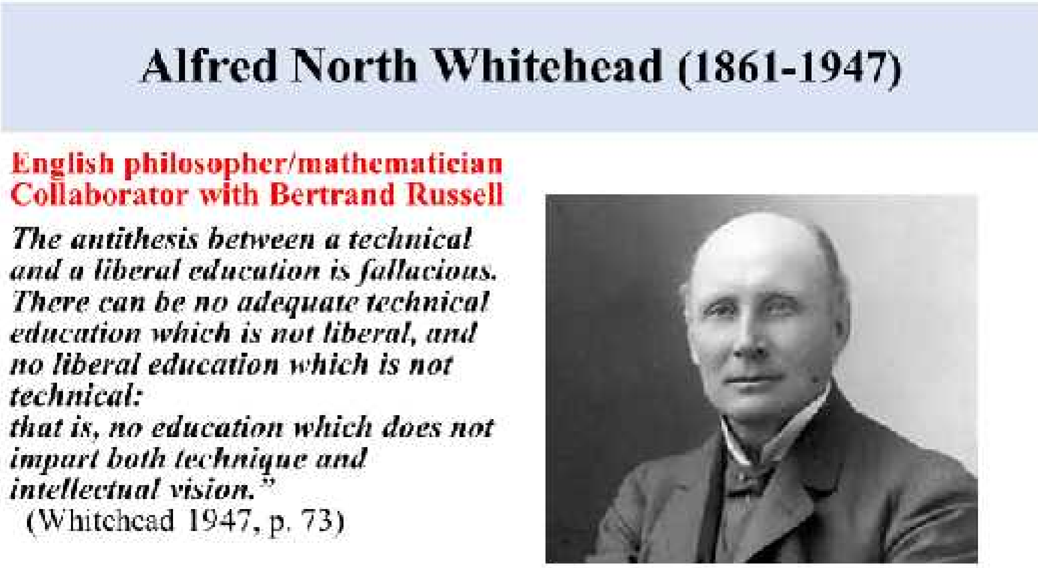


Alfred North Whitehead expressed this view of good technical education when, just after World War Two, he said:

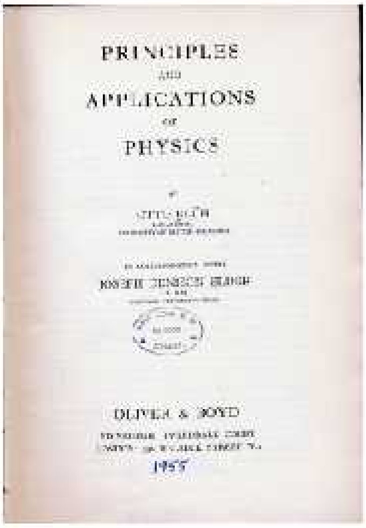
> The antithesis between a technical and a liberal education is fallacious. There can be no adequate technical education which is not liberal, and no liberal education which is not technical: that is, no education which does not impart both technique and intellectual vision. (Whitehead 1947, p.73)

[33]

Otto Blüh (1955)

…. the education of a scientist can be advanced most effectively by giving a significant place to the philosophical, social, and moral implication of physical science *within* the physics curriculum rather than through supplementary so-called humanistic and social studies.

Such course work or reading, valuable in itself, will make its mark on the scientist's intellectual and cultural development only if it is intimately related to his scientific studies proper. (p.vii)



Otto Blüh, a German physicist who was significantly influenced by Ernst Mach, made much the same point in his 1955 physics textbook, where he wrote:

> …. the education of a scientist can be advanced most effectively by giving a significant place to the philosophical, social, and moral implication of physical science *within* the physics curriculum rather than through supplementary so-called humanistic and social studies.
>
> Such course work or reading, valuable in itself, will make its mark on the scientist's intellectual and cultural development only if it is intimately related to his scientific studies proper. (Blüh & Elder 1955, p.vii)

To teach Boyle's Law without reflection on what 'law' means in science, without considering what constitutes evidence for a law in science, and without attention of who Boyle was, when he lived, and what he did - is to teach in a disappointingly truncated way. More can be made of the educational moment than merely teaching, or assisting students to discover that for a given gas at a constant temperature, pressure multiplied by volume is a constant. This is something, but it is minimal.

Similarly, to teach Darwinian evolutionary theory without considerations concerning theory and evidence, the roles of inductive, deductive and abductive reasoning, Darwin's life and times and the religious, literary and philosophical controversies his theory occasioned - is also limited.

Students doing and interpreting experiments need to know something of how description of data relies upon theory, how evidence relates to the inductive support or deductive falsification of hypotheses, how real cases relate to ideal cases in science, how messy 'lived experience' connects with abstracted and idealised scientific theories, and a host of other matters which all involve philosophical or methodological concerns.

Science has a rich and influential history, and it is replete with philosophical and cultural ramifications. An education in science should present students with something of this richness, and engage them in some of the big questions that have consumed scientists.

Curriculum Developments

Of great moment for the HPS&ST programme is the inclusion of history and philosophy of science components in various national school curricula.

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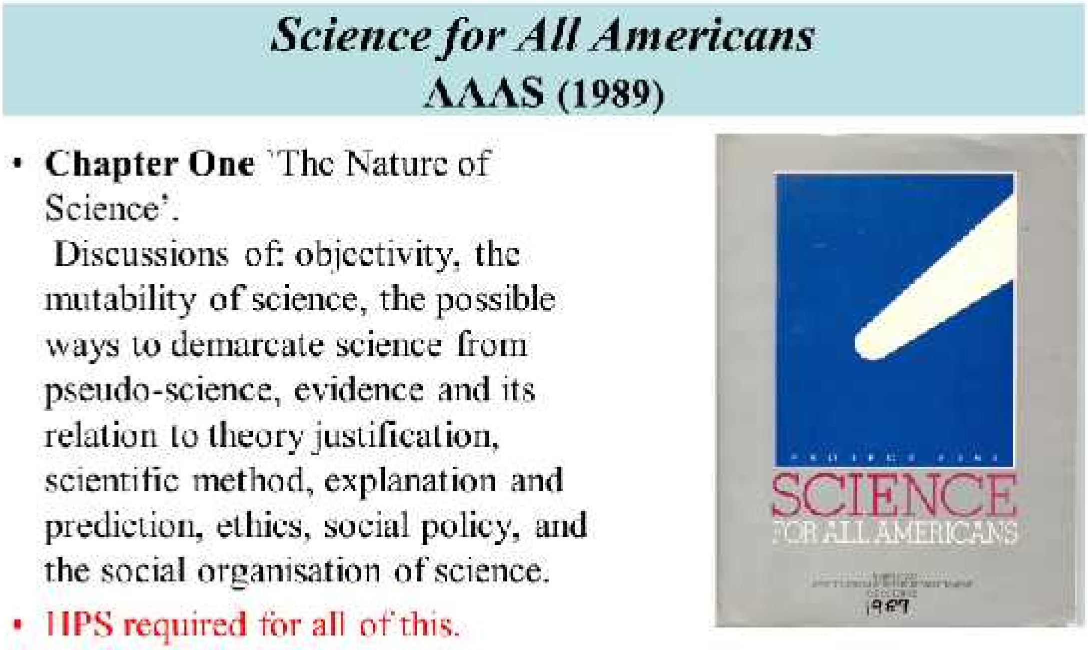


The American Association for the Advancement of Science (AAAS) established in 1985 an extensive national study, Project 2061, to recommend an overhaul of school science. In 1989, after four years of deliberation and consultation, the project published its recommendations in a report titled *Science for All Americans* (AAAS 1989). The report contains 12 chapters giving the recommendations for school science of the National Council on Science and Technology Education.

Chapter One is on `The Nature of Science'. It includes discussions of objectivity, the mutability of science, the possible ways to demarcate science from pseudo-science, evidence and its relation to theory justification, scientific method, explanation and prediction, ethics, social policy, and the social organisation of science. The intention is that these themes be developed and discussed within science courses and that pupils completing school science know something of them; the intention is not that the topics be added to science courses and HPS be substituted for science content knowledge.

[35]

Science for All Americans
AAAS (1989)

- **Chapter Ten** on `Historical Perspectives' says: ``There are two principal reasons for including some knowledge of history among the recommendations.
  One reason is that generalizations about how the scientific enterprise operates would be empty without concrete examples.'

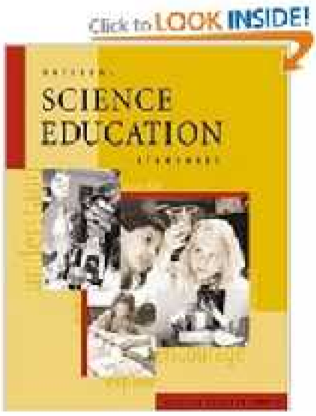
  A second reason is that some episodes in the history of the scientific endeavour are of surpassing significance to our cultural heritage. Such episodes certainly include Galileo's role in changing our perception of our place in the universe'.

Chapter Ten on `Historical Perspectives' says: `There are two principal reasons for including some knowledge of history among the recommendations. One reason is that generalizations about how the scientific enterprise operates would be empty without concrete examples.' It goes on to say that:`A second reason is that some episodes in the history of the scientific endeavour are of surpassing significance to our cultural heritage. Such episodes certainly include Galileo's role in changing our perception of our place in the universe'.

[36] **OMIT**

US National Science Education Standards (1996)

- **science contributes to culture**
- **scientific literacy also includes understanding the nature of science, the scientific enterprise, and the role of science in society and personal life**
- **tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach conclusions that we currently take for granted**
- **progress in science and technology can be affected by social issues and challenges (NRC 1996, p. 199).**
- **All above require IIPS**



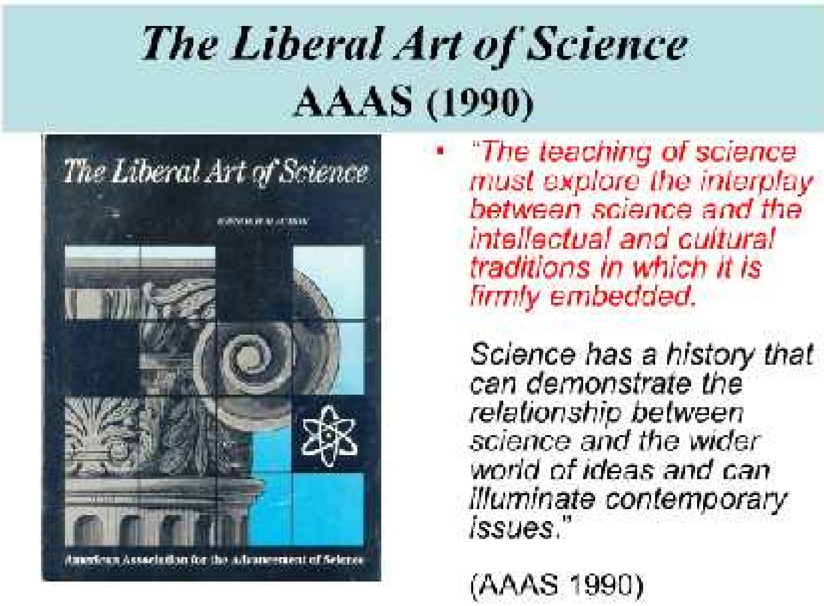
Following the AAAS report, in the USA the first ever National Science Education Standards were published by the National Research Council in 1996 (NRC 1996). They recognise the centrality of philosophical and historical knowledge in the teaching of science, maintaining for instance that students should learn how:

> science contributes to culture (NRC 1996, p. 21);
> curriculum will often integrate topics from different subject-matter areas … and from different school subjects – such as science and mathematics, science and language arts, or science and history (NRC 1996, p. 23);
> scientific literacy also includes understanding the nature of science, the scientific enterprise, and the role of science in society and personal life (NRC 1996, p. 21);
> effective teachers of science possess broad knowledge of all disciplines and a deep understanding of the disciplines they teach (NRC 1996, p. 60);
> tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach conclusions that we currently take for granted (NRC 1996, p. 171);
> progress in science and technology can be affected by social issues and challenges (NRC 1996, p. 199).

These aspirations for science classrooms cannot be achieved without teachers who care about HPS and have some competence in it. A position paper of the US Association for the Education of Teachers in Science, the professional association of those who prepare science teachers, has recognised this in its own recommendation that:

> *Standard 1d*: The beginning science teacher educator should possess levels of understanding of the philosophy, sociology, and history of science exceeding that specified in the [US] reform documents. (Lederman et al. 1997, p. 236)

[37] **OMIT**



The American Association for the Advancement of Science provides a nice summation of the foregoing curricular initiatives when it said in its 1990 *The Liberal Art of Science*

> Science courses should place science in its historical perspective. Liberally educated students - the science major and the non-major alike - should complete their science courses with an appreciation of science as part of an intellectual, social, and cultural tradition. . . . Science courses must convey these aspects of science by stressing its ethical, social, economic, and political dimensions. (AAAS 1990, p. 24) OMIT

Comparable HPS-related curricula statements, or ‘aspirations’ as one might say, are to be found in numerous other national statements, as have been documented in the National Studies section of the *HPS&ST Research Handbook* (Matthews 2014). It should be obvious that for the realisation of the aims of all of these curricula there needs HPS input into documents, teaching materials, assessment schemes, textbooks and teacher education.

Teacher Education

Teacher education is not in good philosophical health. Despite all the concerns and arguments, competence in philosophy and more specifically HPS is rare in Schools of Education, nor is attainment of such competence much encouraged.

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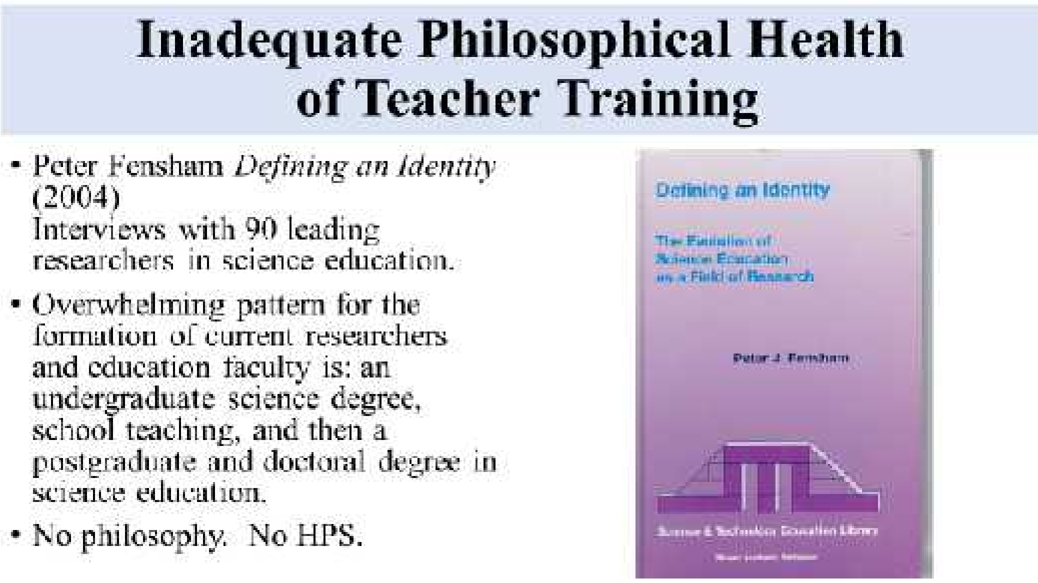

The paucity of serious HPS input into science teacher education is depressingly well documented in Peter Fensham’s book *Defining an Identity* (Fensham 2004). His interviews with leading researchers in the field reveal that the overwhelming pattern for the formation of current researchers and education faculty is: an undergraduate science degree, school teaching, and then a postgraduate and doctoral degree in science education. No philosophy. No HPS. Finding a space for HPS in this typical career trajectory of university science education faculty is difficult.

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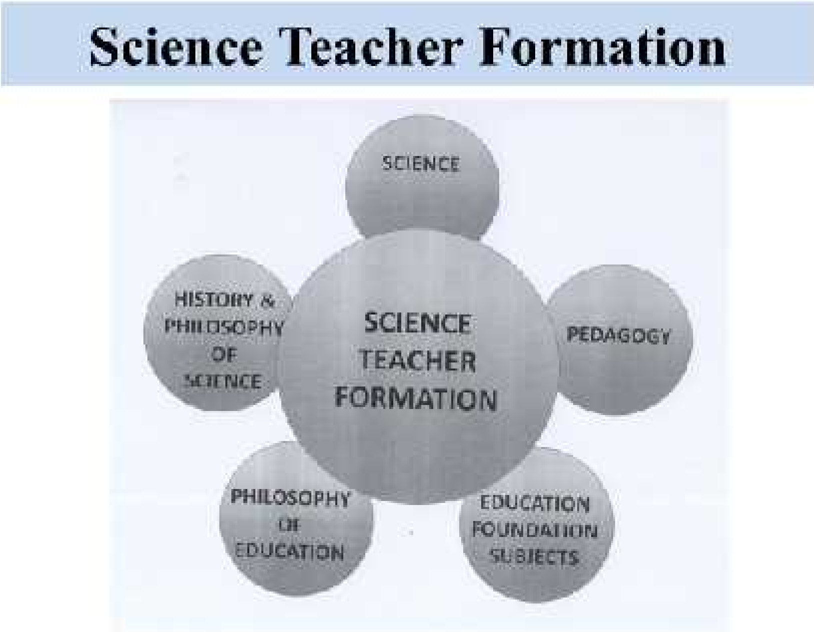
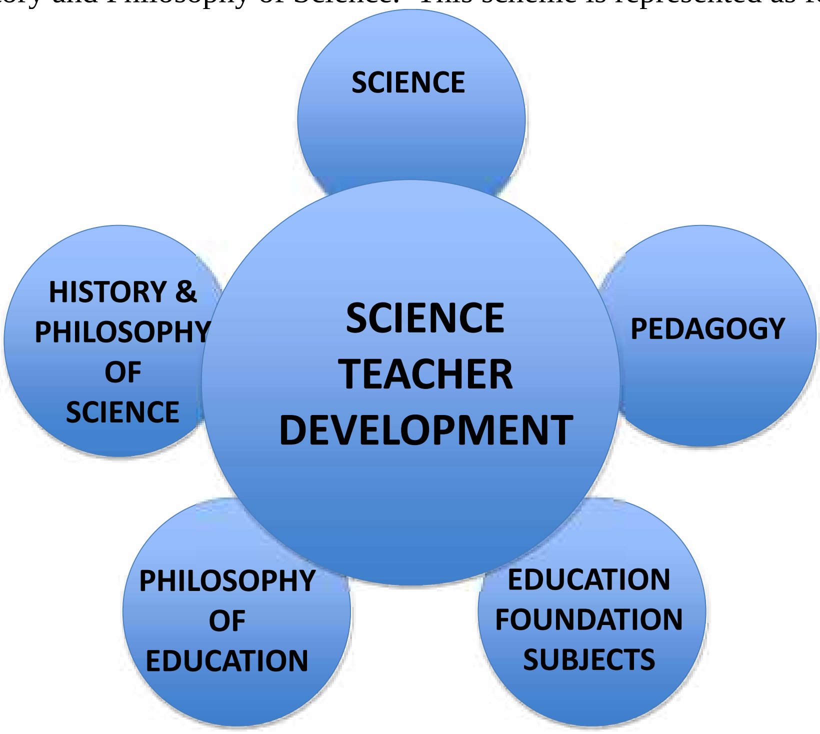


Ideally a programme of teacher education should include input from: Science subjects, Pedagogy subjects and training, Educational foundation subjects, Philosophy of Education, and History and Philosophy of Science. This scheme is represented as follows:



One possible corrective for graduate students is that instead of science teachers doing higher degrees in education after their first or postgraduate degree in science, they could be encouraged to do an undergraduate degree in an appropriate foundation discipline (philosophy, psychology, history, etc.); after that do a PhD in Education. This is good for their personal growth and intellectual development, it might possibly interest students they are teaching; and it is ultimately beneficial to whatever education research programme in which they might engage.

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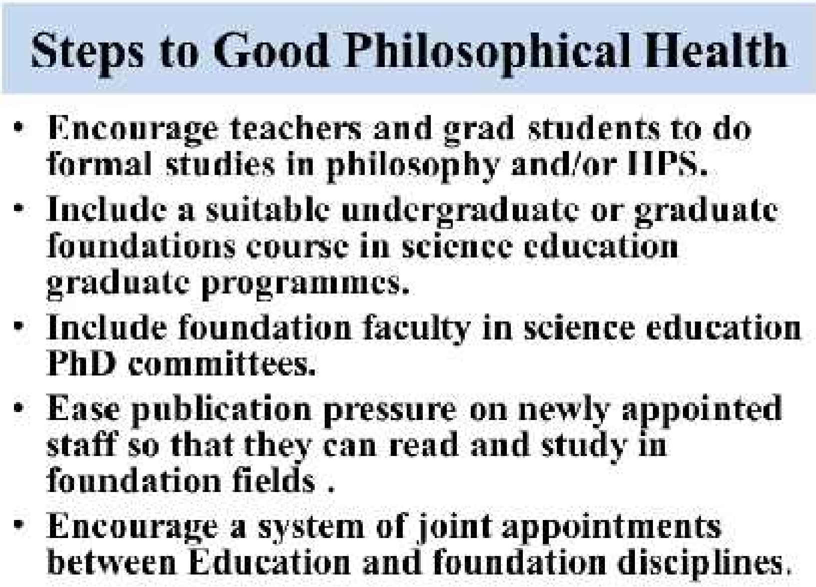

This option worked for me. After my science degree and teacher training, and while school teaching, I completed honours degrees in psychology and philosophy, and then a higher degree in HPS and the PhD in Education while a UNSW faculty member. The years spent outside of education gave me a much better grasp of debates and research within education.

For example, my different studies on the history, philosophy, and social utilisation of pendulum motion (2000, 2005, 2015 chap.6) - had their origin in a graduate philosophy of science course taught by Abner Shimony at Boston University in 1978, where for 14 weeks the only thing read was Galileo's *Dialogues Concerning the Two Chief World Systems*. This opened up the whole fascinating, and scientifically pivotal world, of pendulum motion – as Richard Westfall, Newton's biographer, remarked 'without the pendulum, there would be no *Principia*' (1990, p.82).

Without the HPS detour, I might have been doing a routine study of how students learn the pendulum formulae, or videoing students brain-storming and then arguing over explanations of the pendulum's movement. The latter is important enough, but it is only a small part of the pendulum story; the larger story comes into focus with HPS study. And this is the same for all topics in a science programme: they each have engaging historical and philosophical 'stories' that can engage students, but first the larger stories need to be known by their teachers. OMIT

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Conclusion

Science and its associated technology is the defining feature of the modern world; that they should be better understanding is an educational truism. The inclusion of history and philosophy of science in curricula, teacher education and classroom lessons does not, of course, provide all the answers to the problems of modern education - ultimately these answers lie in the heart of culture, politics and the economic organisation of societies.

But HPS in Chinese school and university science programmes can greatly contribute to the ‘Modernization of Science & Technology’ that Deng Xiaoping exhorted your country to strive for. Additionally, if such HPS-informed science spreads beyond the science class and informs all students and citizens, then as well as the fourth modernization of science, the fifth modernization, the modernization of culture, that many Chinese intellectuals call for, can be advanced.

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For instance, Yijie Tang (1927-2014) is illustrative of contemporary Chinese concerns for expanding modernization beyond the economic sphere to the modernization of politics and of thought. He was one of the most prominent Chinese philosophers of recent decades; a Beijing University professor; and director of the huge National Confucian Project involving 400 scholars working on 5,000 Confucian works. He was sympathetic to the European Enlightenment project and expressed his sympathies in an essay titled ‘The Enlightenment and Its Difficult Journey in China’ (Tang 2015c).

In 1958 he had been expelled from the Communist Party, in the 1966 Cultural Revolution he lost his teaching position at Peking University and was not allowed to resume it till 1980. After rehabilitation, Tang and like-minded scholars were engaged on the task of identifying what it was to be a ‘modern’ Chinese citizen: how to belong and contribute to the Chinese cultural tradition, yet be informed by and contribute to intellectual globalization and universalism, something so clearly required for participation in modern science.

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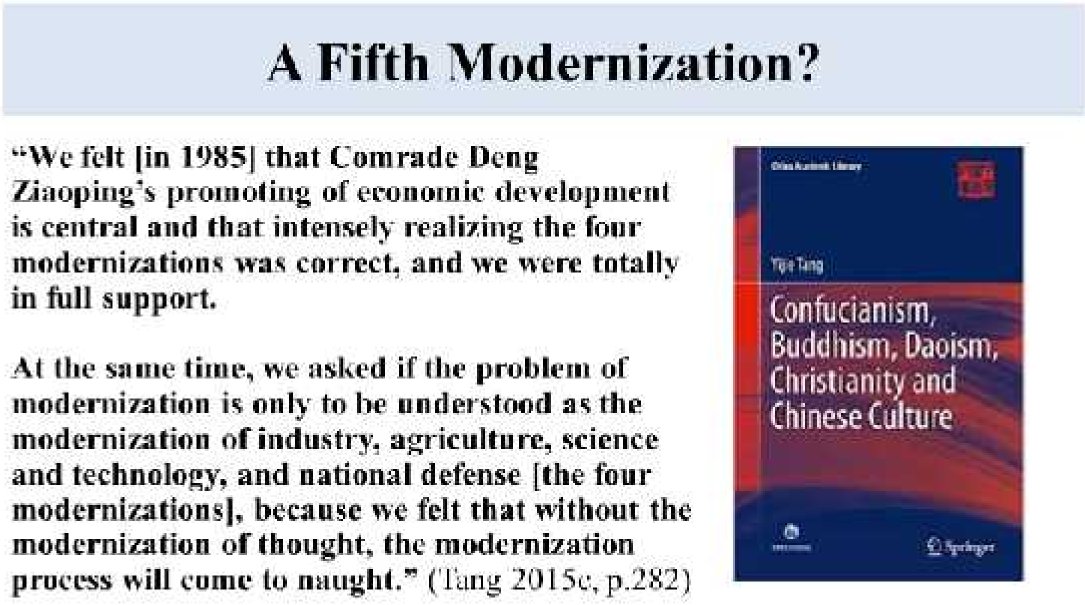

Tang wrote:

> We felt [in 1985] that Comrade Deng Ziaoping's promoting of economic development is central and that intensely realizing the four modernizations was correct, and we were totally in full support. At the same time, we asked if the problem of modernization is only to be understood as the modernization of industry, agriculture, science and technology, and national defense [the four modernizations], because we felt that without the modernization of thought, the modernization process will come to naught. (Tang 2015c, p.282)

This is one of the many challenges facing contemporary Chinese science teachers. I wish you all the very best as you address this and other challenges.

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