Chapter 39
Philosophy of Education and Science Education: A Vital but Underdeveloped Relationship

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> *It was through the feeling of wonder that men now and at first began to philosophize. … but he who asks and wonders expresses his ignorance … thus in order to gain knowledge they turned to philosophy.*
>
> —Aristotle *(Metaphysics)*

39.1 Introduction

This chapter examines the relationship between the two fields of science education and philosophy of education to inquire about how philosophy could better contribute to improving science curriculum, teaching, and learning, above all teacher education. The value of philosophy *for* science education in general remains underappreciated at both pedagogical levels, whether the research field or classroom practice. While it can be admitted that philosophy has been an area of limited and scattered interest for researchers for some time, it can be considered a truism that modern science teacher education has tended overall to bypass philosophy and philosophy of education for studies in psychology and cognitive science, especially their theories of learning and development (which continue to dominate the research field; Lee et al. 2009). A major turn encompassing philosophy would thus represent an *alternative approach* (Roberts and Russell 1975).

Science education is known to have borrowed ideas from pedagogues and philosophers in the past (e.g., from Rousseau, Pestalozzi, Herbart, and Dewey; DeBoer 1991); however, the subfield of *philosophy of education* has been little canvassed and remains on the whole an underdeveloped area. At first glance such a state of affairs may not seem all too surprising since science education is mainly concerned

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with educating students about particular science subjects or disciplines. But this necessarily implies a tight link between content and education. Hence, if education is to mean more than mere instructional techniques with associated texts to encompass broader aims including ideals about what constitutes an educated citizen (i.e., defining "scientific literacy") or foundational questions about the nature of education, learning, knowledge, or science, then philosophy *must* come into view (Nola and Irzik 2005). As is known, an *education in* science can be, and has been, associated with narrow technical training, or with wider liberal education, or with social relevance (STSE), or lately with "science for engineers" (US STEM reforms), an updated version of the older vocational interest.[1] Yet all these diverse curricular directions imply or assume a particular educational philosophy which is rarely clearly articulated (Matthews 1994a/2014; Roberts 1988; Schulz 2009a).

At second glance then, and viewing science education in a broader light, being principally at home in education unavoidably implies an excursion into philosophy of education. In fact, it avoids this subfield of philosophy at its own peril, as argued elsewhere (Matthews 2002; Schulz 2009a, b). Equally, there are lessons to be learned from its own past, yet most science teachers and too many researchers seem little aware, or even concerned to know, about the rich educational philo-historical background of science education as it has developed to the present, whether in North America, Europe, or elsewhere (some examples are Mach, Dewey, Westaway, and Schwab; DeBoer 1991; Gilead 2011; Matthews 1990b). In fact recent critical reviews insist educators must acknowledge and respond to how past historical developments have molded science education while continuing to adversely shape the current institutionalization of school science (Jenkins 2007; Rudolph 2002). A central concern of this chapter is to emphasize the value of philosophy in general and philosophy of education in particular. It will be claimed an awareness of the worth of these fields can have positive results for further defining the *identity* of both the science teacher as professional (Van Driel and Abell 2010; Clough et al. 2009) and science education as a research field (Fensham 2004). The perspective to be taken on board is that to teach science is to have a philosophical frame of mind—about the subject, about education, and about one's identity.

39.2 Philosophy of Science Education Framework

To be clear from the start, there is no attempt made here at formulating a particular philosophical position thought appropriate for science education, in contrast to such discussions having taken place in mathematics education for some time. In that field

[1] The prominent US *National Science Teachers Association* (NSTA) has made STEM a central reform emphasis: www.nsta.org/stem. References for the other more common science classroom curricular emphases are Aikenhead (1997, 2002, 2007), Carson (1998), DeBoer (1991), Donnelly (2001, 2004, 2006), Pedretti and Nazir (2011), Roberts (1982), Schwab (1978), Witz (2000), and Yager (1996).

several educators have articulated and debated the notion of a "philosophy of mathematics education," for example, Platonism and foundationalism versus social constructivism and fallibilism (Ernest 1991; Rowlands et al. 2011). On the other hand, it will be stressed that the development of a "philosophy *of* science education," that is, an "in-house philosophy" for the field, could be significant for reforming science education. It can be acknowledged that math educators have been in the forefront of attempting to establish a "philosophy of" for their educational discipline, while science educators in the main have not yet come to consider or value such an overt evolution in their field. Such an endeavor urges exploration of new intellectual territory.

The sign of the times seems ripe for such an investigation ever since the science educational field became staked out by opposing, even irreconcilable positions "from positivism to postmodernism" (Loving 1997).

In the past constructivism was once seen by many educators as a kind of "philosophy" (though not expressed as such) which was to serve the role as a "new paradigm" of science education. Today, however, this view is considered mistaken, although the topic is divisive (Matthews 2002; Phillips 1997, 2000; Suchting 1992).[2] This judgment has come about largely because many supporters at the time did not reflect seriously enough about the philosophical underpinning of its various forms—cognitive, metaphysical, and epistemological.[3] Constructivism remains a dominant and controversial topic in education, but one lesson to be had from the heated debate of the past three decades is that absence of philosophical training among science educators became apparent (Matthews 2009b; Nola and Irzik 2005). Another lesson learned is the absence of any explicit discussion regarding educational philosophy, even though constructivism in some corners was brashly substituted for one. In hindsight it surprises that constructivism—which after all still finds its principal value as learning theory (and perhaps teaching method)—could be mistaken as a dominant kind of "philosophy of" science education at the neglect of broader aims and concerns relevant to educational philosophy, as to what it *means* to educate someone in the sciences. And science education once again showed unawareness of its own history, since Dewey (1916, 1938, 1945) and Schwab (1978) had previously addressed such concerns. At minimum the case of constructivism had illustrated—although not widely recognized—how interwoven, if not dependent, science education in the academy had become with certain psychological ideas and philosophy of science (notably its Kuhnian version; Matthews 2003a).

In light of this background, it will be of some interest to teachers and researchers to raise anew the question of developing a "philosophy of" science education (PSE),

[2] "Regrettably, much of the constructivist literature relating to education has lacked precision in the use of language and thereby too readily confused theories of knowledge with ideas about how students learn and should be taught" (Jenkins 2009, p. 75).

[3] The literature on constructivism is vast. Critiques are found in Davson-Galle (1999), Phillips (2000), Grandy (2009), Kelly (1997), Matthews (1998b, 2000), and Scerri (2003). Also see chapter 31 in Handbook.

by asking here what that could *mean* and could *offer* the discipline. The intent is to address these concerns and help sketch out contours. With this project in mind, one can draw attention to two useful aspects pertaining to philosophy in general which can come to our aid and contribute to improving science education and developing such a philosophical perspective: the ability of philosophy to provide a synthesis of ideas taken from associated disciplines with their major educational implications and providing what can be called "philosophies of." In this way it will be shown how philosophical thought can be brought to bear directly on educational ideas and practice.

39.2.1 The Synoptic Framework

The role and value that philosophy itself and its two important subdisciplines of *philosophy of science* (PS) and *philosophy of education* (PE) can have is illustrated by the representation below. Note that "philosophy of science education" (PSE) can then be understood as the *intersection* or *synthesis* of (at least) three academic fields. For each respective field of study, some individual points are stressed which comprise core topics of interest to science education pertinent to each, but is meant to be illustrative not exhaustive:

The framework in itself assumes neither prior philosophical positions (e.g., metaphysical realism or epistemological relativism) nor pedagogical approaches (e.g., constructivism, multiculturalism, sociopolitical activism). As a graphic organizer it does provide science teachers and researchers a holistic framework to undertake analysis of individual topics and perhaps help clarify their own thinking, bias, and positioning with respect to different approaches and ideas. The main point is to show that any particular PSE as it develops for the teacher or researcher should take into consideration, and deliberate upon, the discourses pertinent to the three other academic fields when they impinge upon key topics in science education. At minimum it should contribute to helping develop a philosophic mind-set.

In sum (as Fig. 39.1 shows), any philosophy of science education (PSE) is foremost a *philosophy* ("P") and as such receives its merit from whatever value is assigned to philosophy as a discipline of critical inquiry. (This value may not appear at all obvious to science educators.) Furthermore, such a philosophy would need to consider issues and developments in the philosophy, history, and sociology of science ("PS")[4] and analyze them for their appropriateness for improving learning *of* and *about* science. Finally, such a philosophy would need to consider issues and developments in the philosophy of education and curriculum theory ("PE") and analyze them for their appropriateness for education in science, as to what that can *mean* and how it could be conceived and best achieved. A fully developed or

[4] This component is meant to include the associated disciplines and not just the philosophy discipline itself.

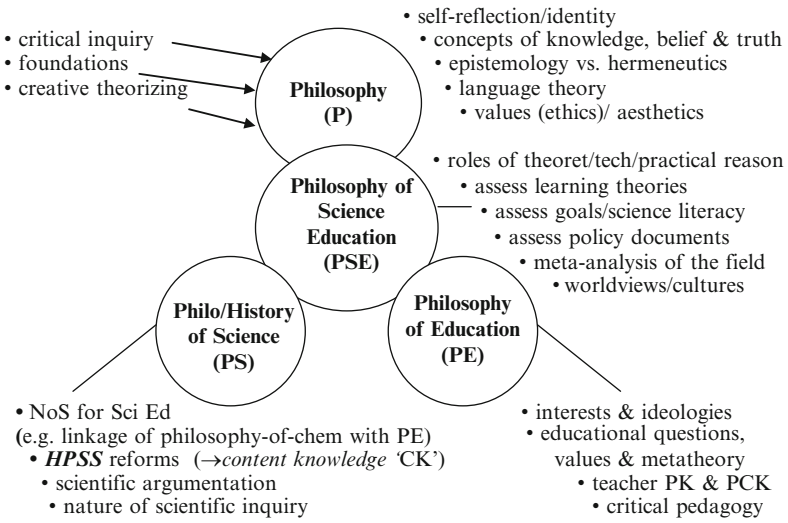

Fig. 39.1 Philosophy of science education (PSE)

"mature" PSE can be understood as an integration of all three fields. It ultimately aims at improving science education as a research field as well as assisting teachers in broadening their theoretical frameworks and enhancing their practice.

39.2.2 Providing "Philosophies of"

Philosophy today has evolved into several specialized subdisciplines. These include philosophy of science, of education, of mathematics, of technology, of history, of religion, and others, which can collectively be called "philosophies of." It is especially the first two that are of immediate concern to us when developing one for ourselves, as Fig. 39.1 illustrates. And yet this conceptualization is not as new as it may appear. Over 40 years ago, the philosopher Israel Scheffler summarized the value of these "philosophies of" for science educators:

> I have outlined four main efforts through which philosophies-of might contribute to education: (1) the analytical description of forms of thought represented by teaching subjects; (2) the evaluation and criticism of such forms of thought, (3) the analysis of specific materials so as to systematize and exhibit them as exemplifications of forms of thought; and (4) the interpretation of particular exemplifications in terms accessible to the novice. (Scheffler 1970, p. 392)

He understood these "philosophies of" would provide invaluable components to a science teacher's identity and preparation, in addition to the common three of (i) subject matter competence, (ii) practice in teaching, and (iii) educational methodology. Especially the inclusion of philosophy of science (PS) topics he

considered vital to allow teachers to be "challenged to reflect deeply on the foundations" of their subjects and "to relate their reflections to the task of teaching" (p.388).

Matthews (1994a, b, 1997) is known to have helped popularize Scheffler's earlier vision, whose call for inclusion of PS has been broadly acknowledged today though unfortunately little implemented worldwide in teacher education programs.[5] He has expanded upon Scheffler's line of reasoning to include additional pedagogical and professional arguments. An improved pedagogy, for example, should include several aspects: wisely evaluating constructivism and the educational aims of curricular documents, integrating HPSS topics, developing critical thinking, allowing science courses to show a "human face," and at minimum making science more interesting and understandable. Enhancing professionalism requires teachers to develop a wider perspective of their subject and its role in education, including becoming versed with topics and questions associated with science and society concerns. These would include religion and science, "multicultural science," feminism, techno-science, environmental ethics, animal rights, and others.

In short, philosophical questions concerning both education and science are at the heart of the science education profession, many of which have kept, and continue to keep, teachers, researchers, and curriculum developers engaged. Broadly speaking, they encompass essential concerns immediately identifiable with the two fields of philosophy of education (PE) and philosophy of science (PS):

> … educational ones about the place of science in the curriculum, and how learning science contributes to the ideal of an educated citizen and the promotion of a modern and mature society. The questions also cover the subject matter of science itself. What is the nature of science? What is the status of its knowledge claims? Does it presuppose any particular worldview? The first category of questions constitutes standard philosophy of education (PE); the second category constitutes philosophy of science (PS) or history and philosophy of science (HPS). (Matthews 2002, p. 342)

The teacher's professional role today has in some cases also come to include cocreating, advising, and assessing so-called national science "standards" documents. Since the 1990s several countries around the world have sought to define curriculum "standards," which harbor considerable agreement on nature-of-science policy statements (McComas and Olson 1998). "Clearly all these curricular exhortations depend on teachers having philosophical acumen and knowledge in order to understand, appraise, and enact them. This requires a mixture of philosophy of science (to understand the substantial claims), and philosophy of education (to interpret and embrace the objectives of the curricula)" (Matthews 2002, p. 343). The same arguments and considerations apply to mathematics education where philosophy *of* mathematics is integral to what, why, and how mathematics is taught and assessed and how teachers understand their professional role and responsibilities.

In the sections below, the intention is to further elaborate on the worth of philosophy as a subject in general, but especially philosophy of education since

[5] Whether or not science students themselves should be presented with PS ideas and controversies is still being debated among researchers (Hodson 2009). One philosopher of education has reversed his earlier standpoint (Davson-Galle 1994, 2004, 2008a).

this topic is usually overlooked. Philosophy of science for educators will only be glossed (above all its newer subspecialties) as this topic has been an active area of research.

39.3 The Value of Philosophy

Philosophy is an academic discipline that seeks to establish a systematic reflection on reality however it may be construed. Its analytic function, often termed rational inquiry, involves critical appraisal of different topics, beliefs, and schools of thought.[6] Because of the complexity of the world around us (both natural and artificial), philosophy has been traditionally divided into separate major fields of study (first accredited to Aristotle) such as metaphysics, epistemology, logic, ethics, aesthetics, and politics. These fields individually have either major or lesser bearing on science education directly. The *first two* have played a significant historical role pertaining to our understanding of the nature of reality, of knowledge, and of science:[7]

- ***Ontology***: the branch of philosophy (metaphysics) that concerns itself with the most general questions of the nature or structure of reality: what "is" or "what is *being*?" and existence. It examines natural and supernatural claims and asks about the feature of essences (e.g., are natural kinds, like species, universal or nominal?). Questions regarding *scientific* ontology are concerned with ascertaining the status (or validity) of the products of human creativity or discovery; included are scientific models and theoretical entities (e.g., gene, field, black hole, tectonic plates), evaluated as to their truth (realism) or merely useful (fictive) construct to solve problems and "fit" experimental data (empirical adequacy).
- ***Epistemology***: the branch of philosophy that studies the nature of knowledge, its scope, foundations, and validity; it deals with theories of knowledge, distinctions between believing and knowing, and justification. *Scientific* epistemology is concerned with describing and ascertaining the nature of both the body of known scientific facts and theories (degree of certainty) *and* the production of new knowledge (i.e., scientific inquiry). *Personal* epistemologies are commonly taken to include individual beliefs, views, and attitudes about a particular subject; hence, they can be considered a "personal knowledge framework"

[6] It has also been historically associated with particular schools of thought (e.g., idealism, rationalism, empiricism, existentialism); hence, particular *philosophies* which themselves are often associated with individual philosophers (e.g., Plato, Kant, Marx, Nietzsche).

[7] This is not meant to discount the next three. Logic has made a renewed appearance in science education under the guise of critical thinking and scientific argumentation; those in ethics intersect with discussions of values and socio-ethical issues (Allchin 2001; Corrigan et al. 2007; Witz 1996; Zeidler and Sadler 2008); even aesthetics has been considered for the field (Girod 2007).

(i.e., "what do you know about 'X', and how do you know (it)?"). Two competing views of epistemic justification are *foundationalism* and *coherentism*.[8]

As mentioned, the significance of *philosophy of science* for science education is generally recognized today—though moreso among researchers than science teachers themselves (Duschl 1994, 1988; Hodson 2008; Matthews 1994a)—while philosophy per se is accorded much lesser importance, notwithstanding the limited forays by some researchers into its subfields, which can be acknowledged (e.g., language studies, post-structuralism, hermeneutics, scientific argumentation, "critical theory"). Why this situation has arisen and persists is an open question and would require its own socio-empirical research, and hence is not of immediate concern of this review. But it remains an important question that should be pursued as it could reveal much about our community, about how science education is perceived and undertaken. In other words, it aims at the core of the self-understanding of science education as profession and identity (Fensham 2004).

A familiar question posed by preservice and science teachers alike is: "What does philosophy have to do with science?" or more succinctly and less pejoratively "how can any sort of 'philosophy' contribute to helping my students better understand difficult *scientific* concepts?" Such questions implicitly assume of course a deep divide between science and philosophy, certainly between science education and philosophy.[9] While science teachers need not be openly hostile to philosophy, they certainly appear indifferent. Much responsibility can be laid at the door of the academy, its structure, culture, and teacher training. Their attitudes and preparation effectively expose much about how teacher identity is formed,[10] about preconceptions of knowledge, but also about the nature of university science education and scientific specialization, including the nature and influence of science textbooks.[11]

Classroom teachers tend to be more concerned with valuable but mundane matters of decision-making regarding immediate instruction, learning, and assessment. For them as pertains their professional duties and identity, these concerns have little if anything to do with philosophy—or so it would seem. A consequence of this disregard makes providing educational rationales of their thinking and practice a

[8] See the chapters in Bonjour and Sosa (2003) for a concise overview; Sect. 39.5.2.2 targets the former.

[9] That one must inevitably justify the value of philosophy for teachers and many researchers suggests a cultural predicament already exists concerning what constitutes "education" in our present age.

[10] Which includes essentially their "orientations" towards teaching, identified in science teacher education research as formative dispositions attached to identity (Van Driel and Abell 2010; Witz and Lee 2009)

[11] Probably the ongoing reality of the academic divide between the "two cultures" maintained as two solitudes in universities to this day (as described by C.P. Snow; Shamos 1995; Stinner 1989) contributes to the hostility or indifference since science teachers are not generally required to endure Arts faculty courses. All this in combination with the common negative *image* that academic philosophy is preoccupied with obtuse speculation, arcane technical jargon, and unresolved disputes are remote from everyday matters. Certainly quite different, encouraging evaluations can be had (Matthews 1994a; Nola and Irzik 2005).

challenge: "When planning lessons, teachers often struggle when asked to express how they decide what science content within a discipline is worth teaching. Rationales are post-hoc and rarely reflect deep thinking about the structure of the discipline, or how students learn …" (Clough et al. 2009, p. 833).[12] Their struggles become quite apparent when further asked to give an explicit account of their "philosophy of teaching" or "philosophy of learning." And this counts not just for content teaching and conceptions of learning but equally for providing truly *educational* objectives for either their individual courses or overall science education.[13] Seldom are the contextual aspects of teaching the subject matter made explicit even though *seven* competing "curriculum emphases" have been identified in science educational history (Roberts 1988). In effect, particular curricular emphases bear witness to buried educational philosophies. The teaching profession itself is mired in a scenario of what Roberts (2007) has astutely identified as two substantial conflicting "visions" of science education.[14] These facts alone warrant developing philosophical acumen for teachers.

If this picture as sketched is indicative of teacher training and science education culture, then emphasizing the significance of philosophy, especially philosophy of education, would require a "paradigm shift" in thinking. Exactly this sort of thing had been recommended by Jenkins (2000) for effective reform of that culture, although the present proposal would encompass a wider scope than was initially suggested.[15]

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[12] They continue: "… Too often the selected textbook defines course scope, sequence, and depth implying that a textbook's inclusion of information, in part, legitimizes teaching that content. Textbooks also exert a significant influence on *how* content is taught…" (ibid).

[13] Many teachers would probably declare "science for all" or "scientific literacy" though seldom with awareness these slogans are replete with ambiguities—the latter goal even suffering inherent incompatibilities due to serious shifts in connotation, and this despite its ultimate prominence in worldwide "standards" documents (Jenkins 2009; Schulz 2009b; Shamos 1995). The science for all theme arguably partially appropriate for junior science nonetheless vanishes when specialty upper secondary or tertiary courses are reached, for here the status quo is maintained as "technical pre-professional training" (Aikenhead 1997, 2002, 2007). In this case an extreme narrowing of the "literacy" notion is found, HPSS aspects are distorted or abused, while the concealment of existent curriculum ideologies remains unrecognized in absence of educational philosophy (e.g., scientism, academic rationalism, "curriculum as technology" or social utility; Eisner 1992).

[14] In his comprehensive review, the categories "vision I" and "vision II" were postulated to account for two major competing images of science literacy behind many curricular reforms. The former designates those conceptions which are "internally oriented," that is, towards science as a knowledge- and inquiry-based discipline and including the image of science education as heavily influenced by the identity, demands, and conceptions of the profession. The latter vision, alternatively, is "outward looking," towards the application, limitation, and critical appraisal of science in society—the image influenced instead by the needs of society and the majority of students not headed for professional science-based careers. Here the question of the "social relevance" of the curriculum is paramount. He claims that while the second vision can encompass the first, the opposite is not true.

[15] For linked views, see Anderson (1992), Fensham (2004), Matthews (1994a/2014, 2002), and Schulz (2009a).

Philosophy in truth cannot be avoided, and not just for analyzing national "standards" documents, providing coherent rationales or detecting curricular ideologies. Science teachers inadvertently find themselves in its territory when confronted by diverse events, such as (i) explaining common scientific *terms* (like "law," "theory," "proof," "explanation," "observation"), or (ii) student-driven *quandaries* ("how do we know X?"; "do models reflect reality?"; "why are we studying this?", etc.), or (iii) when teacher and pupil together come across science-related public *controversies* (e.g., climate change, nuclear weapons, evolution versus intelligent design)—never mind popular beliefs and media reports (e.g., astrology or alien abductions). Such occurrences usually illustrate that "philosophy is not far below the surface" in any classroom (Matthews 1994a, p. 87). Moreover, the scientific tradition (as an integral part of Enlightenment culture) based on rationality, objectivity, and skepticism, which teachers have inherited, is equally challenged by strands of pseudoscience, irrationality, and credulity of the times (Hodson 2009; Slezak and Good 2011). How can teachers illustrate these differences, especially the distinction between valid and reliable knowledge claims from invalid ones (or natural from supernatural claims), without philosophical preparation? Yet it is not just the classroom, contemporary media discourse, or pop culture that is infused with questions, beliefs, claims, and counterclaims of philosophical significance, but likewise the evolution of science itself.

When science is seen historically, its development has always been interwoven with philosophical interests and debates, whether concerning epistemology, logic, metaphysics, or ethics (the major subfields of philosophy proper). A quick survey makes this evident: from debates on the nature of matter or motion in Ancient Greece to questions of logic, method, and truth with Galileo and Kepler during the Copernican revolution (or Descartes and Newton in the Enlightenment), also Lyell and Darwin concerning the age of the Earth or origin of species, respectively, in the nineteenth century (which saw the realist controversy about atoms in chemistry revived). Right down to our present age, philosophical controversies exist whether concerning the onto-epistemological debates in quantum mechanics or reduction in chemistry.[16]

The history of science, furthermore, is not simply a survey of fantastic discoveries, ideas, and theories as too many textbooks would imply, but is equally littered with discarded concepts and discredited theories (e.g., ether, epicycles, phlogiston, phrenology, caloric, Lamarck, Lysenkoism). Can teachers distinguish between quasi-histories and pseudo-histories or unmask how subject matter is organized to reflect the typical linear, non-controversial, and progressive accumulation of scientific knowledge, imitating the myth of "convergent realism?" (Kuhn 1970, 2000; Laudan 1981). The textbook's and one's personal view of scientific knowledge and

[16] It should not be forgotten that the seventeenth-century scientific revolution introduced "science" as a field of research and study under the academic umbrella of *Natural Philosophy* to distinguish it from the reigning scholasticism of the universities, hermeticism, and Neoplatonism. Our modern conception of the term and the severance of philosophy from science are of relatively recent origin. The division emerged historically as a development in intellectual thought and specialization, which evolved within European industrial society in the mid-nineteenth century.

its development both presume prior philosophical commitments (e.g., positivism? empiricism? naïve realism? critical realism? social constructivism?) (Duschl 1988; Säther 2003; Selley 1989; Smolicz and Nunan 1975).

Regarding ethics, one should not forget that Socrates was condemned on moral and religious grounds—as were Bruno, Galileo, and Darwin (though not exclusively). Eugenics, once the scientific "hard core" of the social Darwinism movement, was considered a legitimate topic of scientific research less than a century ago. Even modern physics cannot escape this subject, ever since Oppenheimer made the self-incriminating remark that physicists "had known sin" by developing the atomic bomb. The American philosopher C.S. Pierce had stated: "Find a scientific man who proposes to get along without any metaphysics . . . and you have found one whose doctrines are thoroughly vitiated by the crude and uncriticised metaphysics with which they are packed."[17] Studies in history, philosophy, and sociology of the sciences (HPSS) have made this claim abundantly apparent. These fields cannot be either ignored or glossed during science teacher education, but require time and attention for the emergence of an adequate PSE.

We have already noted the worth of philosophy (along with key aspects mentioned above) to lie in providing teachers with both (i) the perspective for synthesis of their educational enterprise by developing a PSE framework and (ii) making available to them in-depth studies termed "philosophies of." Linked to the latter, coming again to philosophy of science (appearing as the "PS" corner of the Fig. 39.1 triangle), teachers need to be made aware that in the past 20 years, new avenues of scholarship have been developing *within* the subfield itself to help them expand their foundational understanding of their specialty (e.g., philosophy of chemistry, philosophy of biology).[18] Here questions concerning major issues in subject matter content that bear directly on senior courses are being discussed. For example, there is dissention whether laws and explanations in biology and chemistry are of the same order and function as those in physics—normally taken for granted in PS literature.[19] Such "cutting-edge" philosophical research has acute ramifications for secondary and postsecondary education, expressly *subject epistemology*, including nature-of-science discourse (Irzik and Nola 2011; Jenkins 2009; Matthews 1998a).[20]

[17] Quoted in Matthews (1994a), p. 84.

[18] Scientists and philosophers alike have found it necessary to launch important new *subdisciplines* to address foundational questions and concerns arising from their scientific areas of expertise—notwithstanding those scientists who disparage the study of PS overall (e.g., Weinberg 1992). Philosophy of physics (Cushing 1998; Lange 2002), philosophy of chemistry (McIntyre 2007; Scerri 2001), and philosophy of biology (Ayala and Arp 2009) are becoming established research fields, including philosophy of technology (Scharff 2002), likewise lauded for teachers today (De Vries 2005).

[19] Refer to the respective chapter in this Handbook.

[20] Unfortunately it appears that science education worldwide and many science teachers themselves have tended not to keep abreast of these advances and what they possibly offer for curriculum design, instruction, and reform efforts. One might hope these subdisciplines offer, minimally, deeper and improved insights about subject content but, moreso, a better understanding of the essence of the discipline, the core of which teachers are required to inspire and impart to their

In addition to the above mentioned reasons, the worth of philosophy plainly lies in self-reflection. This means nothing less than to reassess one's own practice, educational ideas and aims; even going so far as to reevaluate one's own constructed sociocultural science teacher *identity*. Along with suggesting "philosophies of," Scheffler also argued that science teachers require philosophy as a "second-order" reflective capacity into the nature of their work, their understanding of science, and their educational endeavors. He considered this capacity analogous to the role philosophy of science plays when examining science:

> The teacher requires … a general conceptual grasp of science and a capacity to formulate and explain its workings to the outsider … No matter what additional resources the teacher may draw on, he needs at least to assume the standpoint of philosophy in performing his work … Unlike the researcher [or the academic] he cannot isolate himself within the protective walls of some scientific specialty; he functions willy-nilly as a philosopher in critical aspects of his role. (Scheffler 1970, p. 389)[21]

These proposals of Scheffler can equally be associated today with requirements to enhance teachers' "pedagogical content knowledge" (PCK: Abell 2007; Van Driel et al. 1998; Shulman 1987), which not only means developing *their epistemology* of science (Matthews 1994a/2014, 1997) but in addition their familiarity with philosophy of education topics (Matthews 2002; Schulz 2009a; Waks 2008). Again, Fig. 39.1 displaying the philosophy of science education (PSE) framework identifies these important aspects and illustrates how they are related to, and embedded within, the three corresponding dimensions of P, PS, and PE.

Philosophy in a nutshell then corresponds to the ancient Socratic dictum to examine oneself, and that "the unexamined life is not worth living." Transposing this motto, "the unexamined pedagogy is not worth doing"; in fact it is unsuccessful (as conceptual change research has uncovered)—if not harmful (i.e., indoctrination into scientism[22]).

Such an examination aligns with Kant's famous definition of Enlightenment as the emergence from one's self-imposed immaturity (due to reliance upon

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students. Certainly these are less well known to science teachers and not canvassed by science education researchers to the extent of interest shown in the post-structuralist and "science studies" literature. See Allchin (2004), Collins (2007), Hodson (2008), Holton (2003), Kelly et al. (1993), Nola and Irzik (2005), Ogborn (1995), Roth and McGinn (1998), and Slezak (1994a, b).

[21] With such a faculty, teachers could better function in their role as *mediator* between the scientific establishment and their pupils, also between public discourse about science with pupils or adults not conversant either how science evolves or the nature of modern techno-science (see also Hodson 2009).

[22] The term "scientism" can be interpreted in different ways; most construe it negatively (Bauer 1992; Haack 2003; Habermas 1968; Matthews 1994a/2014). Nadeau and Desautels (1984) attribute five components. Irzik and Nola (2009) are careful to distinguish legitimate scientific worldviews from illegitimate *scientistic* ones: "A scientific worldview need not be scientistic. Scientism, as we understand it, is an exclusionary and hegemonic worldview that claims that every worldview question can be best answered exclusively by the methods of science… that claims to be in no need of resources other than science. By contrast, a scientific worldview may appeal to philosophy, art, literature and so on, in addition to science. For example, scientific naturalism can go along with a version of humanism in order to answer worldview questions about the meaning of life."

outside authority), the ability to freely make use of one's own faculty of reason, to "have courage to use your own understanding!"(Kant 1784). This ambition is inherent of course to the *liberal education tradition* (Anderson 1980; Carson 1998; Matthews 1994a; Stinner 1989), the objective sought after when teachers desire students "think for themselves"—easily an identifiable historical goal of science education (DeBoer 1991, 2000; Schwab 1978). This is inclusive of the newer critical thinking movement (Bailin 2002; Siegel 1988, 1989; Smith and Siegel 2004). The primary focus here, however, is upon the further development of teachers' critical thinking and competence and their own capacity to judge not only curricular and policy documents, but above all their pedagogy, epistemological assumptions, and educational beliefs (whether implied by their textbooks, e.g., naïve realism, inductivism, pseudo-history, or proposed by science educational literature, e.g., STEM, STSE, constructivism, postmodernism, science for social action). The topic of *critical thinking* is well-trodden ground in philosophy of education, although researchers seldom avail themselves of this literature (Bailin and Siegel 2003; Siegel 2003).[23]

Finally, as Wittgenstein (1953) stated, philosophy can even be *therapeutic*. Implied for our theme, this means it can alert science teachers to implicit *images* of science and philosophies of education they may hold unaware. Perhaps they have internalized these through practice or originally picked up through teacher training from university professors promoting their own pet educational ideas and theories. Indeed, the teacher may have developed strong opinions about HPSS or "social justice" topics, "but the point of education is to develop students' minds, which means giving students the knowledge and wherewithal to develop informed opinions" (Matthews 1997, p. 171). In any case, translating Pierce's statement above with science educators in mind, one can write: "Find a science educator who proposes to get along without any philosophy-of-education … and you have found one whose goals, perceptions and methods are thoroughly vitiated by a crude and uncriticised one with which they are packed."[24] While the textbook epistemology is often concealed, a teacher's epistemology and educational theory is usually pieced together during their career and rarely made explicit.

In summary, philosophy cannot be gone around, for as a discipline of critical inquiry, it allows analysis into curriculum, textbooks, learning, best practice, and identity. Relooking at our previous PSE triangle (Fig. 39.1), this includes (i) offering conceptual clarity; (ii) unmasking ideologies (social, political, educational); (iii) sorting out foundational aims, values, and teacher identities; (iv) providing perspectives and theoretical frameworks, as well as synoptic and integrative approaches; and (v) possibly even utilizing *creative* theorizing as solutions to pressing problems (discussed below on educational theory).

[23] Refer to the chapter contribution in this Handbook.

[24] What is being suggested here can be taken to correspond with a key objective of critical pedagogy, popularized by the Marxist teacher educator Paulo Freire (1970), their advance to "critical consciousness."

39.4 Philosophy of Education and Science Education

Philosophy of education, as mentioned, is a branch of philosophy. It seeks to address questions relating to the aims, nature, and problems of education. As a discipline it is "…Janus-faced, looking both inward to the parent discipline of philosophy and outward to educational practice … This dual focus requires it to work on both sides of the traditional divide between theory and practice, taking as its subject matter both basic philosophical issues (e.g., the nature of knowledge) and more specific issues arising from educational practice (e.g., the desirability of standardized testing)" (Siegel 2007). Thoughtful consideration of educational practice and assessing science curriculum is normally considered part of a teacher's professional competence; hence, some sort of philosophical thinking can be justifiably attributed to educators and researchers. What is of issue is the view that science educators can be encouraged to philosophize on a broader and systematic scale, and they can profit from philosophy of education (PE) studies (using their in-depth deliberations on theory and practice).

39.4.1 The Neglect of Philosophy of Education

If as Aristotle (1998) had intimated (by the opening quote) philosophy begins when one is filled with wonder—a state of being which can arise when confronted with some dilemma (hence one's *lack* of knowledge)—then the neglect to articulate a *systematic philosophy of* (PSE) for one's own science pedagogy (let alone the research field) causes one to ponder why so little effort and time have been invested into the subject. The consequences have not been a minor matter—confusion over educational *aims* including the "science literacy" debate, its meaning and competing "visions"[25]; science education's dependence on socio-utilitarian ideologies and competing group interests; science teachers' confusion about their identity and purpose, including the divide between belief and practice; etc.[26]

Jenkins (2001) has rightfully complained the research field is too narrowly construed and suffers from "an over-technical and over-instrumental approach" at the expense of other perspectives, such as neglecting historical studies. Although some recent research work can be taken as mitigating this charge (Gilead 2011; Jenkins 2007; Olesko 2006), even his perceptive critique had failed to mention the worth of

[25] Science education to this day has been unable to resolve the principal dilemma concerning the conflict of the two competing "visions" of its purpose (hence competing conceptions of "scientific literacy"). Roberts (2007, p. 741) admits the community must "somehow resolve the problems associated with educating two very different student groups (at least two)."

[26] Refer to Aikenhead (1997, 2007), Bybee and DeBoer (1994), Donnelly (2004), Donnelly and Jenkins (2001), Pedretti et al. (2008), Schulz (2009a), Shamos (1995), Witz and Lee (2009), and Yager (1996).

philosophical studies. The inertia of traditionalism[27] at the upper levels had prompted Jenkins surprising call for a "paradigm shift," as mentioned—but this is serious talk, nothing less than a plea for somber philosophical contemplation and reorientation. Even at the postsecondary level, the need to reform introductory science classes has received increased attention especially with some new findings in Physics Education Research (PER) indicating that the dominant textbook- and lecture-based instruction in large classrooms is unwittingly producing an antiscientific mind.[28] The appearance in time of three identified public "crises" regarding school science education (1957, early 1980s, late 1990s; Schulz 2009a) and the apparent inability of different "reform waves" to provide for major, long-lasting changes could in turn suggest that a shift towards a more concentrated educational-philosophical examination of the problems lies at hand. It can be argued that the general lack of consideration of educational philosophy and theory, that is, a *philo-educational failure*, could help account for why curricular reforms are particularly vulnerable to the political whims (or "ideologies") of various stakeholder groups, an enduring situation several researchers have taken notice of.[29] It could, for example, better inform policy deliberations when diverse stakeholders are at odds over what should "count" as science education (Fensham 2002; Roberts 1988).[30]

Fensham (2004) argues in his important book *Defining an Identity* that science education is still searching for ways to characterize its own "identity" as a

[27] Grade 11 and 12 specialist science courses continue to serve primarily a gatekeeping function for college and university entrance, and their purpose, structure, and content usually replicate first-year tertiary courses—their chief rationale is exclusively with "science for scientists," and not concerned with the large majority who will not specialize. In other words, as induction into pure academic science but at the neglect (if not deliberate omission) of discussing (never mind integrating), the epistemologies, social practices, and proper history of the sciences—otherwise termed *nature-of-science* perspectives (Hodson 2008; Irzik and Nola 2011; Lederman 2007; Matthews 1998a). Reform movements like *Science-Technology-Society* (STS), *Science-Societal Issues* (SSI), and (lately) scientific argumentation studies have been attempting to counter this dominant school paradigm for some time but continue to make only small inroads.

[28] Yet despite these disturbing findings, researchers in these newer fields of study (also Chemical Education Research) still struggle uphill for respect and acceptance in their academic departments, where educational studies and research continue to be afforded a low priority (Gilbert et al. 2004; Hestenes 1998).

[29] See Aikenhead (2006), Bencze (2001), Donnelly and Jenkins (2001), Fensham (2002, 2004), Roberts (1988), and Roberts and Oestman (1998). Laugksch (2000) draws attention to different social group interests in defining "science literacy." Ernest (1991) also identifies several interest groups as determinants of mathematics education.

[30] Fensham's (2002) paper "Time to changing drivers for scientific literacy" (movement away from the academic driver to "social" and industry-based drivers) provoked a lively response from researchers about the "educo-politics" of curriculum development, especially about what role academic scientists should play, if any (Aikenhead 2002; Gaskell 2002); such a suggestion though would reorientate science education back towards the recurrent (and contentious) "social relevancy" goal and the progressivism of Deweyan-type philosophy (Darling and Nordenbo 2003; DeBoer 1991)—whose educational theory is often concealed. It may even involve a Faustian bargain with industrial- and vocational-driven interests. Gaskell believes the risk is worth it. But given the complexity of techno-science and the great diversity of vocations and business interests today leaves one wondering if any sort of meaningful consensus on curriculum is achievable, even locally.

discipline. (His comprehensive survey canvasses the views and backgrounds of 76 prominent researchers in 16 countries, active from the 1960s to the present.) One would like to suppose that helping to define such an identity would include philosophy, especially a *philosophy of science education* (PSE). And it is not only the identity of the *discipline* that is of issue here, but as referred to in the previous section, that of the classroom professional as well. Hence, it might appear the time has come for science education to return to some philosophical ground work, to come to value philosophy of education (PE), and, in turn, for the research field to inaugurate and develop a new *fourth area* of inquiry—philosophic-historical. This one added next to the common three of quantitative, qualitative, and emancipatory, in support of arguments made previously by others for its development as a "mature discipline" (Good et al. 1985; Kyle et al. 1992).

But Fensham's book, with the sole entry of PE on one page alone (where the significance of Dewey is also cited), bears ample evidence of the disregard of this subject topic for researchers and science teachers alike.[31] One can infer from the evidence to date that the worth of any sort of meta-analysis of their discipline and pedagogy seems to hold little value for the majority, thereto the need to bring systematic educational-philosophical reflection to bear on research, curriculum, and teaching.

This claim is further evidenced by a simple perusal of research *Handbooks* published thus far, where the subject of philosophy of education (including topics "philosophy," "educational theory," "curriculum theory") is missing entirely (Fraser et al. 2012; Abell and Lederman 2007; Fraser and Tobin 1998; Gabel 1994). This absence is likewise attested by recent publications of European Handbooks of research in the field (Boersma et al. 2005; Psillos et al. 2003). Crossing over the other way, most handbooks or "guides" of philosophy of education (PE) exhibit the same paucity by avoiding science education, though art education, moral education, knowledge, feminism, postmodernism, critical thinking, and critical pedagogy as subjects remain prevalent.[32] Two exceptions exist: Curren (2003) and Siegel (2009). Comparing both fields, the claim is reinforced by an inspection of the respective leading research journals in both philosophy of education and science education for the past 30 years, which exhibit an almost complete disregard of the opposing field (barring exceptions). What one finds is that only a handful of philosophers write for the science education journals, and even fewer science educators publish in philosophy of education.[33]

[31] Fensham in fact suggests that it is the "dominance of psychological thinking in the area" which attests to why Dewey is *not* cited more frequently among respondents in the USA (still the most prominent philosopher of education linked with science education in North America).

[32] Important works are Bailey et al. (2010), Blake et al. (2003), Chambliss (1996a), and Winch and Gingell (1999).

[33] Authors in alphabetical order include Bailin, Burbules, Davson-Galle, Garrison, Grandy, Hodson, Matthews, McCarthy, Norris, Phillips, Scheffler, Schulz, Siegel, and Zembylas (see respective references).

If an examination of the preparation of science education researchers is any indication of the kind of academic preparation science teachers themselves receive (before they become researchers), then another look at Fensham's *Identity* book as commented on by Matthews (2009b, p. 23) is revealing. He notes that "the interviews reveal that the overwhelming educational pattern for current researchers is: first an undergraduate science degree, followed by school teaching, then a doctoral degree in science education" (citing Fensham 2004, p. 164). As Matthews observes, unfortunately "most have no rigorous undergraduate training in psychology, sociology, history or philosophy." Fensham himself comments that at best, "as part of their preparation for the development tasks, these teachers had opportunities to read and reflect on materials for science teaching in schools and education systems that were different from their own limited experience of science teaching."[34] Matthews concludes that Fensham's survey reveals an overall "uncritical adoption of idealist and relativist positions" among researchers and that poor academic preparation is a reason why "shallow philosophy is so evident in the field."[35] It certainly appears as if the inadequate science teacher preparation in philosophy of education is mirrored by the widely recognized fact of the inadequate preparation with respect to philosophy, history, and sociology of science.

39.4.2 Historical Background of Philosophy of Education and Science Education

With an eye fixed solely on the mutual historical developments of both fields, this neglect is rather difficult to explain especially because science education is after all about *education*, with natural focus on the science specialty. But philosophy and education have roots that are intertwined in history long past, convincingly traceable back to Plato (*Meno*; *Republic*). Every major philosopher in the Western tradition from Plato (in Ancient Greece) to Kant (European Enlightenment) to Dewey (modern industrial America) has proposed educational projects of some kind (Rorty 1998; Frankena 1965; Whitehead 1929). As Amelie Rorty correctly points out (1998, p. 1): "Philosophers have always intended to transform the way we think and see, act and interact; they have always taken themselves to be the ultimate educators of mankind." Understood in this way, Dewey was on the mark when he famously phrased the view that the *definition* of philosophy is "the theory of

[34] Matthews comments this may be the significant reason why the science education research literature "is dominated by psychological, largely learning theory, concerns" (ibid). Others have also cited the domination of psychology and conceptual change research (Gunstone and White 2000; Lee et al. 2009).

[35] The typical tendency is to adopt philosophical or ideological views from well-known authors outside the field but often not accompanied by critical appraisal of such authors: "… the work of Kuhn, von Glasersfeld, Latour, Bruner, Lave, Harding, Giroux and others is appropriated but the critiques of their work go unread: it is rare that science education researchers keep up with psychological and philosophical literature" (ibid, p. 35).

education in its most general phases" (1916, p. 331)—although most professional philosophers today would probably not construe it as such.

It was the Enlightenment's "project of modernity" (Habermas 1987)—first begun in the seventeenth century—that was expressly formulated as an *educational project* and which saw in the new science of the day an instrument for personal and sociopolitical liberation (Gay 1969; Matthews 1989). It is of course in full awareness of this intellectual and cultural heritage that postmodernists like Lyotard (1984) would outright dismiss the "grand narrative" of this project with its associated role and *image* of science as an emancipatory and positive force, including those science educators convinced by his critique (Loving 1997; Nola and Irzik 2005; Rorty 1984; Schulz 2007).[36] In fact the popularity of strands of post-structuralist Foucault, 1972/1989, 1980; Nola, and postmodernist thinking among some researchers bears witness to the recent discovery of the value of philosophy for the field (Zembylas 2000, 2006).

Looking much further back in time (again at the *Metaphysics)*, Aristotle identifies the man of knowledge—one who has attained expertise either via *techné* or *theoria* (instrumental or theoretical reason)—as the one who is plainly able to teach what he has learned and as such draws one distinguishing feature of the philosopher. To be a philosopher was to be a teacher. Conversely, to be a teacher implies one must do philosophy (of one form or other). Science educators seen in this light are inescapably located within a venerable philosophical tradition *along with* the newer scientific one which they usually and exclusively tend to associate themselves with—though, here too, not fully aware of the latter's cultural roots and significance.

The first mention of philosophy of education as a distinct field of study was in Paul Monroe's *Cyclopedia of Education*, published 1911–1913 (Chambliss 1996b). Philosophy of education, depending upon the given nation and its educational traditions, can be viewed as a relatively new discipline or not. As Hirst (2003, p. xv) points out, "philosophical inquiry into educational questions" was more established in the USA, Germany, and Scandinavia, whereas in the UK philosophy of education as a discipline first came into its own in the 1960s. It was dominated by analytic philosophy and accounts of schooling, although in ethics Kantianism was the major influence. In the USA, the *American Philosophy of Education Society* had already been founded earlier in 1941, along with the Deweyan journal *Educational Theory* in 1951. It was the pragmatist philosopher and educationalist John Dewey in his influential work *Democracy and Education* (1916/44) who had conceived of PE to be a study worked out on an experiential basis—in other words, that educational ideas were to be applied and tested in practice. He also considered that theory and

[36] Related to this topic is the question of what worldview(s) science assumes or requires in order to be sustained, hence which one(s) educators need to be supportive or cognizant of (Matthews 2009a). This further raises the question of the *universalism* of "Western science," whether or not its knowledge and truth claims are necessarily culturally confined, or merely *evolved*. Disputes over the interpretations of "multicultural science" will not be addressed here, but again science educators require philosophical training in order to adequately tackle these controversial topics. Philosophical treatment of this subject can be found in Hodson (2009), Matthews (1994a), Nola and Irzik (2005), and chapters in this Handbook.

practice were interdependent in a kind of feedback loop mutually learning from and reinforcing each other. This stood in contrast to the earlier views of the Englishman Herbert Spencer who instead conceived of education as an inductive science and where PE would serve as a kind of scientific method.

Alternatively, on the continent in Northern Europe, very different views about education had been developing. The ideas of Kant, Schiller, Herder, Herbart, and others had contributed to create the influential *Bildung* paradigm in the nineteenth century.[37] It has become established as the *Bildung/Didaktik* tradition whose conception of education dominates the German-speaking world and the Nordic countries.[38] Today this paradigm is not without its detractors, for by the 1960s this tradition had itself begun to clash with the "critical theory" of the Frankfurt school (Blake et al. 2003; Blake and Maschelein 2003; Smeyers 1994). It continues to engender much debate among educational thinkers and philosophers alike, both in Europe and English-speaking countries. Thereto, advocates of both traditions—Anglo-American "curriculum" and *Bildung/Didaktik*—came together in the 1990s to open dialogue comparing the relative benefits of each (Gundem and Hopmann 1998; Jung 2012; Vásquez-Levy 2002).

The *Bildung* paradigm itself actually represents an *educational metatheory* (Aldridge et al. 1992), a type of "grand theory" in education of which very few have been constructed in modern times (inclusive of Dewey and Egan; Polito 2005). It immediately raises the question of the worth and relation of educational theory to practice, whose merits are currently being contested in philosophy of education (Carr 2010).

The direct link between *Bildung* and science education[39] has been drawn only recently, notably in Fensham's *Identity* Book (2004) and by Witz (2000).[40] Fensham provides a highly informative discussion, explaining the concept and significance of *Bildung* when contrasting the Norse/German tradition with the content knowledge-driven Anglo-American tradition. He contends that a serious shortcoming of the so-called "curriculum tradition" of the English-speaking world is its consistent disregard of metatheory (discussed further below).[41] *He advises science education*

[37] The literature on *Bildung* and *Didaktik* is extensive. Some references to its historical development are Barnard (2003), Beiser (1998), Gadamer (1960/1975), and Schiller (1795/1993).

[38] "On the one hand, the concept *Bildung* describes how the strengths and talents of the person emerge, a development of the individual; on the other, *Bildung* also characterizes how the individual's society uses his or her manifest strengths and talents, a "social" enveloping of the "individual" (Vásquez-Levy 2002, p. 118). Given this interpretation, one could in fairness associate the values and aims of the *Bildung* tradition with two prevalent "curriculum ideologies" identified by Eisner (1992) as "rational humanism" and the "personal" stream within progressivism.

[39] Science education and *Bildung* in Germany have been examined by Benner (1990) and Litt (1963).

[40] One Canadian study involving science teachers had sought to fuse the *Bildung* ideal with the STS paradigm and cross-curricular thinking (Hansen and Olson 1996).

[41] "In the one, the maturing young person is the purpose of the curriculum. In the other, the teaching of subjects is the purpose. In the one case, disciplines of knowledge are to be mined to achieve its purpose; in the other, disciplines of knowledge are the purposes" (2004, p. 150).

should acquire one. The same arguments have long been raised in Germany by Walter Jung (2012).

Another interesting aspect about the *Bildung* paradigm can be noted: it exercised an indirect influence via Herbart's ideas on the philosopher-scientist Ernst Mach. While Mach's impact on Einstein's thinking is generally recognized, his educational ideas are hardly known in the English-speaking world. Already back in the late nineteenth century, he had been politically active for educational reforms, including improving teacher education, and is credited with founding and coediting the very first science education journal in 1887 *Journal of Instruction in Physics and Chemistry* (Matthews 1990b, 1994a). Siemsen and Siemsen (2009) argue his rediscovery at present could provide significant contributions to current European reform efforts.

On a final note, for the English-speaking nations, the USA was in the forefront of the establishment of both disciplines (science education and philosophy of education) that have developed in tandem—simultaneously but separately in the early twentieth century. One would think that because of this pedigree, and in some cases of clearly overlapping interests (as exhibited in the important case of Dewey), science education would be more cognizant, and science teacher training more reflective, of their common roots. Unfortunately, on this matter science education seems to suffer amnesia on both counts, for if it can be admitted that "philosophy of education is sometimes, and justly, accused of proceeding as if it had little or no past" (Blake et al. 2003, p. 1), then this certainly rings true of science education.[42]

The call for a philosophy *of* science education (PSE) is not only to raise awareness of this forgotten earlier period, but *to identify the need to create a subdiscipline within educational studies* that, although new, nonetheless has substantial historical roots going back into the science-educational but especially the philosophical-educational past.

Why science educators do not associate themselves just as intimately with philosophy of education is a fascinating question, one that cannot be pursued here. It almost certainly has a lot to do with several factors (such as the prestige of science in society, how disciplinary knowledge is structured, how their own university science education proceeded, and, not least, how they were trained as educational professionals).[43] What is called "foundations in education" courses, which usually include studies in the history and philosophy of education, are often optional for preservice science teachers, depending upon the prerequisites of their attending institutions.[44]

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[42] Jenkins (2009) notes the same problem with reform movements and policy documents. This complaint (although dated but still relevant) was earlier attested by DeBoer in his Preface to his insightful *History of Ideas in Science Education* (1991).

[43] Roberts (1988, p. 48) draws attention to where teacher *loyalties* commonly lie: "The influence of the subject community is an especially potent force in science education. In general, the 'hero image' … of the science teacher tends to be the scientist rather than the educator [or philosopher]."

[44] Hirst (2008b) has recently complained that in some countries such as England, there are now moves afoot to delist such courses for teacher training altogether. It would not be a stretch to conclude that

39.4.3 Philosophy of Education Today

Coming at last to the present historical culmination, philosophy of education has today progressed to become a respectable, established subdiscipline in philosophy. It comprises evolving research fields, a sizeable literature, professorial chairs, professional associations (e.g. PES), and several leading journals.[45]

There now exists two *Handbooks* (Bailey et al. 2010; Siegel 2009) but also a *Guide* (Blake et al. 2003), *Companion* (Curren 2003), and *Dictionary* of key concepts (Winch and Gingell 1999). An *Encyclopedia* of PE is also on hand (Chambliss 1996a). These can be sought out by science educators to familiarize themselves with the current discussion, inclusive of disputes regarding different topics of individual interest to them. Several newer and older *Introduction* texts are also available (e.g., Barrow and Woods 2006/1975; Tibble 1966), including Carr (2003) and Noddings (2011). For educators seeking immediate information, several encyclopedia articles exist providing succinct, comprehensive overviews of PE (accessible online: Phillips 2008; Siegel 2007).

39.4.4 The Value of Philosophy of Education

Philosophical questions bearing on the different facets of science curriculum, teaching, and learning must be addressed and inspected by the thoughtful educator:[46] questions pertaining to (i) chief educational goals, content selection, and course objectives, or (ii) assessing learning theories, or (iii) bearing on nature-of-science- and techno-science-related issues—thereto, the character of scientific research, knowledge, and societal applications as related to curriculum or policy reforms. Hence, questions also pertaining to who enacts and benefits from such reforms with respect to interests and ideologies. And all this often in spite of, not because of, state-mandated and prepackaged "content knowledge" curricula:

> What are the aims and purposes of science education? What should be the content and focus of science curricula? How do we balance the competing demands of professional training versus everyday scientific and technological competences versus the past and present interactions of science with society, culture, religion and worldviews? What is the structure of science as a discipline and what is the status of its knowledge claims? What are the ethical constraints on scientific research and what are the cognitive virtues or intellectual dispositions

such a downgrade in the general value of philosophy-of-education cannot fail to negatively impact science teacher professional development.

[45] The leading journals of the English-speaking world are *Studies in Philosophy and Education, Educational Theory, Educational Philosophy and Theory,* and *Journal of the Philosophy of Education.*

[46] Some classroom case examples are Hadzigeorgiou et al. (2011), Kalman (2010), and Ruse (1990). Bailin and Battersby (2010), Giere (1991), and Kalman (2002) offer science teacher educators rich material for enhancing science subject-related critical thinking:

> required for the conduct of science? What is the meaning of key scientific concepts such a theory, law, explanation, and cause? (Matthews 2002, p. 342)

If it is indeed true, for example, that precollege and first-year college level science courses are primarily about "technical preprofessional training," then vital questions need to be asked about what differences should exist between training and education in science. It raises cultural, epistemological, and political questions about the nature of school science: whether, for instance, it is truly reflective of the nature of science (in some form) or more reflective instead about courses performing a "gatekeeping" function by limiting access to higher education (a sociopolitical role)—this in turn reflecting norms of school culture and assimilation (as critical pedagogy perspectives contend).[47] Does a hidden cultural bias exist (as "cultural studies" perspectives contend)? Should the worth of school physics and chemistry education, say, be mainly determined by "political/instrumental value" (prerequisites to college entrance courses; Aikenhead 2006)? If so, this would raise more disturbing questions about the nature of, or links between, socialization, training, and perhaps indoctrination (into scientism). There can be little doubt that in such cases a given "vision" of what constitutes "science education" is in place (with hidden "companion meanings"; Roberts and Oestman 1998).

At minimum it should raise questions about subject epistemology or the preeminent *value* placed upon a certain kind (Gaskell 2002). Such topics, though, have been a staple of PE disputes for quite some time—inclusive of deliberating the difference between hidden aims and genuine educational aims of curriculum and schooling (Apple 1990; Posner 1998), or the differences between education and indoctrination (Snook 1972). Not to forget, previous science education reforms have too often been associated with several past "crises" (as cited) which were themselves linked with wider socioeconomic problems in society: were these just pseudocrises manipulated by science education stakeholders and their interest groups? What educational values/views inform such groups and their policies?[48] Again, similar questions are addressed in PE.

39.4.4.1 Philosophy of Education and the Nature-of-Science Debate

Just focusing on one fundamental topic, the *nature-of-science* (NoS) debate, and zeroing in only on one aspect of this debate, the key question is: "who defines science for science educators?" The scientific experts within isolated academic disciplines (as is common)? Philosophers of science? Historians? Sociologists? Or those within cultural and women's studies? Postmodernist-type thinkers and critics?

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[47] "Domination, resistance, oppression, liberation, transformation, voice, and empowerment are the conceptual lenses through which critical theorists view schooling and pedagogy" (Atwater 1996, p. 823).

[48] Different kinds of answers are provided by Aikenhead (2006, 2007), Apple (1992), Bencze (2001), Donnelly and Jenkins (2001), Gaskell (2002), Gibbs and Fox (1999), Klopfer and Champagne (1990), Roberts and Oestman (1998), Schulz (2009a), and Zembylas (2006).

Or possibly students and teachers themselves, according to some versions of social constructivist theory?

The NoS topic alone has been recognized as one chief aim of science education for over 50 years, yet to this day, there exists a poor record of achievement worldwide (Lederman 2007). This fact is due to several interrelated causes, not least of which is the entrenchment of traditionalism (conventional discipline-based paradigm)—but moreso the reality that NoS is itself a contested field in HPSS studies. The "science wars" (initially launched by the Sokal hoax 1996a, b) and their aftermath have made the issue public, and science teachers are inadvertently involved in a contest that is being fought in the academy.[49] Researchers can certainly be found on either side, running the gauntlet from "positivism to postmodernism" (Loving 1997; Turner and Sullenger 1999).[50]

These polarized camps have made the business of science education a messy and complicated affair—it has become increasingly difficult to navigate a pedagogical course between competing views "from diehard realism to radical constructivism" (Rudolph 2000, p. 404). At best consensus can be found that several common classroom *myths* must be exposed, including talk of "scientific method" (Bauer 1992; Feyerabend 1975; Hodson 1998; Jenkins 2007). Teachers clearly require substantial philosophical background to familiarize themselves with the issues, but even *if* consensus could be achieved (which seems unlikely), the question cannot be solely confined and determined on HPSS grounds. This decision would leave entirely untouched the related *pedagogical question* how that (would be) conception of science plays a role in the education of the student, as to what educational *aim(s)* school science is ultimately expected to achieve.[51] In other

[49] For examples of teachers caught in the debate, see Sullenger et al. (2000) and Witz and Lee (2009). For different perspectives on the debate in the academy, see Brown (2001), Giere (1999), Gross et al. (1995), Laudan (1990), Nola (1994), C. Norris (1997), Siegel (1987a, b), and Sokal and Bricmont (1998).

[50] Science educators continue to quarrel whether basic NoS statements *can* or *should* be defined, even where a measure of recognized consensus is said to exist—inclusive of those now written into global policy documents. The dispute centers on how to determine "consensus" (among which experts?), or questions regarding disciplinary distinctions, or about NoS cultural dependence on "Western" science and Enlightenment traditions, among others (Hodson 2008; Irzik and Nola 2011; Matthews 1998a; Rudolph 2000, 2002). Good and Shymansky (2001) make the case NoS statements found in "standards" documents like NSES and *Benchmarks* could be read from opposing positivist- or postmodernist-type perspectives.

[51] This viewpoint aligns to an extent with Hodson's view (2009, p. 20) except for the fact he ignores relating his desired outcomes to educational philosophy and theory: "In my view, we should select NOS items for the curriculum in relation to other educational goals … paying close attention to cognitive goals and emotional demands of specific learning contexts, creating opportunities for students to experience *doing* science for themselves, enabling students to address complex socio-scientific issues with critical understanding…." On what philo-educational grounds the selection is to be undertaken, we are not told though he considers students' "needs and interests" (overlap with progressivism?), views of experts ("good" HPSS—the Platonic knowledge aim?), and "wider goals" of "authentic representation" of science and "politicization of students." His lofty ambition for science education (thus his notion of "literacy"), however, includes too many all-encompassing and over-reaching objectives. These must clash and become prioritized (or so it seems) once his

words, for the educational setting, the question "what counts as science?" must be allied with "what counts as science education?"[52] The historian may have something to say (e.g., correcting pseudo-history in textbooks), at other times the philosopher of science (e.g., correcting misleading epistemology inherent to textbooks), other times the sociologist, etc., each depending upon the context of instruction and in coordination with desired educational objectives and policy deliberations of stakeholders.

The issue is precisely that subject content (inclusive of disciplinary structure) must be "problematized" during curriculum decision-making, and for *two* reasons:

(i) It must be broadened to function as a more authentic and appropriate knowledge base.
(ii) It must be transposed into a form that considers the culture and age developmental stage of learners along with desired educational aims (Englund 1998; Schulz 2011).

That the curriculum needs to be made problematic implies that a *philosophical* (and not just instructional) problem initially lies at hand which requires resolution. This problem lands us squarely in philosophy of education (PE) territory. It requires a close linkage of questions found in PS with those found in PE (the base of the triangle in Fig. 39.1). The philo-pedagogical problem concerns the appropriate or *best didactic transposition* of epistemic content knowledge (CK) into an appropriate form accessible to the learner in accordance with educational aims and theory.[53] There are some educational thinkers who argue this cannot be suitably achieved without educational *metatheory* (Carr 2010; Dewey 1916/1944; Egan 1997).

As an example, while a teacher's content knowledge (CK) in chemistry may need to be better informed by research in the philosophy of chemistry (one crucial component of PSE would involve stressing this factor), nonetheless a PSE is more concerned with how such CK can be made to fit with the requirements of an educational metatheory and its concern with the cognitive-emotive *developmental stage* of the learner, with respect to this subject matter. In other words, a teacher's CK and the curriculum are not at the forefront for learning science (although they are invaluable dimensions), as is commonly done. Rather, they are evaluated in light of philosophy of education and the learner's age developmental mind-frame as befits

three stated criteria for subordinating goals force them under his socio-techno-activist umbrella of politicizing students—the ghost of Dewey beacons.

[52]The focus here is on the normative nature of the question (i.e., what do policy documents, researchers, or theorists stipulate?), as opposed to the empirical (i.e., what is going on in classrooms now?).

[53]This important topic is too often overlooked in curriculum theory or in the science education literature. See Fensham (2004), Geddis (1993), Klafki (1995), Lijnse (2000), Schulz (2011), Vásquez-Levy (2002), and Witz (2000); Dewey, Mach, and Schwab all in their day also identified the issue that the logic of the discipline does not conform with the psychologic of learning the subject matter of the discipline. Thereto, Aikenhead (1996) has argued that learning science involves a culturally rooted "border-crossing" on the part of the student, to negotiate the transition from the personal "lifeworld" to the "school-science world."

what it means to *educate* a person in the sciences. This emphasis necessarily shifts the focus to the substance of a teacher's pedagogical content knowledge (PCK) and educational philosophy.

If, say, NoS knowledge is taken to be an *end* (an aim in itself), then an implicit "philosophy" would be "academic rationalism" (Eisner 1992)—whose objective could be associated with "knowledge-for-knowledge sake," building "mind" (possibly even critical thinking), and likewise similar-sounding ideals coupled to a typical knowledge-driven educational metatheory (Egan identifies it with Plato's historic project).[54] This *can* equally be squared with science teaching within the conventional academic paradigm, though providing subject content with *context* (Roberts "vision I"); on the other hand, NoS combined with "critical thinking" as *means* to create critical-minded citizenry to strengthen democracy in society would couple NoS teaching with Deweyan-type educational metatheory (Egan identifies this educational tendency with a form of socialization; Roberts "vision II"). There are tensions here which may not be reconcilable[55]—tensions also inherent to liberal education (e.g., aims for the individual and society can clash considerably); they are certainly topics of concerned debate in PE. Not to be forgotten, there are those who wish to teach NoS because it stands alone—the *intrinsic* worth to learn about authentic science (or science as a cultural force); others however see it subservient to other ends—for advancing critical thinking (itself), or chiefly addressing science-societal issues (Zeidler et al. 2005), or yet again, for emancipation (critical pedagogy) and sociopolitical action (Hadzigeorgiou 2008; Hodson 2009; Jenkins 1994).[56]

What is really of issue here, though hardly recognized, is how (and which) *epistemic aims* of science education (e.g., knowledge, truth, justification)[57] can or should be met, either apart from, or linked with, or perhaps subordinated to, other identified *moral* and *political* aims of education (e.g., autonomy, human flourishing, citizenship, social justice).[58] A common and depressing feature of several reform programs (e.g., STS, SSI, sociopolitical activism) is the notable confused state of their several suggested educational aims. Moreover, it can be asserted that such avowed and increasingly popular projects for science education as identified presuppose educational metatheory of some kind, whose existence is either assumed or overlooked.[59] Engagement with philosophy of education debates about,

[54] See discussion on the topic of epistemic aims by Adler (2002), Hirst (1974), and Robertson (2009).

[55] See discussion in Egan (1997) and Pring (2010). Smeyers (1994) discusses the European account.

[56] Driver et al. (1996, pp. 16–23) offer five rationales for teaching NoS in classrooms, yet they either assume or overlook their dependence upon different, prior educational theories.

[57] See Nola and Irzik (2005), Robertson (2009), and Siegel (2010) for discussion of these subjects.

[58] See Brighouse (2009) and Pring (2010) for discussion of these subjects. Donnelly (2006) only scratches the surface of the problem with his defined dual clash between "liberal" and "instrumental" educational aims behind community reforms.

[59] This remark also targets research concerning situated cognition models, where it has often been asserted; practice was either *prior* to theorizing or *without* theory. See critiques of Roth by Sherman (2004, 2005).

and analyses of, *indoctrination* can be an antidote to such political-activism programs simply replacing unthinking science lessons with uncritical acceptance of whatever causes teachers or researchers might be energized about. As Erickson has stated (2007, p. 33), the science education community "needs to develop pedagogical models that make explicit the normative premises about aims" in its discourse on scientific literacy.[60] Whenever the topic of educational aims arises, the neglect and need of philosophy of education become only too evident.[61] The time has come for the community to strive for clarity and prioritization concerning which fundamental aims the field can and should achieve (Bybee and DeBoer 1994).

In any event, NoS raises foundational *philo-educational* questions: "What is the ultimate aim of science education?" (or, e.g., of physics education?). "What does it *mean* to be educated in science?" "How is such an education related to human flourishing?" These should ideally be addressed before the subsidiary question "what do we educate people in science *for*?"—often the common starting point of curriculum thinking and policy decision-making, which begins first with the prior value, with its linked presumption of the overall importance, of *social utility*. (The difference so stated is one of choosing between deontologic or teleologic rationales.) The former should not be approached as "mere academic questions" during teacher preparation, for they aim at the heart of what the profession and teacher identity is all about. Yet it should be clear that they cannot be answered without reference to educational philosophy and theory—while the utility rationale, alternatively, presupposes a particular one. In other words, it requires of the science educator a *philosophical valuation* of subject content and aims and an awareness of the broader educational purpose of the science educational field, including some personal positioning among available educational/curriculum theories (Scott 2008).

39.4.5 Overview of Philosophy of Education Subjects and Questions

It is the view of the present author that teachers as well as researchers when becoming more conversant with the ideas and disputes as argued by philosophers of education will help them (at minimum) gain insight and perhaps (at maximum) resolve

[60] He continues: "Too often we try to simply derive pedagogical practices from theoretical positions on learning, or diversity, or language, or the latest research on the functioning of the brain, etc." (ibid).

[61] An example of the confusion which results in science education research when PE is ignored is the paper by Duschl (2008). Here empirical research from the learning sciences and science studies is confused with educational goals, which must be chosen on a normative basis. Such research may very tell us *how* students (and scientists) learn but expressly not *why and what* goals they *should* learn. And to argue for a "cultural imperative" is to *make* a normative claim extrapolated from such research—one is dabbling in PE without its recognition. Moreover, whether the avowed economic, democratic, epistemic, "social-learning" goals, etc. (as they have been historically articulated for the field) can be "balanced" as Duschl simply assumes is by no means obvious—PE debates show quite the opposite (Egan 1997; Levinson 2010; Schulz 2009a).

problems related to issues of *common interest* (the nature and kinds of aims; the nature of language and learning, knowledge and truth, educational theory; feminism, multiculturalism; education for citizenship; critical thinking; ideology, interests, and curriculum; indoctrination, etc.). The field of philosophy of education is a veritable mine of ideas, posed problems, and suggested solutions. This holds true whether the *approach* to PE is simply to:

(i) Study prominent philosophers and their views on education (e.g., Plato, Aquinas, Rousseau, Kant, Whitehead, Scheffler, Foucault)[62]
(ii) Study educational thinkers and their philosophical positions (e.g., Schiller, Herbart, Dewey, Peters, Freire, Hirst, Egan, Noddings)
(iii) Study sub-branches of philosophy and their relevance to education (e.g., philosophy of science, moral and political philosophy, or aesthetics)
(iv) Study "schools of thought" in education (e.g., idealism, realism, Thomism, Marxism, existentialism, critical theory, postmodernism)[63]
(v) Study the philosophical questions of ultimate concern (e.g., the nature of being, of knowledge and cognition, the ideal of an educated person, autonomy)

There is intellectual insight and pedagogical profit to be had in any of these approaches (Barrow 2010). For the more practical-minded science educator though, the approach to PE could imply instead a focus on specific, contemporary educational questions. Here Amélie Rorty's (1998, pp. 1–2) list of essential PE questions serves to illustrate the "down-to-earth" PE approach, when *transposed* onto science education:

> What are the directions and limits of public [science] education in a liberal pluralist society? … Should the quality of [science] education be supervised by national standards and tests? Should public [science education] undertake moral education?[64]… What are the proper aims of [science education]? (Preserving the harmony of civic life? Individual salvation? Artistic creativity? Scientific progress? Empowering individuals to choose wisely? Preparing citizens to enter a productive labor force?) Who should bear the primary responsibility for formulating [science] educational policy? (Philosophers, …, rulers, a scientific elite, psychologists, parents, or local councils?).[65] Who should be educated [in science]?[66] How does the structure of [scientific] knowledge affect the structure and sequence of learning? … What interests should guide the choice of [science] curriculum?

[62] To name just some in the Western tradition; Eastern and other traditions have of course their own major philosophers who have concerned themselves with education.

[63] A classic source of material for this orientation are the essays in Henry (1955).

[64] As those in the *SocioScientific Issues (SSI)*, reform movement today insists (Zeidler and Sadler 2008).

[65] See DeBoer (2000), Fensham (2002), Gaskell (2002), Jenkins (1994), and Roberts and Oestman (1998), for responses to such questions.

[66] Recall the ongoing past disputes between "science for scientists" and "science for all" perspectives on curriculum, goals, and policy (ByBee and DeBoer 1994; DeBoer 1991). The most recent STEM reform movement in the USA can be justifiably accused of redefining science education as "science for engineers."

It is quite clear that common questions and concerns exist and one would have expected more cross-disciplinary discourse than has heretofore existed.

On the other hand, it is not here being suggested that a consensus is to be found among philosophers of education on such questions. In fact there are important disagreements and even diversity of interest and approaches to the solutions, as different PE "schools of thought" display (analytic, existential, phenomenological, postmodern, critical theory, etc.). Indeed, philosophy more often "divides" than it unites, and as one contemporary education philosopher admits: "missing in the present world of diversity of interests is the classic sense of a quest for philosophic unity" (Chambliss 1996b). As Scheffler stressed, "philosophies of" are not forged by some harmony of agreed-upon, sealed discourses. Instead they

> do not provide the educator with firmly established views … on the contrary, they present him with an array of controversial positions. But this array, although it does not fix his direction, liberates him from the dogmatisms of ignorance, gives him realistic apprehension of alternatives, and outlines relevant considerations that have been elaborated in the history of the problem. (Scheffler 1970, p. 391)

The point is not that some sort of philosophical unity should be either expected or had among philosophers or science educators, although of course consensus on common fundamental issues is to be desired. Rather, the nature of the discourse and sophistication of the debate can help illuminate those problems and issues which science educators are confronted by and continue to struggle with or have misconstrued, have overlooked, or for too long avoided.

39.5 Some Major Philosophy of Education Perspectives and Science Education

39.5.1 Educational Theory and Science Education

To talk of "educational theory" is first of all to recognize that it has undergone shifts in meaning ever since Western philosophy began contemplating educational matters in Ancient Greece. For the sake of brevity (and hazarding oversimplification), one charts a course from there to the current age by noting how its worth and purpose have undergone several changes, not only when specifying what *aims* to target, but *who* should carry the prime duty, namely, either philosophers, educationalists, or empirical scientists (Carr 2010; Phillips 2009).

The priority in Antiquity (Plato, Aristotle, Cicero) was to establish the grounds for knowledge to improve moral virtue (the "Good") but conceived more along a priori philosophical lines—hence the emphasis on reason and rationality. This tendency took "an empirical turn" with Rousseau, progressivism, and the rise of the scientific Enlightenment. This science-inspired propensity has continued right down to the primacy of developmental psychology in our age, "the view that the study of human cognition, emotional and social growth and learning ought to be

scientifically grounded" (Carr 2010, p. 38). Largely lost sight of along the way was the previous prominence of moral virtue required to remodel society—reclaimed later in different guises by Deweyan theory (of social adaptation or reconstruction), critical theory/pedagogy, and *Bildung*. The postwar positivistic, language-based "analytic revolution" in philosophy (or "linguistic turn" as Rorty opined) which arose in the US and England facilitated the "new" philosophy of education in the 1960s (e.g., Scheffler and R.S. Peters, respectively).

The "analytic school" in education had sought to improve teacher professionalism by augmenting the usual study of the "doctrines of the great educators" with added philosophical analytical skills to help sort out educational language and thinking (which they had diagnosed as incredibly confused). They also sought to combine their reform effort with guidance sought from research in the social sciences. It allowed for neat separation between the roles of philosopher and scientist, a dualism between theory and practice, and essentially pictured *educational theory as applied science* (a view Piaget held into the 1970s). Needless to say, the "post-analytic revolt" which came afterwards challenged and rejected many of the previous guiding views and assumptions, including its dualism, its epistemological objectivism and deficient language theory, and its philosophy of science (the so-called received view).

In its wake diverse, contemporary "schools of thought" (Barrow 2010) have championed various anti-theory, anti-foundationalist and assorted postmodernist, constructivist, and sociopolitical views. These in turn certainly suffer problems of their own (not to be appraised here), suffice to note others have recently come to reprieve the status of theory.[67] Its proponents not only take issue with anti-theory and postmodern-type arguments but also equally with previous analytic inspired views and dismiss the secondary reliance of educational theory on the social sciences, or worse, its reduction to a mere branch of the field (Carr 2010; Egan 1983, 2002, 2005).[68] They have reasserted the worth of philosophy to deliberate upon educational theory independent from constraints they see placed upon it, especially from scientific psychology.[69] They advocate in spirit that philosophy of education should once again claim its own unique, rightful place, neither accepting subordi-

[67] So that it may "engage in explorations of what [science] education might be or might become: a task which grows more compelling as the 'politics of the obvious' grow more oppressive. This is the kind of thing that Plato, Rousseau and Dewey are engaged in on a grand scale" (Blake et al. 2003, p. 15).

[68] Carr holds that educational theory might be better suited to ethics (moral reasoning) than with any sort of empirical science, which is not to dismiss the worth of some empirical work: "On closer scrutiny, it seems that many modern social scientific theories of some educational influence are often little more than normative or moral accounts in thin empirical disguise" (2010, pp. 51–2). This deduction leaves unanswered the important question as to what the proper role and value of empirical research for educational theorizing is to be. The topic is controversial and engenders debate in PE. See Egan (2002) and Hyslop-Margison and Naseem (2007) for a negative assessment and Phillips (2005, 2007, 2009) for a positive view.

[69] "We have suffered from tenuous inferences drawn from insecure psychological theories for generations now, without obvious benefit" (Egan 2002, pp. 100–101).

nate status nor intending to displace the social sciences, rather seeking complimentary standing.

On a related issue, because "theory" is often ill-defined in education (Thomas 1997) and usually strictly identified with learning theory in science education (e.g., Norris and Kvernbekk 1997), one needs to distinguish this term from "grand theory" or *metatheory*—the sort of thing Plato, Rousseau, and Dewey were concerned with (Schulz 2009a).[70] The original emphasis on the requirement for a metatheory in education had been discussed by Aldridge and associates (1992) following the proposal first put forth by Egan in the early 1980s encompassing his critique of "scientific psychology" and the demand educational studies stake out independent territory (Egan 1983). Such a theory could very well insist on the difference between psychological and educational development. *The essential merit of metatheory lies in creating curricular coherence, properly transposing subject content knowledge for the learner, and steering educational aims.*

Any educational metatheory must need be a normative one, for it seeks to *prescribe* an educational process to ultimately yield a certain outcome or *aim* (Hirst 1966). This is usually a kind of person or the ideal of what an educated individual should aspire to become given the values and dispositions to be cultivated and methods employed in the specified program (Frankena 1965). Further, it is in the worth of that final aim that the pedagogical methods of the educational project are justified, which traditionally have themselves been framed within the values and aspirations a society has deemed of ultimate importance: "The *value* of this end-product *justifies* the stages that lead towards its realization. Becoming a Spartan warrior justifies training in physical hardship. Becoming a Christian gentleman justifies exercise in patience and humility" (Egan 1983, p. 9; original italics).

In Western civilization a succession of diverse aims or ideals have historically followed since the time of Ancient Greece, and some of the greatest Western minds have been preoccupied with formulating various philosophies of education to define their respective ideal and suggest ways to realize it (Lucas 1972): Plato, the (philosopher-king) man of knowledge; Aristotle, the "good" or "happy" active citizen; Augustine and Aquinas, the Christian saint; Locke, the successful Christian mercantile gentleman; Rousseau and romanticism, the natural development of self-actualization; Kant, the autonomous individual, self-ruled by moral "good will"; and Dewey, personal and social "growth" through ever-changing experience, as the basis for democratic living.[71]

[70] Phillips (2002, p. 233) terms these "classic theories of teaching and learning."

[71] It should be noted that Dewey's aim is among the least predetermined of the others, although it could reasonably be argued that Kant's ideal is also dynamic insofar as he allows for education's dual aim, the "perfecting" of man *qua* man plus the improvement of society and "the human race." In addition, Frankena (1965, p. 156) also notes that such a dual aim in Dewey could considerably conflict—that the expected growth of the individual and society may clash—in anticipation of Egan's critique, which claims the clash is inevitable insofar as modern schooling is molded according to progressivist precepts. Alternatively, for Dewey, but also for Aristotle and Kant, such a possible conflict was thought to be reconcilable in principle.

Frankena (1965) insists any philosophy of education must ask itself three basic questions: *what* dispositions (or "excellences") to cultivate, *how* to cultivate them, and *why*?[72] When examining the position of the educational theorist Kieran Egan (1983), he seems to have these same in mind but reformulates and generalizes them with a slight shift in accent. Instead of using terms like "dispositions to be cultivated" and "ideal," he talks in terms of "end product" and "aims" while explicitly raising the important fourth component of *development*—it is of the essence of an educational *metatheory*, he writes, that it answers four key questions: what to teach (curriculum), how to teach (instruction), when to teach it (stages of learner development), and most importantly, why to teach it (specification of the end product, aim, or ideal). That said, the similarity in questions and intent is obvious.

Egan (1997) has further argued that *three* long-standing yet venerable and operative *ideas* in education (themselves inexorably embedded within science education) are undermining each other.[73] Schools in the West as educational projects are ineffectual primarily because they are caught between three chief objectives (or rationales) which successfully serve to check or undercut each others' intended aims: whether to teach science for (1) intellectual development (knowledge), or (2) for individual fulfillment (character), or (3) for socioeconomic benefit. (The first can be associated with the original knowledge-based educational project of Plato, the second with Rousseau, and the last is a cross-cultural and timeless expectation of most societies.)[74]

39.5.1.1 Educational Metatheory and Scientific Literacy

When science educational goals are examined historically, these three are ubiquitous; they persistently present themselves albeit in different guises, and they certainly can be identified throughout science educational reform history (Bybee and

[72] Such questions are actually the purview of what is demanded of an educational *theory*. Philosophy of education properly understood is a much broader field of inquiry that encompasses an analysis of such theories and questions (Peters 1966), which today usually overlaps with curriculum studies. Frankena seems to have been working with a constricted conception solely at the level of theory.

[73] Smeyers (1994) identifies the same quandary for Western European education.

[74] In brief, socialization conflicts with the "Platonic" (knowledge-focused) project because the former seeks the conformity to values and beliefs of society while the latter encourages the questioning of these; socialization also conflicts with the "Rousseauian project" since the latter argues that personal growth must conflict with social norms and needs. It sees growth and hence education in *intrinsic* terms instead of as utility for other socially defined ends. (Here exists the principal tension between the *Bildung* tradition and the dominating utility view of education and science literacy of the English-speaking world.) The Platonic and Rousseauian projects conflict because the former assumes an epistemological model of learning and development and the latter a psychological one. In the former "mind" is created and the aim is *knowledge*; in the latter it develops naturally, requiring only proper guidance, and the aim is *self-actualization*.

DeBoer 1994).[75] Considering the current controversies about prioritizing goals in science education, one may be surprised to learn that even educational debates have a long history. Once again, PE can offer insight into long-standing science educational dilemmas. Aristotle records:

> But we must not forget the question of what that education is to be, and how one ought to be educated. For in modern times there are opposing views about the task to be set, for there are no generally accepted assumptions about what the young should learn, either for virtue or for the best life; nor yet is it clear whether their education ought to be conducted with more concern for the intellect than for the character of the soul. (Aristotle, *Politics*, VIII ii: 1337a33; 1962/1981, p. 453)

It is remarkable to contemplate how his discussion mirrors the debate of values and aims that has steered science education since its inception in the nineteenth century. Consider if you will the conflicting meanings (post-WW2) of "science literacy,"[76] still identified as the overall objective of science education as discipline and practice: whether it is to be primarily understood as personal self-fulfillment (i.e., "virtue" as its own intrinsic worth) or for "critical citizenship" in a democracy (i.e., as instrumental worth; "the best life": STS), or rather solely for development of "mind" per se, as mastery of subject-based formal knowledge and as a tool for developing inductive (later redefined as "critical") reasoning (i.e., "intellect" development; science "processes": traditionalism; "scientific argumentation"). Lastly, whether it should encompass foremost moral development when arguing "socioscientific issues" (SSI) or "science education as/for sociopolitical activism" (i.e., "character of the soul"—always seen by Aristotle in terms of sociopolitical *activity*).

Note as well that the three fundamental goals underlying education (as elaborated above) can be identified here and mapped onto the corresponding conceptions of literacy and onto existing school science educational paradigms.[77] Some critical

[75] No one normally holds exclusively to one or the other, although usually one or the other is emphasized over the other two at a given time (depending upon the defined "crisis" at hand and under influence of respective social group interests), and the modern school and indeed many "standards" documents aim at a sort of *balance* between them. Roberts (1988), too, holds that "balance" is both desirable and achievable during public policy curriculum deliberations. Egan though insists that the attempts to achieve "balance" are illusory and must undermine the strengths of any one at the cost of the others.

[76] The term itself first came into use in the late 1950s. Initially broadly framed in terms of science, culture, and society relationships, it soon came however to mean learning technical, subject-specific knowledge: "This emphasis on disciplinary knowledge, separated from its everyday applications and intended to meet a perceived national need, marked a significant shift in science education in the post-war years. The broad study of science as a cultural force in preparation for informed and intelligent participation in a democratic society lost ground in the 1950s and 1960s to more sharply stated and more immediate practical aims" (DeBoer 2000, p. 588). By the 1980s the phrase had become commonplace: "Yet despite the problems of definition, by the 1980s scientific literacy had become the catchword of the science education community and the centerpiece of virtually all commission reports deploring the supposed sad state of science education" (Shamos 1995, p. 85).

[77] As can the seven "curriculum emphases" behind science curricula, identified by Roberts (1988)

observers had thus come to the conclusion that already by the late 1980s, the usefulness of the literacy concept had exhausted itself.[78] *We have a situation here where a discipline cannot agree on the most fundamental purpose and goal of its educational endeavor.*

One can therefore conclude, given this consistent mode of discourse about "science literacy," that the community is placed before one of *three* choices:

(i) *Exclusivist* option: one chooses either an already given or hoped for curricular paradigm; this could be the knowledge-based, specialist "vision I" literacy conception (the given: traditionalism) or, at the other end of the spectrum, opting for an "extreme" form of "vision II" (as Roberts (2007, p. 769) remarks), by redefining literacy as "collective praxis"—such as the (hoped for) image held by Roth and Barton (2004).

(ii) *Inclusivist* option: one agrees instead to hold fast to as many conflicting meanings as possible (e.g., Hodson 2009). Along with DeBoer (2000), one simply accepts the term stands for "a broad and functional understanding of science for general education purposes" (p. 594), and "because its parameters are so broad, there is no way to say when it has been achieved. There can be no test of scientific literacy because there is no body of knowledge that can legitimately define it. To create one is to create an illusion" (p. 597). Rather, only specific goals can be achieved in a piecemeal fashion, where his historically identified *nine* different conceptions are chosen as in a smorgasbord, attentive to the context of school culture and society wishes, and where "schools and teachers need to set their priorities" (ibid.). With this option, divergence is chosen. It is then assumed that "consensus about one definition throughout the worldwide science education community is a goal not worth chasing" (Roberts 2007, p. 736).[79]

(iii) *Abandonment* option: one chooses to reject the term as both useless and meaningless for educational purposes, along with Shamos (1995) and Solomon (1999).

In any case, if an educational metatheory is to be of service to science education, it must also acknowledge and address these options in the deadlock.[80] It may also

[78] Shamos has insightfully argued that its common conception tied to citizenship is fundamentally flawed, that the community is chasing a utopia, that it continues to refuse to accept the grounds why it has failed in achieving it, and finally that many rationales typically put forth to justify it are a *myth.*

[79] Option two although seemingly attractive on the surface does not seem viable, and one can imagine numerous problems associated with it. Just mentioning one, it assumes a degree of autonomy for schools and teachers which they generally lack and which in the climate of "accountability" and standardized testing and under the influence of powerful outside social groups would seem to check their ability to make the kind of choices DeBoer would like. A reversion to option one would in all likelihood result, namely, the default traditionalist position.

[80] A series of papers presented at a recent conference attempting to articulate "a more expansive notion of scientific literacy" illustrate the problems associated with this deadlock once more and why the sought-after solutions remain so elusive; discussions including educational theory and philosophy are conspicuously absent (Linder et al. 2007).

put into question the assumptions and scope of the discussion and even the entire character of the discourse which has heretofore been conducted (Schulz 2009b, 2011; Witz 2000).

39.5.1.2 Educational Metatheory and Advance of Science Education as a Research Field

Fensham's *Identity* book (2004), interestingly enough, also offers an important look at the role of theory (Ch.7) within the science education research community. He admits that the development of theory is a significant indicator of a discipline's advance as a research field:

> If the existence of theory and its development is a hallmark of a mature research field there is some evidence that the research in which the respondents have been engaged in science education has reached this point. On the other hand, the role that theory plays in the respondent's remarks was so variable that it is not possible to attach this hallmark in a simple way to much of their research. (Fensham 2004, p. 101)

With that admission he acknowledges that the usage of theory is restricted and there was little interest on the part of researchers to develop their theory of choice further. What is significant though is the range of *borrowed* theories from outside research fields that the researchers have heavily relied upon.[81] The spectrum stretches from social anthropology, ethnology, and cultural theory to psychology, cognitive science (e.g., information processing; schema restructuring), and philosophy of science (e.g., conceptual change theory).[82] He notes those researchers employing a "political framework" to curriculum, or concepts of power and ideology, shift the common focus of science education onto entirely different factors that influence science teaching and learning. Essential PE-type questions like "what counts as science education?" or "how are ideological meanings reproduced in science education?" are raised, but surprisingly not addressed with that perspective or discipline in mind. One observes rather that in all cases educational theory and philosophy of education nowhere make an appearance.

To the point of the subject at hand, Fensham does mention the topic of "grand theory" (p. 107). He writes that only *one* respondent had admitted to theorizing on this scale, namely, the biologist and educator Joseph Novak, who had earlier published *The Theory of Education* (1977).[83] Novak has today continued to hold, as

[81] "This borrowing can have the healthy effect of bringing new insights to bear on the problems of science education, but it can also lead to superficial descriptions that do not seem to be pushing for deeper understanding" (2004, p. 101). He fails to mention a *third* possibility that outside theories can do outright damage to education, as Egan (1983, 2002) argues for the cases of behaviorism, Piaget, and progressivism. The presumed relevance of cognitive science has lately come into question as well (Slezak 2007).

[82] Reliance upon psychology is clearly predominant, primarily Bruner, Gagne, and Piaget in the 1960s and 1970s and the significant role they played marking the revolt against behaviorism.

[83] This book, however, as is familiar today, is based on the psychologist Ausubel's quasi-neural theory of meaningful learning in combination with Toulmin's philosophy of science and principally restricted to learning theory.

Fensham comments, to the value of this theory and the belief that "theories in science education would be developed that have predictive and explanatory power, just as theories in the natural sciences have" (p. 106). This belief closely aligns educational theory with empirical theories in the natural or social sciences,[84] an arrangement both Hirst (1966) and Egan (1983, 2002) explicitly reject.

39.5.1.3 Educational Philosophy and Science Education as "Sociopolitical Activism"

One contemporary reform movement (spearheaded by some international researchers and popular with some policy advocates), namely, "science education as/for socio-political action," has been articulated with intentional philosophical perspectives. It could reasonably be interpreted as a rudimentary sort of "*philosophy of*" science education (PSE) as here elucidated (though granted, not formulated in this fashion). The position that science education *should* be oriented (if not exclusively so) to perform sociopolitical action is a normative claim argued on philosophical grounds, justified because of the apparent promise/claim of enhancing critical-minded citizenship and forwarding democracy. It patently stipulates categorical answers to the key questions: "What counts as scientific literacy?" "What counts as science education?" "What is it for?" Whether or not such a muscular and singularly focused PSE can do justice to the other historically identified aims associated as central to science education (including the *aesthetic* component of science; DeBoer 2000; Girod 2007), and therefore the best option for policy deliberations and reform, is a matter for some dispute—although a considered debate especially one involving philosophy of education (PE) is surprisingly lacking to date.[85]

That this sort of politicized PSE represents a "radical program" to challenge common school science education is understood (Jenkins 2009; Levinson 2010). Here our focus is to ask: is such a "program" an adequate PSE?[86] Science education, for example, could plausibly "do" sociopolitical action at times while rejecting "as" and "for." In any event, does politico-social activism as put forth substitute ideology

[84] It is admitted that Novak's writings offered an important counter-theory in support of the growing dissatisfaction with the dominance of Piagetian theory arising in the late 1970s (although some science educators continue to hold neo-Piagetian views). With the growth of conceptual change and constructivist research in the 1980s and the influence of Kuhnian philosophy-of-science, this dominance was gradually displaced in the research community. On the other hand, Erickson (2000) cautions there is much common ground between Piaget and the newer constructivist theories. Egan's cultural-linguistic metatheory (1997) is inclusive of learning theory but goes beyond it and outright rejects Piaget (Schulz 2009b).

[85] Leaving aside questions if its individual educational claims are either warranted or empirically validated. Strong advocates for this kind of politico-social activist PSE (just naming some researchers) are Hodson (2009) and Roth and Desautels (2002). Criticisms leveled against it are provided by Hadzigeorgiou (2008) and Levinson (2010).

[86] Does it fully take into consideration the three dimensions of the synoptic framework shown in Fig. 39.1?

for philosophy?[87] Does it presuppose educational metatheory? The present author would argue it must (although this feature is seldom articulated; i.e., social reconstruction). Stepping back, must *any* methodical PSE presuppose metatheory (of some kind)—or can it be gone around for, say, a list of rationales, principles, and exhortations? That debate has not yet begun, but would be welcomed.[88]

One of the responsibilities of a philosophy of science education (PSE) at the research level would be to expose educational theories (especially metatheories), as well as better clarify the relationships between such theories in PE and theories in other (empirical) disciplines (as to their nature, value, and limits), whether one of independence or interdependence.[89] In other words, a philosophical appraisal of several domains, such as conceptual clarification and the validity of borrowed ideas; scrutiny of epistemic and/or moral and political aims—their character and prioritization; analysis of the theory-practice dilemma; also the character, quality, and significance of kinds of assessments or tests employed (range of usefulness), etc.; and hence the question of boundaries, applicability, and relevance.

39.5.2 Epistemology, Knowledge, Understanding, and Hermeneutics

39.5.2.1 Epistemology, Belief, and Epistemic Aims

That science instructors and their technical textbooks are so concerned with accurate and exhaustive transmission of canonical scientific knowledge clearly reveals the central significance of epistemology to science education.[90] One can identify this preoccupation of academic sciences courses (a chief aim of school and college science) with the constricted and popular rendition of the customary *knowledge aim*.

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[87] Roberts (1988, p. 50) had earlier cautioned the research community about the "*individual ideological preference* of professors of science education" which can "indoctrinate science teachers into believing that what counts as science education is the ideology of a single curriculum emphasis (or perhaps a few emphases)" (original italics).

[88] It seeks as well to address the common blurring of lines between "descriptive" and "normative" research work, the expectation *that* classroom research *should* change classroom teaching and learning, as Sherman (2005) points out, but strictly in accordance with a specified (ideological) program. This academic conflation may indeed be due to our culturally inherited situation, i.e., "if we can't be objective, we'll be openly ideological" (p. 205), but regrettably real "openness" is rare. The argument here in a nutshell is that science education avoids (c)overt ideology for candid philosophy.

[89] Such a conversation can be considered an extension of one already discussing the difference between epistemology and psychology (Duschl et al. 1990; Matthews 2000; Southerland et al. 2001) or critiquing the assumed validity of cognitive science theories for science education (Slezak 2007).

[90] For some time a major portion of science education research has in fact been focused on analyzing and critiquing the strengths and weaknesses of school science epistemology, whether of subject content, or of the student, or of the teacher.

Here is another area where PE discourse can provide relevance, for the knowledge aim or truth aim has been fundamental in the traditional view of education, including its *liberal* construal—notwithstanding significant attacks on that objective from different educational perspectives (e.g., progressivism, post-analytic, postmodernist).

> Although transmitting knowledge is not the only aim of education, it is surprisingly substantial in its ramifications. Because we can compare various educational practices to determine which ones better advance students' knowledge, the knowledge-aim offers educational guidance, justifies central educational practices, and exposes complexities in the educational policies it supports. (Adler 2002, p. 285)

Science teachers plainly assume their courses or textbooks provide (technical) knowledge, indeed substantially *true* knowledge—and for the most part, they would be correct (e.g., propositional knowledge of final form science; Duschl 1990).[91] Yet being philosophically inclined means giving pause to reflect on what *basis* this can be claimed (expertise of the authors? Authority of the scientific community?). HPSS-based reforms do insist, of course, that *content knowledge* (CK, of teacher or curriculum) requires expansion and corrections (e.g., historical and epistemological *context* to be properly understood and learned).[92] But stepping back and asking about justifying CK, or "what is knowledge?"[93], is to venture into both philosophy (P) and PE territory (the right segment of the triangle in Fig. 39.1). The kinds of answers to these questions have vital educational ramifications. How, for example, can one justify teaching evolutionary theory if its stake in knowledge and truth cannot be established against intelligent design claims? Or taking the "culture wars" into view, is cultural indigenous knowledge of nature *true* scientific knowledge? Are there other kinds? If so, how are they legitimated? How to best distinguish them from science?[94]

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[91] This has also been referred to in the research literature as the "disciplinary view of knowledge" in contrast to "personal learner epistemology" and "social practice views of epistemology" (Kelly et al. 2012). The latter defers to science studies research and how knowledge is attained and justified through discourse practices within epistemic cultures (Knorr Cetina 1999). What is significant is that "within this perspective, knowledge is seen as competent action in a situation rather than as a correct, static representation of the world" (p. 286). What is not being acknowledged is that the two stated perspectives are themselves beholden to two different epistemological philosophies, namely, pragmatism and objectivism. While science education has traditionally been in the thrall of the second and is now expected to shift to the first, it could better take advantage of the respective benefits of each.

[92] Even when basic science "subject matter" is taught, it is always accompanied by some context that may operate covertly (e.g., preparatory, socio-utility, etc.). Such contexts have been called "meta-lessons" (Schwab), "curriculum emphases" (Roberts 1988), and "companion meanings" (Roberts and Oestman 1998).

[93] Also, what kind of science knowledge is of *most* worth (a key question of prioritizing subject content)?

[94] A very informative discussion on such questions, including examining beliefs, learning, knowledge, and critical inquiry pertaining to the aims of science education, can be found in Nola and Irzik (2005). The comments which follow can be considered supplemental to their work.

Students, when not just assuming the authority of the textbook or teacher, occasionally wish to have explained to them the grounds for knowing, grounds that can only partially be established when "doing science" (i.e., scientific inquiry). Four possible harmful *dispositions* to knowledge students can develop from science classrooms are cynicism, dogmatism, skepticism, and relativism, and Norris (1984) rightfully asks "can all these be avoided?" Teachers require philosophical intelligence not just for telling these apart, but awareness when they crop up during instruction and for strategies to overcome them.[95] Thankfully there already exists a tradition in PE that can assist them, which has sought to demonstrate the relevance of epistemology for education (Adler 2002; Carr 1998, 2009; Siegel 1988).

The standard account of knowledge is "justified true belief" (JTB), which stipulates three conditions in order for someone to say they "know X." For instance, science educators would not be satisfied if a student stated they "know" the Earth orbits the Sun but could not provide any evidence for this proposition. In this case the student has a *true belief* (two conditions met), but without justification could not be said to have attained knowledge. Even if philosophers have brought forth serious challenges to JTB[96], this doctrine of traditional epistemology still retains its value in assisting science teachers' thinking about the differences between knowledge, belief, and justifying conditions in the classroom as they arise (Southerland et al. 2001). It highlights the drawbacks of traditional instruction which can overstress the value of rote learning, algorithmic problem solving, and decontextualized subject content, especially if tied to a policy of exaggerated standardized testing (Hofer and Pintrich 1997; Mercan 2012).

JTB can equally shed light on other cases which can occur where knowledge and belief appear conflated, such as when a student has learned content but refuses to believe it (e.g., "I understand evolution, but I don't believe it"; "I can explain the Bohr model but don't believe atoms exist"). Southerland and associates (2001) have provided an overview of the differing conceptions and occasional clashing views concerning how "knowledge" and "belief" are employed as terms in the separate research fields of philosophy, educational psychology, and science education. They also raise the important pedagogical question whether science education should limit its aim to providing knowledge (or understanding) and not demand changing student beliefs (as required by conceptual change research). An interesting exchange of views between Smith and Siegel (2004) and Cobern (2000, 2004) on this topic illuminates that science teachers need to sort out not just their own presuppositions about knowledge and beliefs but require sensitivity to historical and cultural dimensions of these concepts while attending to philosophical arguments.

Within the field of science education research, Norris (1995, 1997) has analyzed how the JTB view of knowledge finds expression in the aim of *intellectual independence*, one key content-transcendent goal articulated since Dewey and progressivism.

[95] Certainly the relatively recent research studies to enhance *scientific argumentation* in the classroom also aim towards resolution of the issues and questions raised here, but are not of present concern.

[96] These will not be discussed here; instead see Siegel (2010) and Norris (1997).

He identifies several serious shortcomings of past and recent formulations of this goal (e.g., as found in constructivism and notions of scientific literacy). Norris notes especially the philosophical controversy surrounding the question to what extent, if any, non-experts can reason independently of experts' knowledge and community—hence, to what extent they can be justified to trust in authority and yield to scientists' judgments (and by association, their textbooks). The outcome of the dispute remains contested, but it appears some reliance is indeed unavoidable.

The degree to which intellectual independence is attainable (or not) has major ramifications for the character and educational aims of science education reform movements (like STS, SSI, HPS, social action). It could impose severe limitations, depending upon the stipulated objectives and overall ambition they desire to advance for the discipline, notably which independence-based goals they mistakenly assume school students can rightfully achieve.[97]

Returning to a previous point, Smith and Siegel (2004) in their paper had also named *understanding*—along with knowledge, and *not* (changing) belief—as primary goals for science instruction. The focus here though is not to address their position nor the dispute with Cobern (but noting its significance) rather to point out that "understanding" as both concept and goal has been largely overlooked in the research literature. Its merit with respect to epistemology and the traditional preoccupation with "knowledge" yields a checkered history, too (Toulmin 1972).[98] Yet its prominence does come to the fore in *philosophical hermeneutics* (Gadamer 1976, 1960) as well as Egan's educational metatheory. A systematic investigation of "understanding," its contrast to knowledge, and its merit for science education has yet to be presented.[99]

One fertile perspective on "understanding" has been provided by the late physicist and philosopher Martin Eger (1992, 1993a, b). He had insightfully shown the relevance of Gadamer's "philosophy of the humanities" for science education with regard to the *interpretation* of nature but especially of science *texts*. Hermeneutics, an age-old scholarly discipline, ties understanding to the ability to achieve personal meaning when interpreting text (utilizing the "hermeneutical circle" method). The significance of his ideas lies in offering an alternative approach to viewing science learning and knowing, drawing science education away from psychological and cognitive science perspectives and towards philosophy and the humanities (Bontekoe 1996; Donnelly 2001; Gallagher 1992). Today his ideas are finding useful expression in some research work (Borda 2007; Kalman 2011). He explicitly shifts the emphasis away from epistemology towards *ontology*, away from "knowing" in the

[97] Kuhn (1970) was skeptical about what science education could achieve in terms of developing independent thought and argued instead the conservative view of reinforcing the conventional paradigm—in part because this furthered "progress" and in part because students had no competence to do otherwise. Schwab held a different view and thought students could be educated to become "fluid inquirers" within and about a discipline. Siegel (1978) has admirably contrasted the two opposing positions.

[98] Mason's (2003) "*Understanding* understanding" is one of the few to explore the contrast.

[99] Some researchers have ventured into this territory; see, for example, Wallace and Louden (2003).

objectivist sense to interpreting, meaning, and being. This shift, or "interpretative turn" (Hiley et al. 1991), has not been entirely endorsed as regards questions surrounding the nature of language, ontology, and the relationship between epistemology and hermeneutics. The next section provides science educators with an unconventional but updated outlook regarding these major topics.

39.5.2.2 Epistemology and/Versus Hermeneutics

Any discussion involving philosophical hermeneutics recognizes two current state of affairs, namely, the ongoing unresolved dispute over the self-conception of philosophy and the so-called interpretative turn from epistemology *to* hermeneutics.

To the first, one identifies that the modern Anglo-analytic philosophical tradition has fractured into two differing schools of thought as to what the nature and role of modern philosophy *is* and can accomplish (represented by the opposing views of Dummett and Rorty; Bernstein 1983). This opposition is reflected as well in contrasting perspectives on language theory—which Charles Taylor has characterized as the *designative* and *expressive* traditions (Medina 2005, p. 39). That said, authors like Bernstein, Rorty, and Taylor nonetheless all comment on the convergence of thinking in both the Anglo-American and Continental traditions which reject *foundationalism* or the former project of grounding philosophy, knowledge, and language ("objectivism"), as Descartes, Kant, Russell, and the early Wittgenstein sought but failed to do.

With the current preoccupation of repudiating this formerly eminent epistemological tradition[100], the task of "overcoming epistemology" has come to mean different things to different thinkers (Baynes et al. 1987). Dewey and Bentley (1949), for instance, sought to overcome subject/object dualism with his pragmatic focus on "transaction," the active/practical behavior taking place between the knower and known. Taylor (1987) correctly views both Quine and Rorty as abandoning foundationalism (with the former attempting to "naturalize" epistemology), while he solely targets overcoming the conception of knowledge as *representation* that lies behind the ambition of the foundationalist project since Descartes:[101] "If I had to sum up this understanding in a single formula, it would be that knowledge is to be seen as correct representation of an independent reality.

[100] "Current attitudes toward foundationalism, as they have been since Descartes, are sharply divided. The minoritarian conviction (Chisholm, Apel, Habermas, Haack, Swinburne, and others) that some version of foundationalism is or is at least potentially viable is outweighed by the majoritarian belief that in the debate since Descartes, foundationalism has died a natural death and cannot be revived" (Rockmore 2004, p. 56).

[101] Rorty, of course, also surfaces representation, but he explicitly ties it to philosophy as a profession whose role as a foundational discipline (with its "theory of knowledge" being essentially a "general theory of representation") was to adjudicate all cultural knowledge claims, eventually including scientific ones. His view is comparable to Taylor's "To know is to represent accurately what is outside the mind; so to understand the possibility and the nature of knowledge is to understand the way in which the mind is able to construct such representation" (1979, p. 3).

In its original form it saw knowledge as the inner depiction of an outer reality" (p. 466).[102] One notes representation plays a significant role in science and science education, and Giere (1999) argues, in contrast, for its continued importance in science independent of foundationalism. Indeed, some philosophers and science educators have argued for a "fallibilist epistemology" as a viable alternative to opposing foundationalist and radical constructivist views of knowledge and belief (Siegel 2001, 2010; Southerland et al. 2001). The collection of papers in Carr (1998) intends to help guide curriculum policy beyond "rational foundationalism" and "promiscuous postmodernism." The discussions in these works can contribute to advancing teachers' epistemological conceptions and deliberations, whether concerning science, curriculum, or student learning.

The second aspect, as mentioned, acknowledges an "interpretative turn" to have taken place not only in philosophy (due initially to Heidegger 1977) but in the natural and social sciences as well (inclusive of language theory)—though granted, still subject to much dispute—that also seeks to move "beyond objectivism and relativism" (according to Bernstein 1983).[103] Such a move can be considered a shift in the philosophical emphasis entirely "from epistemology to hermeneutics," as both Rorty and Gadamer have claimed[104]; certainly it can be admitted the relation between the two modes of inquiry is contentious and differing conceptions of language inform both.

Furthermore, although there are many similarities in Rorty's and Gadamer's positions, there exist important differences as well as to the nature and task of epistemology and hermeneutics, which is instructive. For example, while Rorty would agree that Anglo-analytic philosophy of language has slowly come to abandon the notion of language as correct "picture of the world"[105], he would disagree with Gadamer's universalist perspective of philosophical hermeneutics (with its inherent view of language as the *medium* of all understanding). Both agree that hermeneutics is not to be considered a successor to epistemology, rather that it involves an entirely different approach to comprehend the world—indeed Rorty construes it as a kind of "paradigm shift" (one that is holistic, historicist, and pragmatic). While Rorty makes

[102] Taylor links the success of "knowledge as correct representation" standpoint with two factors: its link with the rise of mechanistic science in the seventeenth century, whose mechanized worldview overthrew the Aristotelean one with its notion of "knowledge as participation" ("being informed by the same *eidos*, the mind participated in the being of the known object, rather than simply depicting it," p. 467); secondly, the influence of Cartesian philosophy that insisted a new reliable "method" was required that could guarantee certainty of the representation. Yet this method entailed, unlike in philosophical antiquity, the reflective and critical cast of individual *mind* performing a subjectivist inward turn. Rorty's view is similar (1979, p. 248).

[103] He cites such authors as Rorty and Taylor (in philosophy), Gadamer (in language theory), and Kuhn and Hesse (in philosophy of science). Other philosophers of science endorsing hermeneutics are Heelan (1991) and Ihde (1998).

[104] See especially Rorty (1979, Chap. 7) and Gadamer (1989, p. 235).

[105] "Putnam now agrees with Goodman and Wittgenstein: to think of language as a picture of the world—a set of representations which philosophy needs to exhibit as standing in some sort of nonintentional relation to what they represent—is *not* useful in explaining how language is learned or understood" (1979, p. 295; original italics).

a sharp distinction between the two but sees them as complementary and mutually supportive (epistemology for "normal discourse" and hermeneutics for "abnormal"), Gadamer views them rather as antagonists: hermeneutics as the universal condition of understanding (and hence of *being; Dasein*)[106] but epistemology as a failed *epistéme*-based, historico-philosophical venture whose time has come and gone. The project has died and should be buried. Rorty correctly stresses that Gadamer had emphasized *Bildung* as historical enculturation (hence the crucial role of education) as a proper goal of hermeneutics—construed as an open project of how understanding takes place through interpretation and dialogue, a form of *intersubjectivity.* This is seen in contrast to "knowledge" possession and obsession of isolated, individual cognition (the foundationalist project), but he would not consent that such "understanding" entails knowledge. Rorty is clear that "knowledge" is fallible and constrained to the "normal discourse" of a particular (historical) sociocultural paradigm (explicitly referencing Kuhn's ideas).[107] But taking such a position on a *standard* of knowledge one can argue, alternatively, must implicate Rorty's outlook as committed to the epistemic assumptions of Cartesian foundationalism.[108]

There is certainly more that can be surveyed here in the debate about the shift "from epistemology to hermeneutics." Siegel (2010), for instance, takes issue with Taylor's arguments for "overcoming" epistemology, while Suchting (1995) criticizes many of the "lessons" supposedly drawn from hermeneutics. Several very important questions exist that still need addressing, such as if the common division between *explanation* and *understanding* is abandoned—which has long been accepted as *the* major difference between the natural and social sciences (Mason 2003)—and "interpretation" comes to characterize all human inquiry, does or should a "contrast class" exist in opposition to it? Thereto, how can or should one demarcate the lines between the humanities and the different sciences? Moreover, how does one adjudicate between better and worse interpretations? Is hermeneutics[109] really an alternative

[106] This hermeneutic perspective on learning and understanding corresponds with the newer epistemological perspectives of the field: "… increasingly, science education researchers are viewing meaning as public, interpreted by participants (and analysts) through interaction of people via discourse including signs, symbols, models, and ways of being" (Kelly et al. 2012, p. 288).

[107] Hence his complaint that one can distinguish between "systematizers" (those engrossed in normal discourse) and "edifying" philosophers (anti-foundationalists like Dewey and hermeneutic thinkers like Heidegger, Gadamer, who disrupt it) within the tradition—the latter whose status as "true" philosophers is often questioned by academic professionals.

[108] Rockmore (2004, p. 57) writes that Rorty maintains "a strict but wholly arbitrary distinction between epistemology and hermeneutics in order to equate the failure of foundationalism with a form of skepticism that cannot be alleviated through a hermeneutical turn." He accuses Rorty of still clinging to a standard of knowledge that he admits cannot be met. Rorty freely concludes that one can no longer hope to bring the mind in contact with the real and that *interpretation* must be the alternative, but just denies this will lead to knowledge in the conventional sense. Alternatively, Rockmore argues that "the main strategy for knowledge is, and always has been, interpretation" (ibid), not to be taken as tantamount to skepticism.

[109] This is not meant to imply this field of study is monolithic, and commentators commonly distinguish between "right-wing" (Gadamer) and "left-wing" (Derrida) factions. Yet such a categorization

paradigm to epistemology (as Gadamer and Rorty insist) or another albeit extraordinary version of epistemology itself, just not of the classical foundationalist sort (as Rockmore (2004) and Westphal (1999) contend)?[110]

There are fundamental issues and concerns identified here that a philosophy of science education (PSE) would equally need to consider and evaluate, which have necessarily arisen in the dispute between the advocates of epistemology, hermeneutics, and their different perspectives on language, knowing, and understanding.

39.6 Conclusion

Philosophy and philosophy of education continue to remain outside the mainstream of thinking in science education. The chief purpose of this chapter has been to bring them closer into the fold. Philosophy is, on the one hand, underappreciated and ignored by science teachers, on the other, occasionally raided, used, and abused by science education researchers. Philosophy of education by contrast (and when compared to philosophy of science) has the dubious distinction of being disregarded by both groups.

Philosophy as a discipline of critical inquiry enables teachers to develop a thoughtful, critical capacity to reflect upon curricular, epistemological, and popular media issues as they arise, whether during classroom discourse or professional policy deliberations. Philosophy is not far below the surface in any classroom, and in truth cannot be avoided. This holds especially when discussing common terms like "law," "theory," and "proof," or justifying content knowledge, or analyzing national "standards" documents, or providing coherent educational rationales for their courses, or for detecting curricular ideologies and conveyed textbook myths (e.g., academic rationalism, indoctrination into scientism, epistemological positivism, historically defined convergent realism, evolution versus intelligent design arguments, ambiguities and hazards of modern techno-science, cultural and personal bias). Philosophy of education as a subdiscipline prepares a forum of informed analysis and discussion on a range of topics and issues that bear directly on science education as an educational project, which has deep roots in the historico-philosophical past.

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is equally overly simplified. Those in educational studies—see Gallagher (1992)—distinguish four separate schools: conservative (Dilthey; Hirsch), moderate (Gadamer; Ricoeur), radical (Derrida; Foucault), and critical (Habermas; Apel).

[110] Rockmore maintains that the shift leads to a *redefinition* of epistemology, from "knowing the way the mind-independent world is" to "the interpretation of experience" which is justified by the standards in use in a given cognitive domain. In this reformulation "then epistemology as hermeneutics presents itself as a viable successor to the traditional view of epistemology—indeed as the most likely approach at the start of the new century" (p. 11). Westphal criticizes Rorty for failing to distinguish between classical epistemology and hermeneutics seen as a generic epistemological task, hence, to differentiate the replacement of only one type (foundationalism): "*hermeneutics is epistemology,* generically construed … it belongs to the same genus precisely because like them it is a meta-theory about how we should understand the cognitive claims of common sense, of natural and social sciences, and even metaphysics and theology" (p. 416; original italics).

A philosophy of science education (PSE) can be understood as a *synthesis* of (at least) three academic fields of philosophy (P), philosophy of science (PS), and philosophy of education (PE), each of which have distinctive contributions to make in its development. It can be interpreted as a "second-order" reflective capacity on the part of the teacher, as an extension of their pedagogical content knowledge. The research field requires this capacity to think deeper and more systematically about the unique educational dimensions of teaching and learning of science as philosophy, as profession, and as practice. It should be inaugurated as a new *fourth* area of research inquiry.

PSE is ultimately concerned with the explicit *problematizing* of school science and its epistemology for two substantive reasons: (i) to recognize the current inadequate portrayal as inauthentic science and so to improve the content knowledge (CK) of both the curriculum and teacher through HPSS studies and integration and (ii) to allow for the effective didactic transposition of subject content for the culturally rooted, age-appropriate learner in accordance with educational aims, philosophy, and theory.

Pertaining to performing useful functions, its value is taken as being *threefold:* it serves to, first of all, provide a platform for both researchers and practitioners (in their separate ways) to perform meta-analysis (critical function); secondly, to reconceptualize, remake, and reform curriculum and instruction (creative function); and lastly, to implement, as an example, effective critical thinking for teacher and student, appropriate to subject content and age level (pragmatic function). In the process it is understood such a philosophy when developed would be articulating in essence its meaning of "scientific literacy" and thus specifying and prioritizing essential objectives for science education. Whether or not it could successfully perform these functions without an explicit educational metatheory at hand is open to challenge and debate. In any event, it would ultimately aim at improving science education by broadening the research field and opening new territory for exploration, as well as assisting teachers in broadening their theoretical frameworks, sharpening their critical acumen, and enhancing their pedagogical content knowledge.

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