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THE MISSING LINK:TEACHING PHILOSOPHY OF SCIENCE

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Abstract

The relations between science and philosophy are so close that philosophy of science is a central concern of both, philosophers and scientists. Moreover, science education research considers philosophical aspects to improve science education. Over the last decades, science education has depicted philosophical perspectives on science that target understanding concepts and the nature of science as well as socio-scientific issues. Surprisingly, didactics of philosophy is not very much concerned with the connection between philosophy and science education. Teaching philosophy of science in secondary schools is not very popular even though science constitutes a dominant and pervasive aspect of students' lives. Hence, this paper focuses on philosophy of science as a missing link, connecting students' direct experience and science's growing influence on their lives with the general statements, methods, and concepts of science generated to a large extent within secondary school subjects. To counter potential misunderstandings, I examine some misguided ways of thinking of philosophy of science in schools. The aim is to institutionalize philosophy of science in upper secondary schools and to foster the interconnection of subjects within post-compulsory education.

Keywords: philosophy of science, nature of science, epistemic agency, preconceptions, Family Resemblance Approach

1. Introduction

While research and practice of didactics of science have been contributing to a rapprochement between science education and philosophy, philosophy (education) widely ignores these developments. Science education has shown a significant engagement in philosophy of science; however, not much has changed on philosophy's side since Duschl has found "twenty-five years of mutually exclusive development" according to science education and philosophy of science (Duschl 1985, title). It seems still to be true what Ennis (1979: 138) stated in his comprehensive review of the US literature on philosophy of science and science education – more than four decades ago: "With some exceptions philosophers of science have not shown much explicit interest in the problems of science education." In spite of the high volume of theoretical and empirical research concerning philosophy's impact on didactics of science in science education research and the need for students' awareness of how scientific knowledge is generated and validated, contributions of philosophy (of science) and didactics of philosophy are quite rare.

The connection between philosophy (education) and research in science education is obvious and there is currently an increased interest inexploring the relationship between science education and history and philosophy of science. Globally, science education has become intimately associated with themes that occupy a central place in (didactics of) philosophy. It particularly underlines that there is to focus on students' attention on how we know and how we justify what we believe to know. The preparation of scientifically literate students who understand how science works and how the knowledge science produces is generated is a perennial goal of science education (cf. AAAS 1993, NRC 1996). Thus, science education focuses both on the knowledge that science produces as well as on knowledge about science. It reflects the philosophical idea that scientific activities are theory-laden, value-laden, and aim-driven. Surprisingly, teaching philosophy of science in a philosophy class is not very popular even though science constitutes a dominant and pervasive aspect of students' lives. Hence, didactics of philosophy should be concerned with the nature of science and its implications for teaching and learning as well as for curriculum writing and teacher education programmes.

Philosophy is not routinely integrated in the curriculum in all countries and it is not taught in the same way throughout the countries. There are considerable differences in how and whether philosophy is taught and learned, for example, in Europe or even within Germany. Education in some countries is assigned to provincial jurisdiction. This applies, for instance, for the provinces of Canada and for the federal states ("Bundesländer") of Germany. In Germany, only a few federal states offer philosophy courses and these are not necessarily compulsory but, rather, a substitute or alternative subject to religious education (compulsory elective). However, I am committed to the view I explain in the following, namely that it is time to put philosophy on the curriculum and – in upper secondary education – philosophy of science in particular. Apparently, the scope has not to be narrowed to aspects of philosophy of science, but questions and reflections on the enterprise of the sciences should be part of formal education in upper secondary education.

In particular, I distinguish two general stances of integrating philosophy in formal education which complete each other and facilitate interdisciplinary learning:

1. Philosophy as a guiding principle of education: Philosophy can contribute to key educational goals. Philosophy as a general principle of education helps students to construct and reconstruct their understanding which is generated within different school subjects as well as in everyday life. Philosophical inquiry can make contact with every learning area and fosters substantive questions about the concepts, claims, assumptions, and methodologies of all subjects students are supposed to learn. It deliberately focuses students' attention on aspects of the nature of the sciences during classroom instruction, discussion, and questioning. This means to envisage (a) more general aspects of philosophy (of science) addressing topics like knowledge, belief, evidence,

justification, truth, proof, law, and explanation as well as (b) more specialized aspects, such as philosophy of mathematics, of chemistry, of history, etc.

2. Philosophy as a discrete learning area in the national curriculum: Philosophy teachers and teachers of other subjects – from time to time – coordinate their classes according to some chosen themes and arrange them for cross-referencing intending to disseminate units of work.

I called these two main lines of interdisciplinary teaching "the integrative (implicit) approach" and the "additional and cooperative (explicit) approach".[1]

In the following, I explain why teaching philosophy of science is valuable to be integrated in secondary education and why some objections against this idea are not convincing. I first turn my attention on the tradition of teaching about the nature of science which primarily offers aspects of the *integrative (implicit) approach*. Second, I discuss some misconceptions concerning science and teaching philosophy of science in philosophy class. Finally, I outline a rationale for why to teach philosophy of science in upper secondary schools in light of the aims of education.

2. The tradition of teaching about the nature of science

In research over the last decades, science education emphasizes developing and understanding the nature of science (NOS), history and philosophy of science (HPS), and socio-scientific issues (SSI). It focuses on conceptual and epistemological aspects as part of science education. In his review of major reforms in science education,Duschl (2008) proposed a shift away from only the products of science towards a more comprehensive approach. He stressed science education to be organized around conceptual, epistemic, and learning goals. Characteristics of scientific beliefs, the epistemology of science, its presuppositions, methodological assumptions, boundaries, values, and goals as well as the development of scientific thinking within a particular culture and historical circumstances are to be reflected.

Moreover, habits of mind like epistemological curiosity and respecting evidence became central features of didactics of science. Argumentation and its philosophical and cognitive foundations have emerged as a key area of research in science education. The shift away from the focus on the results of scientific research towards the installation of argumentation as a central issue in science education has been called "argumentative turn" (Adúriz-Bravo 2014: 1449). Numerous studies have focused on the appropriation of criteria and evidence for the evaluation of the quality of arguments. There is an emerging interest inhow to support students' engagement in argumentation. Useful instructional tools have been developed (Zohar & Nemet 2002; Osborne, Erduran & Simon 2004; Erduran & Jiménez-Aleixandre 2008; Erduran & Jiménez-Aleixandre 2012; Erduran & Kaya 2016; Erduran 2019). Relations between students' argumentation, their epistemological ideas, and their epistemic practices have been examined (Sandoval & Millwood 2007). Reform efforts continue to demand a

[1] A conceptual framework for the issue of cross-curricular teaching with regard to philosophy and science in upper secondary school has been set forth in Lampert (2020).

"philosophically more valid science curriculum" (Hodson 1988, title).

Nola and Irzik (2005) take on this task. They set out philosophical theories of knowledge and science that impinge on science education. Concerning education in general, they defend the normative view that its core aim is critical inquiry. They stress the idea that "a science education that does not concern itself with critical inquiry is a lame conception of education, whether in science or any other subject matter" (Nola & Irzik 2005: 4).[2] Since its introduction into science education research literature by Irzik and Nola (2011), the Family Resemblance Approach (FRA) has been adopted by science educators (cf., for instance, Erduran & Dagher 2014) and Erduran, Dagher & McDonald 2019 who provide an overview of research and development efforts utilizing the FRA). It takes into account that science is not a unified type of activity and highlights a variety of shared and distinct features that characterize the sciences. Therefore, it is not asked for necessary and sufficient criteria of science or one essential common feature but rather for family resemblances as Wittgenstein put this idea forward in his *Philosophical Investigations*. We find a series of overlapping similarities, none of which is completely general. The FRA focuses on the aims and values of science, its methods, knowledge, and practices as well as social-institutional aspects of science. It synthesizes philosophical perspectives and provides a framework for the understanding of science as a cognitive-epistemic as well as a social-institutional system. It encompasses types of activities that are quite familiar to philosophy educators.

Policy reports, curriculum guidelines, and documents such as *Beyond 2000* in the UK (Millar & Osborne 1998) and the science curriculum reform in the USA in the context of the *Next Generation Science Standards* (developed as K-12 science content standards to improve science education in the USA) which were drawn up by the National Research Council (NRC)are related to a public understanding of science and the epistemic goals of science education. They demand students' support in posing and answering questions according to standards of disciplinary accountability. This means to position students as epistemic agents (Elgin 2013). The two major science education reform documents in the US *Benchmarks for Science Literacy* (AAAS 1993) and *National Science Education Standards* (NRC 1996; 2012) as well as PISA focus on a deeper understanding of content (scientific literacy) and demonstrate consistent calls for the inclusion of typical philosophical themes and competences such as the "identification of assumptions, use of critical and logical thinking, and considering of alternative explanations" (NRC 1996: 23). "Teaching science as inquiry" became a core principle for science education. Philosophy of science offers a valuable bridge between philosophical and scientific inquiry. And, philosophy of science can use scientific practices (as studied by students in science class) as a starting point of philosophical accounts of products, processes, values, and aims of science.

Educational concerns with teaching NOS, HPS, SSI, critical thinking, and basic

[2] There is a widespread embrace of inquiry-based pedagogy in science education as well as in philosophy education.The roots of the inquiry approach to the teaching of science can be found in the deliberative curriculum theory of Joseph Schwab (1962), who – following John Dewey – pursued to reconceptualise the teaching of science in all levels of schooling. Both, Dewey and Schwab, held that an active process of inquiry was central to science (education). They railed against approaches to science teaching which frequently have presented science "just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject matter" (Dewey 1910: 124).

philosophical competencies can be seen in many English-speaking countries. Robert Ennis defines critical thinking as “reasonable reflective thinking focused on deciding what to believe or do” (Ennis 1989: 10), and he provides a set of criteria for assessing it. Critical thinking can be used as a framework for addressing NOS and philosophy of science issues in philosophy class. This line of research has a long-standing presence in the Anglo-American science education.Science education research makes contributions to theoretical questions as well as to pedagogical and curriculum questions. It strives for an understanding of the character of scientific knowledge and methods. The relevance of scientific claims in personal and public decision-making is considered, too. Philosophy’s contribution in science education research is theoretically clarified as well as empirically proven. Since its inception in 1992, the research journal *Science & Education: Contributions from History, Philosophy and Sociology of Science and Mathematics* is devoted to the field of history and philosophy of science and mathematics education. It promotes the engagement of these fields with theoretical, curricular, and pedagogical issues. The *International Handbook of Research in History, Philosophy and Science Teaching* (Matthews 2014) has grown directly from this journal. This line of research stresses the need to provide students with the opportunity to scrutinize the nature of scientific knowledge and methods as well as the role of science in culture and society. Moreover, there are various rationales for infusing interdisciplinarity in science education. Understanding does not abide by disciplinary boundaries; philosophy alone does not lead to a scientific understanding and scientific knowledge alone does not lead to an understanding of how science operates. These aspects reinforce one another, and an interdisciplinary awareness of the role and value of philosophy has to be cleared. The dialogue between the (natural and the social-cultural) sciences on the one hand and between the sciences and philosophy on the other should be fostered.

Although there has been some disagreement among philosophers of science about what ideas comprise NOS (cf. Alters 1997; Eflin, Glennan & Reisch 1999), there is broad agreement within the NOS research that philosophy of science is a crucial part of science education. Moreover, according to mathematics education, there has been considerable research on the philosophy of mathematics in school curricula. Modern philosophical and didactical approaches to mathematics intend to include philosophical reflection in the standard mathematics curriculum. They strive for an explicit presence of philosophy in the mathematics curriculum (cf. François & van Bendegem 2011) that concerns critical attitudes, attention to the possibilities and limitations of mathematics, and its historical and cultural components. And the case for (most) social sciences and humanities could be similar: From a philosophical perspective, students should reflect on how the (disciplinary) knowledge is generated and validated, what counts as evidence to support (and oppose) it, and how to detect error, fraud, and bias. In emphasizing the conjectural and controversial aspects of sciences, philosophy of science fosters the development of knowledge, skills, attitudes, and values to address socio-scientific issues, too. This concerns nearly any subject in formal education. As Matthews puts it:

> Any intelligent and informed teaching of a subject inevitably leads teachers and curriculum writers towards an appreciation and understanding of the history, epistemology and ontology of the subject they teach, organise and frame for students. The same holds for mathematics, economics, psychology, theology and all disciplines (Matthews 2018: ix).

Thus, my approach – intending to inspire a rapprochement of philosophy (of science) and other school subjects – applies not only for the natural sciences but also for mathematics, the social sciences, and humanities. Philosophy (of science) in this educational context strives to attain some elucidation of claims, questions, and habits drawn from aspects of our experience in ordinary life in view of the sciences. It is not understood as a body of doctrine or a theory but, rather, is characterized as reflective inquiry. Nonetheless, the focus is not on reflection on philosophy of science. Thus, teaching philosophy (of science) does not primarily mean to teach the topics of philosophy (of science) as they are expounded in textbooks.Rather, it offers a venue to reflect on the enterprise of the sciences, the aims, and values, methods and practices as well as on social-institutional and socio-political aspects from students' perspective.[3]

Sandwell (2019), for instance, explains for history education that students should not only look at the past but also take into consideration *how* we approach the past. And the Council of Europe (2001: 8) declares that "[t]he learning of history should at all times make use of the educational potential of a cross-disciplinary and multidisciplinary approach, forging links with the other subjects on the curriculum as a whole, including literature, geography, social sciences, philosophy and the arts and sciences." Doing philosophy can also be essential in order to extend students' thinking beyond mastery of historical facts within the history classroom. Epistemological and conceptual concerns relating to how we can come to know the past are recently prevailing. The significance of reflecting about what we think, how we think and why we think what we think has been notoriously emphasized within educational research in general. Thus, my idea is that students should reflect on the disciplinary and procedural aspects of *any discipline* they have to learn. Considering philosophy is a matter of all lessons and requires thinking across disciplinary boundaries against entrenched habits of teaching and learning.

3. Some misguided ways of thinking of philosophy of science in schools

Arguments have been offered purporting to show that the attempt to teach philosophy of science in upper secondary education (and particularly in cooperation with science subjects) was misguided. These reservations lay primary stress on mainly three ideas:

1. Some humanistic approaches presuppose that teaching philosophy of science was tied to economic competitiveness and growth and they understand the relation between science and humanism (*Bildung*in Germany) as being antithetic.

[3] What it is in this educational context to do philosophy (of science) is further explained in Lampert (2019; 2020).

2. Some constructivist and postmodern conceptions claim that philosophy of science tends to harbour a strong allegiance to scientism which they recognize to be inappropriate.
3. Some teachers believe that upper secondary students usually cannot deal with the complex and sophisticated issues of philosophy of science which are seen as being far away from students' lives.

In the following, a critical consideration of these reservations against teaching philosophy of science in upper secondary school shall make clearer the idea to teach philosophy of science and help in warding off prevalent misconceptions about it. It turns out that these objections obscure the substantial idea of teaching philosophy of science. Hopefully, the debate will not continue along its misguided path.

3.1 Reservations from humanistic perspectives

Humanistic perspectives tend to view the relation between science and humanism as antithetic. They warn of science's inappropriate intrusion into humanistic realms. Some identified a "positivist-reductionist nature" which has been seen as one "major failing of science" (Cross & Price 1992: 7). And philosophy teachers, on occasion, feel a tension between (philosophy of) science on the one hand and the ideal of humane education on the other.[4] They fear a hidden curriculum penetrating students' minds with the value system of science. Science has been seen as being contradictory to humanistic perspectives ("humanistischeBildung" in Germany) associated with technical rationality. Basically, "the cultural thesis of *Bildung*was that what really matters is not what happens in the state, society, or science – the outer realm of life – but what goes on in the inner realm of the soul with its potential for beauty and harmony" (Horlacher 2015: ix). The classical-humanistic ideal of education has been the dominant educational ideal in 19th-century Germany and the idea that science excludes humanistic values is a product of the "typically 19th-century way of thinking" (van Bommel 2015: 70). As a national construct, the concept of *Bildung* focuses on the development and formation of personality (formation of the self, self-cultivation, self-determination) and has become an "educational slogan" as well as a "political fighting word" in education policy debates (cf. Horlacher 2015). *Bildung* still seems to be a "container word" ("Container-Wort") which can be filled up with a variety of different meanings, as the German educational philosopher Dieter Lenzen pointed out (Lenzen 1997). However, at least it is opposed to mere training (Ausbildung).

Some slogans for a humanistic perspective (particularly in Germany for *Bildung*) might be too rash and myopic in fighting the idea of teaching philosophy of science. Contrasting a humanism and a scientific world view does neither do justice to humanism nor a critical scientific approach including philosophy of science.Humanistic perspectives intend to fend off attempts to prepare a citizenry that would have the skills to function effectively in a scientific world. However, teaching philosophy of science is not an attempt to prepare

[4] Occasionally, I am confronted with this objection expressed by philosophy teachers, complaining about philosophy of science-informed curricular proposals.

students for the next level of science course, engineering degree programs, or their future science-related careers, nor is it – as science education apparently has been seen – a "pipeline" for success in university programs which supplies the next generation of scientists (cf. Tytler & Osborne 2012: 597). Although it is true that education sometimes has been regarded as part of the human capital theory and there have been calls for more scientists to engage with the public, there are other reasons why teaching philosophy of science is necessary, reasons that have less to do with the needs to address societal challenges and more with the students' perspectives and their epistemic agency.

Agency is the possibility for an agent to act on the world, and affect it. Epistemic agency is the agency on one's practices to form and to hold believes that are warranted, justified and reasonable. To educate for epistemic agency means to equip students with the knowledge, abilities, and motivations to control aspects of their belief-forming practices and doxastic dispositions. This implies reflecting on how science arrives at its conclusions, "and both why and to what extend conclusions arrived at in this way are credible" (Elgin 2013: 149). Science is part of our cultural heritage and part of who we are as epistemic agents. *Understanding* science is a significant aspect of coming to grips with the flood of scientific information and the decisions students have to make. The information sources are greatly influencing students' conceptions, interests, and attitudes towards science and they often promote controversial, stereotypic, or gender-biased images of science and researchers. Philosophy of science in the classroom can illuminate the historical, sociological, and psychological context of the generation of knowledge as well as students' preconceptions on it. In view of the prevalent humanistic ideas on the one hand and the compulsory science lessons on the other, philosophy class has to offer a venue to reflect on the nature of science.

Following John Anderson, Nola and Irzik (2005) put emphasis on education being the acquisition and application of the means of critical inquiry. Critical inquiry as a normative goal for education is *not* something extrinsic, such as enabling someone to fit into society, acquisition of a vocation, or addressing social needs of society with competent drivers for future growth:"Critical inquiry can be said to be the intrinsic goal of education in the sense that it is not regarded as a means for yet some further end" (Nola & Irzik 2005: 10).

Furthermore, it seems clear that humanistic perspectives on science (including NOS, values, social aspects, etc.) *in the science curriculum* (and typically in the science-technology-society curriculum) have a long history and have been described in various ways (cf. Aikenhead 2006, particularly chapter 2:*A short history of humanistic perspectives in school science*). It is hardly denied that social and historical factors as well as theoretical commitments play an essential role in science. To consider this in philosophy class is quite reasonable in view of both, some naive beliefs in science and strong forms of relativism. Science has to be reflected as something that human agents are involved in and as a body of knowledge. However, the crucial question is not whether science-extern factors have an influence on scientific statements (which undeniably is the case), but rather which influences play a significant role. Hence, comprehensive perspectives and responsibility must be taken into account, too. Responsibility formed one of the major conceptions for a humanistic perspective in school science. Emphasis on science in the context of technology, society, and environment (STSE) has been part of science education discourse for decades in many countries. There are consistent calls for science education to be more than the transmission of abstract concepts and theories (AAAS 1993; Millar & Osborne 1998). And there is no question about philosophy being more than this. However, there is a difference between philosophy teaching and science teaching, particularly with regard to the expected outcome. Philosophy's focus is on doubt and questions about methods and concepts. Philosophy class seeks to develop a more critical and autonomous attitude towards these topics. It explores the epistemological issues and the social and political context in which science operates and should contribute to interdisciplinary discussions.Philosophy is interested in science as a human activity accomplished by limited human agents with expectations. This has been addressed by attention directed towards the socially relevant philosophy of science (cf. Potochnik 2014). Consequently, a dichotomization between a humanistic ideal of education on the one hand and the idea of integrating philosophy of science into education on the other is not adequate.

Philosophy education focuses on students' appreciation of philosophical inquiry as a process of asking questions which takes into account methodological sensitivity and conceptual tools as well as established standards and criteria. And philosophy reflects the pre-philosophical matter from which it sets out. Clearly, philosophy class is conceived as a venue that helps students to construct and reconstruct their understanding of their knowledge and habits within a problem-based framework. Hence, problem-oriented didactics of philosophy strive for exploring students' questions and, for instance, their epistemological ideas about the nature of knowledge and its production. Inquiry-oriented activities prepare students to discern what questions are to be asked and how they are tackled in real life challenges. Therefore, doing philosophy of science can foster students' media and information literacy and their ability to make educated decisions, for example, about climate change, the safety of new drugs, corona virus pandemic, or vaccination (vaccination discourse on the internet, for example, is characterized by misinformation and by appeals to emotion and ideology; Kata 2010, 2012). In cooperative school settings (for instance, philosophy alongside biology) we have the opportunity to examine more carefully the arguments for and against vaccination and other issues.

This goes beyond any cost-benefit-reasoning or vocational training. Moreover, doing philosophy of science encompasses the development of structural traits that play a major role in the individual's agency and authorship. Admittedly, the intellectual value of philosophy (of science) as a humanistic discipline is not (primarily) to be assessed in terms of how useful it is for the subjects of study (here: science) or society, even though philosophy of science has a social function and serves needs of democratic societies. This has been demonstrated convincingly, for instance, by studies of Philip Kitcher about the uses of scientific findings in social contexts (Kitcher 2001) and the relevance of democratic values to scientific activity.[5] However, even from the perspective of a "renewed humanism" as it is put forward by Julian Nida-Rümelin, philosophy is

[5] This is in addition to internal values (semantic, epistemic, methodological, etc.). Kitcher (2001) considers external values (ethical, social, political, and cultural) as having a recognizable role in science.

> significant to convey to the youth from early times onwards an appropriate understanding of the scientific thinking and to integrate the main results of science into a coherent image. Philosophy – as an integration-discipline, the only discipline which maintains a more or less strong connection to all other disciplines – can render this integration achievement. Philosophical epistemology and philosophy of science provide the fundamental concepts and methods of analysis. (Nida-Rümelin 2017: 19; translation Y. L.)

Apparently, the idea of personal and cultural maturation of a rational subject (*Bildung*) necessarily includes the individuals' reflection about their everyday practices and conceptions concerning science. Thus, it does not seem to be conclusive to feel a tension between (philosophy of) science and the ideal of humane education. There is no clear-cut dichotomy between the investigation of the nature of science on the one hand and individual development of personality or the cultivation of a free human being, called "Bildung", on the other hand. On the contrary, since science constitutes a dominant and pervasive aspect of students' lives, education that strives for understanding the fundamental cultural enterprise of science is a necessary condition for the development of "the whole person" living in the 21st century.

3.2 Reservations from constructivists and postmodern perspectives

There is still a great deal of disagreement about what counts as science and what its role in society is. Science denial and pseudoscience proliferate on social media.

> Science (and the idea of using reason as the basis for human belief in general) is routinely questioned, resisted, denied, ridiculed, rejected, and outright disrespected at the hands of those who do not wish to believe the sometimes inconvenient conclusions that are forced on us by reason (McIntyre 2015: 11).

Attacks on much of science have gotten so bad that in 2017 and 2018 there was a *March for Science* in many cities around the world (advocating "science not silence"). One aim was to advance evidence-based policymaking. Science and its limits is a topic of public interest discussed in blogs, popular magazines, and newspapers such as *The New Republic*, *American Scientific, The Atlantic,The Guardian, The Guardian's* online magazine *The Observer*,and *The New York Times* (whose online version – responding to the growing acceptance of "alternative facts" – in 2017 opened with a pop-up that asserted: "TRUTH. It's grounded in facts").

Strong forms of constructivism and the concern for radical plurality challenge the concepts of truth and knowledge, and they seem to be antagonistic to science as well as to education. Indeed, constructivism is not a unitary theory and the term has a very wide application. It encompasses a variety of different views some of which would not be especially controversial. Depending on the answer tothe question "what is it that is constructed?", "we get a plausible or a totally unacceptable version of constructivism" (Nola & Irzik 2005: 151). It is beyond the scope of this article to analyze the different (weak and strong) forms of constructivism and relativism. My focus is on some variety of relativism which seems to fuel students' relativistic attitude concerning scientific or moral matters, sometimes expressed in statements like "right and wrong as true and false is just a matter of opinion – what is right/true for you may not be right/true for me."

Particularly at school levels, there is a struggle over multicultural perspectives on science challenging the view that the standard account of science is the only account of science. McCarthy (2018) discusses several postmodern theses about the nature of science, the nature of truth, and the nature of knowledge that are prominent in the context of science and science education as well as in philosophy education. She argues that the prevalence in science education of "erroneous post-modern interpretations [...] contribute[s] to the social problem of cultural disdain for, or neglect of, modern science, its practices and its findings" (McCarthy 2018:100). A similar pattern might be seen in philosophy education. McCarthy explains that the way for the acceptance of "'alternative facts' and 'alternative truths' in Donald Trump's presidential-advisory circles" was prepared by a misinterpretation of the nature of modern science in the course of cultural studies of science (McCarthy 2018:123). Social studies call for a "constructive postmodernism" of science, considering science as being "mechanistic, materialist, reductionist, empirical, rational, decontextualised, mathematically idealised, communal, ideological, masculine, elitist, competitive, exploitive, impersonal, and violent" (Aikenhead 1997: 220).Cross-cultural science education challenges the view that modern science is a prominent way of knowing. It intends to demonstrate that the intellectual tradition of the scientific community can coexist with the traditions of Indigenous[6] communities (Aikenhead & Michel 2011). However, the idea that long-standing belief systems *must* be getting something right seems to be quite implausible and not easy to stabilise. Furthermore, dogmatic acceptance of traditional spiritual beliefs which are fundamentally inconsistent with modern science often derives "from stories taken to be scared" (McCarthy 2018: 112). McCarthy explains thoroughly why it is not justified to treat modern science "as if it were an ineluctably culture-based belief system, just one among many other equally valuable 'ways of knowing'" (McCarthy 2018: 113). She describes "the radical re-conceptualization of the concept of science and the subsequent reconstruction of science education" (McCarthy 2018:104) as a key intellectual aim of the literature that makes up cultural studies of science education. And she identifies "a disturbing disinclination, in some quarters, to see modern science inquiry and knowledge as relevant to solving social/cultural/physical problems" (McCarthy 2018: 99). The idea that assertions of facts about the natural world can be true in one culture and yet be false in another seems to "systematically confuse facts and values, truth

[6] The term "Indigenous" encompasses the original inhabitants of a place and their descendants who have suffered colonisation. It particularly refers to Aboriginal peoples. Therefore, "Indigenous knowledge" is also called "Indigenous knowledges", "Indigenous science", "Aboriginal science", "Native science", "traditional ecological knowledge", "Indigenous ways of living in nature", etc. in publications of multi-cultural sciences. The main idea is that modern science is deeply alien to Indigenous peoples and – as a matter of respect for persons and culture – it is held that "Indigenous science" as any traditional belief system is to be respected equally. However, "respect for persons does not entail respect for the belief-systems of those persons" (McCarthy 2018: 132). Respect for others does not require respect to non-scientific systems of belief not warranted by scientific inquiry. Relativist views are often motivated by the demand to be tolerant. The confluence of tolerance (as a matter of ethics) and relativism (as a matter of epistemology) has created the unfortunate idea that to be tolerant one has to be a relativist.

and belief, the world and our knowledge of it" (Sokal & Bricmont 2004: 18). Within some postmodern and constructivist approaches, there has been some sort of "truth-phobia" and sociologists such as Shapin, Lyotard, and Latour[7] have done much damage in science studies (Nola 2003).

Whether these and other – quite popular anti-science – approaches are reasonable or not and how we can clarify questions about it might be an interesting question for students and should be a relevant theme in teaching philosophy of science, too.Philosophy (class) has to provide differentiated points of view, for instance about the idea of the social relativity of descriptions or the description dependence of facts. Sokal, Bricmont, and others (see, for instance, Boghossian 2006: 26f.) criticise "extremely weird written statements" (Sokal & Bricmont 2004: 19, note 9 and Bricmont 2001, note 4) constructivism brings forth, such as Latour's remark on the tubercle bacillus, which was discovered 1882 by Robert Koch: "Before Koch, the bacillus had no real existence" (Bruno Latour, "Ramses II est-il mort de la tuberculose?", quoted and discussed in Sokal & Bricmont 1998: 92f.; quotation: note 123).

To be sure, cultural and social influences have a substantial and lasting impact on methods and assumptions of science, and even ordinary perception is "social" in some sense. Nonetheless, philosophy of science is not to be seen as an offer of merely a rich array of different perspectives on science, from which each student may choose whereas "the only criterion of choice, once a correspondence theory of truth is rejected, is that the chosen knowledge system either has utility for or makes sense to the individual; these are subjective criteria" (McCarthy 2018: 106). Philosophy of science in the classroom is not meant just to replace students' gained scientific skills and knowledge in science class by the idea of science as a cultural product of the West, being no more justified as other belief systems. Philosophy (class) should offer more than some postmodern perspectives on science or relativistic and anti-science attitudes that are around.

It seems to be pedagogically required to help students shaping a distinctive epistemological attitude. Philosophy class can offer them a perspective beyond scientism and strong forms of epistemological relativism and scepticism. It can provide the opportunity to reflect on one's current state of beliefs. As McCarthy puts it:

To fail to teach to one's students the critical evaluation of their own belief-systems, which is necessary in the effort to maximize true belief and to reduce false belief, is a matter of fundamental disrespect for persons, and constitutes a profound mis-education (McCarthy 2018: 132).

The epistemic and pedagogical goal of having true beliefs about the world "is justified by its contribution to achieving valued and end states of action" (McCarthy 2018: 124).

Nola and Irzik (2005) raise awareness of some fundamental philosophical issues according to education. Particularly, they question the abandonment of ideas such as universalism, trans-cultural rationality, scientific method, objectivity, and truth.The American philosopher of science and education, Israel Scheffler, made strong normative judgements on the aims of education, too. In his book *Conditions of Knowledge: An Introduction to Epistemology and*

[7] Latour has diverged from his former constructivist approach and noted in 2017 that he was – in the age of "post-truth era" and "alternative facts" – interested in helping to rebuild trust in science (Frazier 2018: 7).

Education (Scheffler 1965), he serves an introduction to the subject of epistemology interrelating epistemological and educational concepts and concerns. To him, rationality and critical thinking are central aims in education; "critical thought is of the first importance in the conception and organization of educational activities" (Scheffler 1973: 1). In his work philosophy of education, epistemology, and philosophy of science are closely related: "Rationality [...] is a matter of reasons and to take it as a fundamental educational ideal is to make as persuasive as possible the free and critical quest for reasons in all realms of study" (Scheffler 1973: 62). Thus, philosophy of science in the classroom should be committed to the understanding of the (social) role of science and its epistemic nature as well as the value of scientific seeking knowledge about the external world – in some sense or other.

3.3 Reservations concerning philosophy of science's relevance to students

Around the globe, science education in compulsory schooling is envisioned for all students, irrespective of their vocational and academic interests. Students learn about science in formal (schools, textbooks), non-formal (science slams, science centers, and museums), and informal (mass media such as newspapers, journals, films, youtube, and blogs) ways. Social media such as Facebook, YouTube, WhatsApp, Instagram, Twitter, Snapchat became students' primary source of (scientific) information and this promotes accelerate and amplify information *and* disinformation. There is a gap between information access and valid knowledge formation. And there are wide gaps between the attitudes of scientists and the public on several issues (Pew Review Center 2015, Funk, Hefferon, Kennedy & Johnson 2019). Rejection of science is triggered when scientific findings challenge entrenched tenets of people's world views. Philosophy of science in philosophy class should also include the epistemic and communication practices, namely the mechanisms of communication, its mediation, and intentional disinformation. Therefore, didactics of philosophy can provide perspectives on the development of media and information literacy, too. Information infrastructure, i. e. communication networks that constitute the conditions for knowledgeand hence determine what is to be known, could be a vital theme in philosophy class. The use of a variety of criteria such as accuracy, clarity, effectiveness, potential biases, relevance of facts can be developed in connection with knowledge and skills acquired in other subjects.

On March 11, 2020, the day the World Health Organisation announced the Covid-19 outbreak as a pandemic, there were more than 19 million mentions of the corona virus across social media. The pandemic became "an existential moment for the use and abuse of knowledge" (de Rijcke 2020: 175). Science was "powered by uncertainties, error margins, competition, disclaimers, collaboration and stress. In dark times, all of that can be weaponized", as de Rijcke (2020: 175) underlines. Possibly refutatory sources of information sometimes are rejected in favour of dogmatism or political purposes. Google and other online platforms have been trying to root out misinformation about the corona virus and other subjects.

The phenomenon of "post-truth"[8] describes the epistemic hazards of our media culture. It

[8] The Oxford English Dictionarycommittee that was responsible for choosing "post-truth" as Word of the Year for 2016 defines "post-truth" as "relating to or denoting circumstances in which objective facts are less

displays what happens when facts face political, personal, or commercial pressure. Feelings and unreasoned beliefs sometimes matter more than facts. Education must be responsive to the challenges thrown up by the “post-truth era”. Students should be able to critically evaluate reports of scientific findings to take part in public debates and everyday practice of giving and taking reasons. Philosophical reflections on what counts as science are – especially in the midst of a pandemic – pivotal. Science class cannot cover all the philosophical aspects of science, and these issues require more than input from science. Particularly, an understanding for analyzing and assessing scientific statements, especially in the media, has to be developed in philosophy class, too. Generally, (scientific) knowledge and concepts emerge within specific practices and contexts. Philosophy is interested in the processes of generating knowledge as well as in the ways it is initiated and maintained. For instance, the Covid-19 pandemic’s impact on contemporary science, society, and students’ life has to be reflected. (How) do students understand the measurement of mortality (why is it difficult to determine whether people have died as a result of Covid-19?)? What does it mean to measure how infectious a disease is? Can they differentiate between the basic reproduction number (R_0,when there is no deliberate intervention in disease transmission and no immunity from past exposure or vaccination) and the effective reproduction number (R)? Do they realize that there are several variables thataffect R_0 and R (duration of infectivity of affected people, rate of contact in the host population, etc.)? The implications of downloading tracking apps, social distancing, self-isolation measures, learning through online resources, and long-distance learning communities are problems philosophy education has to face within its complex context, too. Hence, I give priority to a student-centered point of view opposed to a scientist-centered perspective aimed at scientific or science-related careers.

Supporting students in acting as social and epistemic agents means to encourage them to ask and discuss scientific issues. Improving students’ ability to analyze and construct arguments about controversial science topics should be a desired outcome of philosophy education, too. Understanding of NOS can be used as a tool for decision-making and participation in debates about SSI. And if we do not offer the opportunity to reflect on these complex themes and to develop an account of why scientific explanations are taken to be superior, why should students accept attending science class at all?

Some students place confidence in science and actually intend to study at university. Young climate activists, who took part in the global wave of school strikes for climate, known as *Fridays for Future,* tend to rely on science. A team of social scientists from universities across Europe that surveyed protesters in 13 cities in nine European countries found that a majority of respondents think that science can contribute to the solution of environmental problems and that politicians need to do more to act on science (Wahlström, Kocyba, de Vydt & de Moor 2019). They sum up:

influential in shaping public opinion than appeals to emotion and personal belief.”, see, e.g., *The Guardian* 15 November 2016: https://www.theguardian.com/books/2016/nov/15/post-truth-named-word-of-the-year-by-oxford-dictionaries, 30 March 2021.

> "In line with much of the framing used by movement leaders like Greta Thunberg, it is above all science that demonstrators rely on. About 54% are convinced that modern science can solve our environmental problems and about 79% agree or strongly agree that 'Governments must act on what climate scientists say even if the majority of people are opposed'" (Wahlström et al. 2019: 17).[9]

Science has traditionally been billed as the most reliable means of acquiring knowledge. Scientific knowledge is held in high regard because it satisfies epistemic standards. People around the world insist that science is beyond dispute. By ignoring the results of science, it is suggested, we are risking our health and future.

On the other hand, privileging the findings of science has been seen as a dubious matter and strategic science scepticism is contesting science in order to promote particular non-epistemic (e. g. political and economic) interests. There is a rise of anti-science rhetoric in public discourse. Hence, science as a school subject often fails to provide students with a coherent picture of science and it is in the view of (at least some) students not useful in everyday life (McSharry & Jones 2002); those who acknowledge the relevance of science rather stress the instrumental value of it (Osborne & Collins 2001). Students' knowledge about science is ambiguous and sometimes reflects complete ignorance of how science works, however their preconceptions can be altered in several dimensions (Scherz & Oren 2006). Students' conceptions of science and scientists are often stereotypic and controversial (Finson 2002). Science is seen as fundamentally contradictory to long-held religious convictions, and therefore potentially contradicting to aspects of some students' cultural context as well as to some of their epistemological beliefs. Students' pre-scientific conceptions, frequently determined to be misconceptions (also called "alternate conceptions"), often rely on intuition as well as on what has been taught in other settings. These preconceptions are sometimes inconsistent with the concepts being taught within a domain-specific context and need to be acknowledged.[10] They can conflict with fundamental concepts of science students are supposed to learn. Students sometimes gain knowledge that prima facie is counter-intuitive, alien, or incoherent. Philosophy class has to consider this situation which is faced by upper secondary students. The claim is that philosophy class has to offer a venue for students to critically reflect on their preconceptions and convictions which can be replaced, reorganized, or completed (cf. Zimmermann 2016: 67f.). Pre-scientific ideas can be seen as a starting-point for philosophical reflection. Lessons should provide learning experiences that will help students to make connections between new concepts and the knowledge they already have. This is not only a didactical consideration but also reflects on the sociology of concept

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[9] Cf. Greta Thunberg, February 2019 in Brussels: "We know that most politicians dont't want to talk to us – good. We dont't want to talk to them either. We want them to talk to the scientists instead and listen to them", https://www.euractiv.com/section/climate-environment/news/greta-thunberg-we-just-want-politicians-to-listen-to-the-scientists/, 30 March 2021.

[10] Students' preconceptions have been identified in a variety of ways. Particularly in science education a large amount of research on students' preconceptions has been conducted. Teachers are expected "to be aware of and understand common naive concepts in science for given grade levels, as well as the cultural and experiential background of students and the effects these have on learning" (NRC 1996: 31). Recently, there has been some attention on students' preconceptions in didactics of philosophy, too (cf. Lampert 2009: 249ff.; Zimmermann 2016; Thein 2020).

formation and the analysis of the development of modern scientific concepts, such as the concept of syphilis. Ludwik Fleck – mentioned in the Preface to Kuhn's *The Structure of Scientific Revolutions* as having anticipated many of Kuhn's ideas –stresses in his analysis of the history of ideas on syphilis that "many very solidly established scientific facts are undeniably linked in their development, to pre-scientific, somewhat hazy, related proto-ideas or pre-ideas, even though such links cannot be substantiated" (Fleck 1979: 23).

So, science seems to be a matter of confusion which requires debate among different views and the ability to critically evaluate the different stances on it. Philosophy of science within the integrative (implicit) approach as well as within the additional and cooperative (explicit) approach (see introduction) can provide the opportunity to reflect the various sources of (potential) confusion and the misuse and abuse of key concepts of science in public discourse.

3.4 Philosophy of science and the aims of education

Philosophy of science in the classroom is not very popular but this theoretical backsliding did not attract much attention. Notwithstanding, philosophy class has to face central and new epistemic and social problems concerning presentation, transformation, reduction, reconfiguration, and recontextualization of scientific information. The discussion of questions about what knowledge claims and sources of expertise can be recognized as being credible and how knowledge is shared is grounded in the students' immediate daily experiences as well as in the social and political context of their lives. Philosophy teachers, too, should be disturbed by some recent escalations of political assaults on scientists. Philosophy education (as all education) should reflect on implications for the educational response to post-truth and engage in the development of epistemic agency. And didactics of philosophy could be vital in this mission. *Thus*, I remain doubtful about the "practical turn of philosophy" (cf. Nida-Rümelin et al. 2017: 10). We can support the claim of members of the US National Academy of Sciences who underline with a letter published in the journal *Science*:

> We are deeply disturbed by the recent escalation of political assaults on scientists in general and on climate scientists in particular. All citizens should understand some basic scientific facts.There is always some uncertainty associated with scientific conclusions; science never absolutely proves anything. (Gleick et al. 2010: 689)

Science, no doubt about it, is a source of controversy and debate. The revisionary nature of science and scientific frauds and misconduct could potentially lead to a radical scepticism about science which threatens the justificatory basis for (scientific) knowledge claims. And, possibly, the way epistemology at the introductory level sometimes is taught (in evil-demon style) might encourage, rather than discourage, such scepticism. However, doing philosophy of science can help students to understand disagreement on a more fundamental level by providing an understanding of the strengths and limitations of science. Understanding the nature of science, particularly presuppositions, standards of evidence, modes of explanation, the relation between science and values, and science's role in society, culture and students' personal lives helps in making informed decisions. Moreover, the interactions of science and scientists with social issues and institutions external to the scientific community as well as the social interactions of scientists within the scientific community have been occasionally emphasized. Driver and colleagues (1996: 12) refer to these aspects as "science *in* society" and "science *as* society". Ratcliffe and Grace (2003) have identified several key features of SSI evolving where data and evidence may be incomplete, conflicting, or confusing. Zeidler and colleagues (2005) describe SSI-oriented teaching in terms of its emphasis on developing habits of mind (open-mindedness, scepticism, critical thinking, etc.). They emphasize the idea of "empowering students to consider how science-based issues reflect, in part, moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them" (Zeidler, Sadler, Simmons & Howes 2005: 357). The concerns and priorities of the SSI-oriented approach overlap with those of didactics of philosophy in many respects.

Doing philosophy of science can foster the attitude of an epistemic agent who appreciates rigorous thinking and conceptual clarity. Epistemic agents are seeking out new sources of information in order to analyze and evaluate them using background beliefs and knowledge. Most distinctive to science is its attitude: the idea that scientists care about evidence and are willing to change their views based on new evidence (McIntyre 2019). The development of such an attitude can also help bursting epistemic bubbles and echo chambers in which other voices are not heard or actively undermined (Nguyen 2020).

Education and philosophy education in particular focus on the aim of autonomous thinking and acting. Philosophy is "the discipline of thinking for oneself par excellence" (Nida-Rümelin et al. 2017: 10). Doing philosophy – echoing Kant's (and Horaz') directive "sapereaude!"– has been seen as a key element of emancipation. In a note appended to the close of his essay *What does it mean to orient oneself in thinking* (1786) Kant defended his "enlightenment principle": "*Thinking for oneself* means seeking the supreme touchstone of truth in oneself (i.e. in one's own reason)" (Kant 2001: 18). According to Kant, heteronomous subjects are bound by constraints that they neither make nor endorse. Hence, a heteronomous subject is not strictly an agent, for she/he does not act but merely reacts, driven by beliefs that are not under her/his control. To behave autonomously does not mean to put not weight on the claims of others. On the contrary, it sometimes is rational to take a judgement of others (as being authoritative persons offering expert testimony) on trust. In any case, we need the *possibility* to come to know matters "on the basis of the exercise of our own power of reason" (Nola 2018: 58). The interests and questions of the students have to be taken as a starting point for philosophical reflections on science in their lives as well as in society and culture. Emphasis is on philosophical problems rather than schools of thought.

The aim of education is the development of "people who can be rational and critical inquirers into whatever subject matter or discipline in which education is being acquired" (Nola & Irzik 2005: 7). This broad aim allows any subject matter to be the object of critical inquiry and "concerns the process of criticism itself" (Nola & Irzik 2005: 9). It strives to develop the "ability to critically evaluate any beliefs, any assumptions and presuppositions, any attitudes, judgements and evaluations (including those of critical inquiry), and any traditions and customs of one's society and culture" (Nola & Irzik 2005: 8). Given the "normladen" notion of education introduced by Nola and Irzik, education gives us "the grounds for believe, and/or reasons as to why each believe *ought*, or *ought not*, to be held" (Nola & Irzik 2005: 48). It is "a role for philosophy in setting out some of the principles of critical inquiry found in logic, epistemology, methodology and elsewhere, and then in providing a justification for them" (Nola & Irzik 2005: 48).

Philosophy of science is situated at the junction between science (class) and students' direct experience. Science and philosophy can be regarded as "two ends of one chain" which "connects the statements about our direct experience with the general statements of science", as Philipp Frank claims in his *Philosophy of Science* (Frank 1957: 13).[11] Philosophy of science can be understood as the "missing link between the sciences and the humanities without introducing any perennial philosophy that could only be upheld by authorities" (Frank 1957: xv).

Philosophy of science in upper secondary school should reconnect to the philosophical issues of other subjects arising within the philosophy of different domains (philosophy of chemistry, mathematics, history, etc.) as well as to more general aspects such as knowledge, belief, evidence, justification, truth, proof, law, and explanation. It offers potential for improved learning of the important yet vague concepts and methods of science and for learning about the nature, goals, and values of the operations of science. However, it has to do so not in a somehow detached way, but rather connected to students' personal experiences. And at best this also means in connection to their experience in science class. Since education as well as philosophy is inherently interdisciplinary it would be wise to see philosophy education as an interdisciplinary research field, too. Emphasis is on students' various views of the world and themselves to help them find a meaningful and responsible orientation in life. Philosophy education should draw more attention to the questions on what contribution other subjects give to philosophy and what philosophy's contribution to other fields could be. This requires thinking across disciplinary boundaries against entrenched habits of teaching and learning.

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[11] In the preface to his book Frank states: "A main purpose of the present book is to show that one does not need to diminish research and teaching in science in order to enhance interest in the moral and philosophical aspects of the world" (Frank 1957: iv). Frank played a central role in the development of the Vienna Circle, which was part of the intellectual movement of European philosophy of science. The American Unity of Science movement at Harvard began with Frank's organisation of an "Inter-Scientific Discussion Group" in 1944 (Galison 2001). Frank argued that the history and philosophy of science should be part of curriculum for all science teachers. Only recently, studies have begun to draw attention to his work.

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