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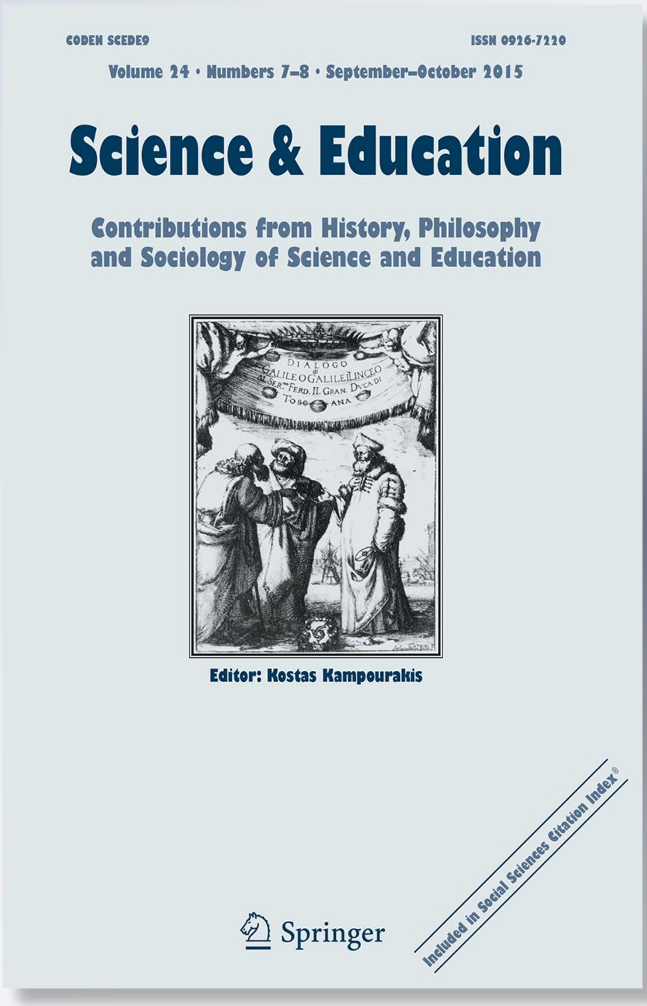

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ARTICLE

Scientism and Scientific Thinking

A Note on Science Education

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Abstract The move from respecting science to *scientism*, i.e., the idealization of science and scientific method, is simple: We go from acknowledging the sciences as fruitful human activities to oversimplifying the ways they work, and accepting a fuzzy belief that *Science* and *Scientific Method*, will give us a direct pathway to the true making of the *world*, all included. The idealization of science is partly the reason why we feel we need to impose the so-called scientific terminologies and methodologies to all aspects of our lives, education too. Under this rationale, educational policies today prioritize science, not only in curriculum design, but also as a method for educational practice. One might expect that, under the scientistic rationale, science education would thrive. Contrariwise, I will argue that scientism disallows science education to give an accurate image of the sciences. More importantly, I suggest that scientism prevents one of science education's most crucial goals: help students think. Many of my arguments will borrow the findings and insights of science education research. In the last part of this paper, I will turn to some of the most influential science education research proposals and comment on their limits. If I am right, and science education today does not satisfy our most important reasons for teaching science, perhaps we should change not just our teaching strategies, but also our scientistic rationale. But that may be a difficult task.

1 Introduction

Different sciences aim at describing how different parts of the world operate; their many successes cannot be denied since they have allowed us to explain, predict, and intervene in a variety of phenomena; moreover, they have produced important technological advancements, from refrigerators to medical ultrasounds that better our lives. So far so good. However, it is often suggested, implicitly or explicitly, that all the information worth knowing is scientific information. The rationale implied here is that, since the scientific method is successful, it is

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supposedly applicable to every aspect of our lives. This move from respecting science to *scientism*, i.e., the idealization of science and scientific method, is as simple as that. We go from acknowledging the sciences (in the plural) as insightful and fruitful human activities that inform our lives in a variety of ways to deifying science and the scientific method (in the singular), oversimplifying the ways that sciences work, and accepting a fuzzy belief that science will give us a direct pathway to the true making of the *world*, all included. Even all the questions on ethics, esthetics, or even existential questions on the meaning of life then, will be solved by science. In fact, it is often suggested that if science cannot answer a question, it was not much of a question to begin with. This is the scientistic stance that many popular books evoke (e.g., Crick 1996; De Waal 2009; Harris 2011; Rosenberg 2011). Pigliucci tried to summarize this stance:

> A totalizing attitude that regards science as the ultimate standard and arbiter of all interesting questions; or alternatively that seeks to expand the very definition and scope of science to encompass all aspects of human knowledge and understanding (Pigliucci 2013, p.144).

There is a huge discussion over scientism today: lots of distinctions of its many varieties (e.g., Stenmark 2001; De Ridder 2014); some praises (e.g., Pinker 2013; Rosenberg 2011; Ladyman 2011); some criticism (e.g., Sorell 2013; Stenmark 2001; Haack 2007; Kitcher 2012; De Ridder 2014; Van Woudenberg 2011; Peels 2017). Part of the disagreement depends on different definitions and conceptions of scientism (e.g., Sorell 2013; Stenmark 2001; Kitcher 2012; Hughes 2012; Pinker 2013; Rosenberg 2011; Ladyman 2011; Ross et al. 2007; Peels 2017; Mizrahi 2017). After all, *scientism* is a rather vague term, echoing an overall *pro-science* attitude. I should note then, that I am pro-science all the way. However, here I try to explore the dangers that an extreme, vague, uncritical, and often implicit scientism holds for science education. Such an extreme stance is what Haack (2007) or Kitcher (2012) have in mind when they see scientism as a threat to *science*. I like to add then, that scientism is also a threat to *science education*.

> According to Haack:
>
> Scientism is an exaggerated kind of deference towards science, an excessive readiness to accept as authoritative any claim made by the sciences, and to dismiss every kind of criticism of science or its practitioners as anti-scientific prejudice (Haack 2007, p.47).

Following this line of thought, I take scientism to evoke an excessive admiration of science that is based on a naive, exaggerated conception of it as a single, non-speculative practice or method, which can and will answer all possible questions (Kidd 2014). Often we talk about scientism as a tendency to impose supposedly scientific concepts or methodologies where they do not apply (Stenmark 2001; Sorell 2013). However, even this tendency begins from misconceptions of *what science is*, within forms of study that are conventionally called *science* (Haack 2007; Kidd 2014; Stanford 2016).

Misconceptions and idealizations of science as a singular term are partly the reason why we feel we need to impose the so-called scientific methodology to all aspects of our lives. Education is no exception to the rule. Indeed, under this rationale, educational policies today prioritize science in curriculum design, but also as a method for all disciplines, including educational practice itself. Many have argued how worrying scientism is for education today (Bridges and Smith 2007; Smith 2008; Stickney 2009; Standish 2012; Gasparatou 2017a). In this article, I want to also include *science education* in our worries. One might expect that, under the scientistic rationale, science education would thrive. Contrariwise, I argue that scientism makes it impossible for science education to accomplish one of its crucial goals: help students think.

In the Section 2, I summarize our basic reasons for teaching science and suggest that, in order to satisfy these reasons, science education ought to facilitate certain thinking skills. In Section 3, I explore such thinking skills and suggest that science education should at least enable us to coordinate and re-coordinate data and theories in a fairly controlled manner. After all, data-theory coordination is often thought as the very basis of scientific—or even rigorous—thinking. In Section 4, I show how the scientistic rationale disallows science education to promote such skills. Many of my arguments draw on findings and insights of science education research. Finally, in Section 5, I turn to some of the most influential science education research proposals and comment on their limits to address scientism. If I am right, and science education today does not satisfy the very reasons for teaching science, perhaps we should not change just our teaching strategies, but also our scientistic rationale.

2 Why Teach Science?

Many different reasons for including the sciences in the curricula have been given (Bybee and Ben-Zvi 1998; Davson-Galle 1994; Lawson 1995; Longbottom and Butler 1999; Davson-Galle 2004; Reiss 2007; Östman and Almqvist 2010). In this section, I outline some basic, almost commonsensical ones.

One of the reasons why we teach science is to create future scientists (Davson-Galle 1994, 2004; Lawson 1995; Reiss 2007). It is crucial however, to ask why we feel that we need new scientists. Surely we do not just want people working the ultrasound devices and whatever other equipment we already have or just looking for more verification of what we already know. We do not want a generation of technicians and practitioners, but rather *full-blown scientists*. It rather seems there is more to know then. Aiming at the making of new scientists entails that we anticipate that the sciences will go on advancing our knowledge, our theories, and our technologies. Insofar as we feel, we will always need new scientists, new sciences, and new insights; we accept that science is an ongoing and ever-ending process. And then, the mere passing of current scientific information to the next generation will not do. We rather need courses that not only teach students the current scientific theories, but also promote habits of mind and practical skills that could contribute to the making of new science.

Nevertheless, not all our science education students will become scientists. We are fully aware of that. And yet, ideally, we would not want to exclude anyone from science courses. We want to have an educated public and we acknowledge that scientific advancements are crucial parts of our collective civilization. Moreover, we are fully aware that some understanding of the sciences is crucial today for all kinds of decisions. If I want to have a child, or if I do not want to have a child, I would have to know how children are conceived and born; had I have one, I would have to know where to look for advice about upbringing or vaccinating them; if my tooth aches, I would have to know what to do, where to go and what to ask. Many kinds of everyday decisions and practices require some scientific literacy (Davson-Galle 1994, 2004; Lawson 1995; Reiss 2007).

Scientific literacy however, is not just limited in having the right information; you also need to know when and how to use each piece of information and how to link them (Davson-Galle 1994, 2004; Lawson 1995; Reiss 2007; Östman and Almqvist 2010). Besides, the information is too much and in many cases changing in fast pace. There is no way one can grasp it all, once and for all, when at school. Moreover, nowadays it is not all that difficult to find the information if you know what you are looking for; you just google it. If we want a science-educated public, we should make sure that science education enables them to access, understand and assess the information they might need, at least at some level. And then, again, science courses would have not to just pass on the information, but also promote habits of mind and practical skills that could contribute to the basic understanding of scientific knowledge. Science education, for example, should encourage students to be careful not to rush to pre-reached conclusions, be open to different interpretations, try different methods, discuss with their peers, make informed decisions, etc.

Promoting certain habits of mind and practical skills is essential for all education, science education included. And this is one more reason we teach science, probably the most central one (Davson-Galle 1994; Lawson 1995; Davson-Galle 2004; Reiss 2007). Besides, insofar as we think that sciences employ rigorous thinking methods, science education is qualified to teach us how to think rigorously. The making of future scientists or a science-educated public relies on it.

3 Can Science Education Teach Thinking?

I will not attempt to define the concept of *thinking* here. Different disciplines (e.g., philosophy, psychology, biology, neurology, linguistics, cognitive science, computer science, etc.) and different schools within these disciplines provide many, often meticulous, however distinct or even incompatible, theories about thinking. Insofar as it is hard to come up with a unanimous view about *thinking* in general, I will also not attempt to say what *kind of thinking* the sciences employ or what it means to *think rigorously*, *critically*, *or scientifically*. So, I will not discuss here whether all thinking is alike, or about which kind of thinking is broader or narrower than which. It seems however, that we should not avoid the discussion about cultivating thinking skills altogether, just because the terms are so broad. We would better pinpoint some skills that critical or rigorous or scientific thinking involves. And it seems that there is at least one key feature, which all rigorous thinking should include and which science education could and should promote. Science education should facilitate the development of the skill of coordinating one's theories with the data at hand. In this section then, I summarize what the skill of data-theory coordination amounts to. In the next section, I comment on how scientism prevents the development of this skill.

Scientific knowledge is not just founded on experience and experimental processes, as naive scientism implies (Stenmark 2001; Van Woudenberg 2011; De Ridder 2014; Peels 2015). It uses logic, introspection, and makes all kinds of presuppositions that experience alone cannot ground. Moreover, scientific knowledge rests on interpretations and re-interpretations of the many different experiences we consider as data at times (Laudan 1986; Chalmers 2013). Neurath (1921) illustrated this process, paralleling our collective theories about the world, i.e., our knowledge, with a *ship*:

> We are like sailors who on the open sea must reconstruct their ship but are never able to start afresh from the bottom. Where a beam is taken away a new one must at once be put there, and for this the rest of the ship is used as support. In this way, by using the old beams and driftwood the ship can be shaped entirely anew, but only by gradual reconstruction.

From our overall experience of the world, we pick certain instances and count them as data. We keep gathering data that are at reach and use them; we interpret them in ways that may or may not fit what we already think and articulate theories. In light of these theories, we may change our mind about what kinds of data matter. Certain elements of our ship may be abandoned or used in different ways. In light of the new data at hand again, we might alter our interpretations and formulate new theories. We consider and reconsider different kinds of experiences as data and we interpret and reinterpret whatever data we may reach, while trying to promote our explanations and predictions of how the world works.

Quine (Quine and Ullian 1978) echoed the same idea when talking of our worldview as a dynamic *web* of beliefs in which all beliefs are open to revision; Kuhn (2012) and Lakatos (1978) emphasized the role of history in this process; we build scientific *paradigms* or *research programs* that allow different interpretations of the world. As Conant (1951), among others, explained, even experimental sciences are speculative; we speculate not only about how to perceive the data at hand, but also about what to perceive as a datum.

In fact, most philosophers of science would agree that a dynamic process of data-theory coordination lies at the very heart of scientific practices, even when they disagree on how this process is performed (Laudan 1986; Chalmers 2013). After all, data-theory coordination may well involve many different thinking strategies. And a variety of factors, linguistic, historical, or social, may influence this process. However, different sciences and different scientists in different eras try to make sense of the world through such coordinations. Psychologists and science education researchers, such as Kuhn (Kuhn and Pearsall 2000; Kuhn and Park 2005; Kuhn and Pease 2006) or Jiménez-Aleixandre (1992) then, are rather well-justified to suggest that data-theory coordination lies at the very root of scientific understanding. It is in fact a key skill of scientific—or even rigorous—thinking.

In order to be able to coordinate data and theory, the first one would have to be able to separate data *from* theory. Now, when talking about *theories* here, one might include all kinds of perspectives. *Theory* in this context might involve hypotheses, interpretations, beliefs, or systems of beliefs. And talking about *data*, one might include all kinds of results, observations etc. that are at hand. Separating data from theory then, requires being able to look for what would count as evidence for what. For example, if I show pictures of a running race and ask people who won, they should be able to point out to the pictures that are relevant to the question and can be considered as evidence of winning; pictures of whoever is breaking the winning line first, not pictures of the fancy shoes that the winner is wearing, as sometimes seems to be the case (Kuhn and Pearsall 2000). Separating data from theory is also the first step in order to offer alternative interpretations of the same data. For example, if I want to make tea and the water does not boil, perhaps the electricity is off, or my heater is broken, or perhaps I did not put anything in the cattle, or perhaps what I thought was water is a different kind of liquid. Being able to provide alternative interpretations is important; it will take me to the next level of my investigation and guide me to the solution of the problem at hand.

Each level involves coordinating data and theory, that is being able to move upwards from the data to new interpretations, hypotheses, perspectives, or theories; and downwards from theories to exploring the fitness of our data, including new or dismissing old ones; and then back again to provide new interpretations, perspectives, and theories. It is important to see that the direction of this coordination is two-way; it does not just go from the data to the theory as it is often assumed. It actually requires being able to run up and down the data-theory ladder nonstop. For example, at some point people, biologists included, thought that whales are fish; all the observations (e.g., they live at sea, they look like fish morphologically) supported this theory; and vice versa, the biological theory of the time, with all the definitions it had about *fish*, *mammals*, etc. supported this reading of the data. At some point, observations led to discriminating whales; for example, we found out that they breastfeed or that they do not have gills. Biologists had a choice: either come up with a definition of *fish* to include whales or read whales out of the fish-class. They chose the latter. Their new biological theory reads the data in a new light and vice versa; the data support this new theory with all its terminology (Quine and Ullian 1978, pp. 54–61).

Data-theory coordination is an ongoing task, which a science-educated person ought to be able to do in a conscious and controlled manner (Kuhn and Pearsall 2000; Kuhn and Park 2005). This skill is crucial for understanding and making new scientific knowledge. But it is also important for all human decision-making. Imagine I work for Oxfam and we decide to sell teddy bears in order to collect money for a Christmas charity. We wonder which type of teddy bear would help collect more money; I think the pink silky teddy bear would be the best selling one; my plan is to argue in the meeting that this is the prettiest one, so that this is the one to sell. Some colleagues had a different idea: they organized a poll; Oxfam store customers voted which teddy bear they would be more likely to buy and most said they would buy the red furry one. I should then, either agree we should sell the latter, or amend my argument somehow to support my preference; perhaps argue that the poll had some methodological flaws; or argue, say, that the pink teddy bear costs less for Oxfam, so it would bring more profit even if it does not sell that much. Such a change of strategy requires some kind of data-theory coordination, and similar studies suggest that not everyone is capable of finding ways to accommodate new data within their perspective (Kuhn and Pease 2006).

It is important to note that talking about data-theory coordination is not to talk of *one unique* method. Such coordination may actually involve many different methods; induction or deduction, argumentation, the inclusion or exclusion of different types of data, e.g., experimental, observational, phenomenological data, narratives, or testimonies, etc. Values and norms are also taken into account. In a nutshell, data-theory coordination has to do with the ability to think about our thinking; think about one's evidence, their inferences, and interpretations. It relies on developing good thinking habits so that you avoid common fallacies, such as confirmation bias, polarized thinking, etc. It gets easier if you learn to discuss with others and with oneself and try to look at the world with fresh eyes (Gasparatou 2017b). Data-theory coordination engages reasoning and imagination working together, and it is done better collectively, e.g., when answering to a community of peers.

Data-theory coordination should be within the intended skills of science education; it should also be within the skills it explicitly aims at, since it is so important for understanding science, educating a science literate public and a generation of good scientists. In fact, such a skill would be helpful even for coping successfully in everyday life. In a way, *making sense* of the world depends on it.

Such a skill however, is not value-free (Laudan 1986; Östman and Almqvist 2010). It does not solely rely on information, nor is it a simple know-how. It demands certain character traits; at the very least, some kind of openness or open-mindedness; even a certain amount of tolerance or modesty (Zagzebski 1996; Battaly 2006; Kotzee 2013; Smith 2016; Carter 2016). Yet, again the direction is a two-way one: I cannot keep trying to achieve data-theory coordination, if I am not open-minded or modest; but I might never be either, if I do not learn to coordinate and re-coordinate theories and data in conscious and controlled ways. In other words, a skill may become a habit and facilitate certain character traits; yet, in order to make it a habit, I first need to master it as a skill. Insofar as science education supports students to develop their thinking skills, it can facilitate important thinking habits and character traits.

4 Teaching Science Under the Scientistic Rationale?

The question is whether the scientistic rationale allows science education to accommodate the thinking skills involved in data-theory coordination. Many of the dangers of scientism have been addressed. Kitcher (2012) suggested that scientism makes us impatience with history and prevents dialogue. De Ridder (2014) suggested that pop-science scientism harms the public's scientific literacy. I will argue that the same goes for *scientistic* science education too.

Under the scientistic rationale, students in science education courses are expected to learn science: current, physics, biology, chemistry, and some geography. Part of the teaching may involve short experiments and other hands-on activities, which, depending on the teacher, may very well be performed like cooking recipes, with students just following instructions. Scientistic ideology encourages passing on information together with some minimal practices that usually straightforwardly verify the information. Such are the teaching habits that most science education researches challenge today (Davson-Galle 1994, 2004; Erduran and Jiménez-Aleixandre 2008; Kuhn 2010; Lederman and Abell 2014; Bruguière et al. 2014).

None denies the importance of learning valid scientific theories. However, any curriculum or educator that focuses on the mere transmission of scientific information reinforces the idealization of science: students only learn the successful outcome and get nothing about the process, the mistakes it involved, the corrections that were made, or the limits of each theory. Instead, students should get the whole story, e.g., about how the structure of DNA was put together, how competitive the whole process was, how many years it took, how many people were involved with their own ambitions, expectations, insecurities, etc. (Olby 1974). Students should also face true problems within authentic educational settings; educators should, for example, ask students to design ways to explore the validity of a theory by themselves and give them the chance to reflect on their ideas and their findings. Such educational practices confront scientism because they reveal that science does not always progress in straightforward ways and does not always get things right from the start. They also educate students in the true making of science, help students develop the data-theory coordination skill that most scientific thinking entails, and teach patience, dialogue, open-mindedness, and courage.

Contrariwise, under the scientistic perspective scientists seem like modern prophets who, in a state of enlightenment—sometimes even with the help of yet again another apple—took a picture of the mechanisms of nature and came up with laws and theories that describe how nature works. One does not even need to tell the story of Newton and the apple (Fara 2015), in order to promote this ideal of a scientist. They only have to write Newton's law on the school board and never explain what a *law* actually is, when and how Newton came up with it, how long it took him and why, what other people did he read or talked to, what his laws' actual limits are, and how they are being re-worked by other scientists ever since.

Whenever we teach science by reproducing information and then asking students to apply it, we encourage the assumption that there is one single method, which all scientists follow and which can produce true findings (Rowbottom and Aiston 2006). It is as if we indoctrinate students in the new dogma in town, the new magic that will solve all our problems, the method that anyone can follow, and come up with the same results. Students are usually expected to take a formula, apply it to different problems, and get true/false answers. But then, they fail to see that even within each science there is no universal method (Lederman and Lederman 2014). Not all physicists work the same way, not all biologists work the same way and so on (Thurs 2015).

The method depends partly on the problem; a theoretical and an experimental physicist then will employ different methods, just like a molecular biologist will turn to different methods than a zoologist. Methods also rest on the individual or the community's preferences, customs, or values. Doing science is not a context-free activity. The scientific enterprise, even when performed in solitude, is a collective endeavor. Lots of people work on the same problems, exchanging arguments. The reliability of scientific processes partly relies on their social character; scientific research has always to answer to a community (Gasparatou 2008). But then, social, historical, and cultural factors interfere with science, as well as with any kind of human pursuit (Longino 1990). What methods are allowed or available, what kind of research is prioritized, all the above partly depend on the community's resources and values.

Isolating scientific pursuits from the rest of human activity belittles scientists' creativity and imagination too (Lederman and Lederman 2014). Scientists come up with new questions, new methods and techniques, new equipment, and new interpretations. They sure need knowledge and sound reasoning for all that, but reasoning does not exclude imagination or even sentiment (Solomon 1988; Damasio 1994).

Under the scientistic rationale then, students fail to see that scientific theories and laws are human products and as such they are subject to change. Scientific knowledge is tentative. This does not mean that it is not reliable. It just means that it may evolve or it may be modified or even sometimes abandoned (Quine et al. 2013). New evidence may come to light or new interpretations may be put forward. The history of science is full of change and we still hope for more new theories, or even sciences to come up (Haack 2007).

Idealizing science then, promotes a false conception of what sciences and scientists do (Haack 2007; Kitcher 2012). Many studies over the past decades have shown that indeed science educators and students share such misconceptions (e.g., AAAS 1994; Chen 2006; Lederman et al. 2002; Lederman 2006; Liang et al. 2009; Lederman and Lederman 2014). The findings should not come as a surprise; after all, misconceptions like these are in line with our overall scientistic ideology.

At the rock-bottom of all these misconceptions that ground scientism, one finds the integration of data with theory. Scientific knowledge is seen as the result of data plus a good calculus. Whenever teaching science as merely describing facts, we miss all the creativity, all the social factors: the entire struggle of data-theory coordination. And then, one important thinking skill that students should get from science courses is neglected. Students fail to understand that scientific knowledge is not something you see in the world. It may be based on data, but it also needs interpretations in the light of theories that allow making sense out of the data. Scientists are expected to choose what to count as evidence; their choice has to do with what they already know and expect, and then again, what they find out might cause them to change their beliefs and theories or even their choice of data. And certainly all kinds of factors may interfere with this coordination process, from community's values to individual preferences, so that any such coordination is subject to dispute, and re-coordination. If students miss this coordination process, they miss an important skill that science education should promote. Scientism deprives them of it.

5 Can the Proposals of Science Education Researchers Resolve the Problem?

Science education researchers are very much aware of the many misconceptions that current teaching practices may produce. Their proposals for overcoming them invite many different strategies that implicitly challenge scientism. Sometimes however, they run to the opposite end and invite a strong relativistic conception of science (Nola and Irzik 2006). In any case, addressing the scientistic ideology that underlies such misconceptions is hard. Here, I summarize some of the most promising proposals that science education research has put forward over the past decades; but I also briefly comment on how they can be hijacked by the scientistic rationale. For the devil is always in the details: the subtexts and the subtle practices of science educators (Gasparatou 2016).

From the 1980s and onwards, many scholars have proposed that science education should include the *history of science* (Matthews 1988, 1990; Brush 1989). Explaining the history behind theories, experiments or terminology can indeed illuminate certain features of the nature of scientific knowledge. For example, it can make students realize what a great influence society has on scientific pursuits or how the imagination of certain people produced new insights; ultimately, it can show how many different interpretations of similar observations have been given over time. However, it is important to realize that not *any* historical or anecdotal story about some scientists or the sciences would help. Depending on how the history of science is taught, it may strengthen the scientistic myths or it may result in leading students to pure relativism and a total disrespect of scientific knowledge (Numbers and Kampourakis 2015; Solbes and Traver 2003). It is important then, to see the *philosophy* behind the history (Wandersee 1992; Wootton 2015; Matthews 2017). For example, if I teach history of science under the influence of the historicism movement in the philosophy of science, and I overplay the importance of the historical context in scientific process, I may avoid scientism but I cannot facilitate data-theory coordination adequately either. Just like scientism fails to implement data-theory coordination because it oversimplifies the power of the data over theory, an extreme historicist stand may equally fail to implement data-theory coordination because it may oversimplify the power of the theory over data.

A similar idea is put forward by the nature of science (NOS) enthusiasts: use the history of science to teach students the NOS (Solomon et al. 1992; Lederman et al. 2002; McComas 2008; McCain 2016; McComas and Kampourakis 2015). They develop lists of characteristics that need to be taught, addressing the many misconceptions about how scientific knowledge is produced. For example, one is to teach that *scientific knowledge is a (a) social*, *(b) creative*, *(c) tentative*, *(d) human product that (e) involves many different methodologies*, *(f) none of which relies on an automatic processing of data*, etc.. And they are right; scientific knowledge rests on all the above. However, when looking closely at the NOS literature, one may find that some of its enthusiasts implicitly reproduce the very core of the misunderstandings they explicitly address. Under the NOS acronym, *science* is again used to refer to the natural sciences; just them, and all of them collectively under one name. The myth of the one scientific method is again then, implicitly reinforced, even if explicitly denied. In fact, not only one method, but also one NOS is now discovered and explicitly taught to students. And this nature often amounts to a list of characteristics that students might be asked to repeat and memorize, thus driven to infer that each of the characteristics must be true in order for something to count as a *science*. This is an essentialist view of science (Eflin et al. 1999) that can easily echo the scientistic ideology. To be fair, there is some debate today about which acronym is best to use and how to use it (Kampourakis 2016b). For example, some use the acronyms NOSK (nature of scientific knowledge) or NOSI (nature of scientific inquiry), instead of NOS. The K or I in the acronym may make all the difference, for it turns the focus away from the misconception that there is one thing to be called science. The focus now turns to more abstract concepts: our collective scientific knowledge or our collective inquiry practices. In any case, many of the

NOS(K/I) science education researchers suggest a mixed methodology for its teaching, relying on explicit cues along with some inquiry-based activities, reflective discussions, and some philosophy of science (Lederman 2006; Lederman and Lederman 2014; Kampourakis 2016a). Some of the proposed teaching materials and strategies for NOSK could indeed help students engage with scientific thinking and practice some data-theory coordination.

In order to promote scientific thinking, many researchers highlight the value of inquiry-based science education (IBSE) (Driver et al. 1994; Huber and Moore 2001; Minner et al. 2010; Bergman et al. 2012; Ergazaki and Zogza 2013). IBSE includes *hands-on/minds-on* activities. And indeed it is a very good idea. Yet again, mis-implementation is possible. For example, just adding some hands-on activities in science courses will not do. As IBSE theorists suggest, it is important that experiments are not performed like following cook-book instructions or like just playing with stuff. Both would misrepresent the ways scientists work. Science education researchers insist that any experiments should be performed in the light of well-defined questions and reflective discussions with the aim to reach conclusions about them. This is the only way students can actually engage in data-theory coordinations.

An additional proposal here is teaching through argumentation (Ergazaki and Zogza 2005; Duschl 2008; Erduran and Jiménez-Aleixandre 2008; Jiménez-Aleixandre 2002; Kuhn 2010; Kuhn and Crowell 2011). For instance, a real-life based dilemma may be given to the students about an ecological disaster that happened in their country. They have to use the information they have already studied, in order to decide what to do when confronted with a real-life dilemma. This could be a fruitful method too. It can allow students work through all kinds of factors (data, interpretations, values, habits etc.) that may influence scientific decision-making and data-theory coordination. Moreover, discussions facilitate the creation of a community of inquiry, help students witness community's correction strategies, and understand the social dimension of science (Burgh and Nichols 2012). But again, this requires great mastery in choosing dilemmas, facilitating the discussions, and connecting them to what is taught (Simonneaux 2002, 2008, 2014; Jiménez-Aleixandre 2008). The danger here is again twofold. If on one hand a teacher puts forward too easy cases, in which the data point straightforwardly to one direction, there is no real need for discussion, reinforcing the view that science alone can point to a straightforward answer. If, on the other hand, a teacher puts forward a fully ambivalent case in which the data may equally support all kinds of interpretations, they may turn the class into an argumentation forum of mere opinions, reinforcing an opposite view that suggests there are no answers even in scientific issues. The former strategy is aligned with scientism; the latter with relativism. Both prohibit the exercise of data-theory coordination as a thinking skill.

Another idea is including some philosophy of science or epistemology in the curricula (Forge 1979; Matthews 1988, 2004; Davson-Galle 2004; Kampourakis and Nehm 2014; Östman and Wickman 2014). That too, needs to be done carefully. Again, the mere passing on of information about what any philosopher said on science is not enough. The point is not to teach students that the "wise," whether philosophers or scientists, hold the answers, but rather to engage them in a philosophical type of thinking and make them think about what they and other people think. Teachers then need to be able to facilitate discussions about philosophical proposals; and what is more, help the class think about scientific problems and theories using the insights of epistemology and philosophy of science, preferably on top of some inquiry-based activities, so that the discussions connect to concrete cases. Philosophy can indeed help cultivate the habit of thinking about thinking. Especially when combined with inquiry-based teaching, epistemological discussions about specific methods, norms, criteria, concepts, or even terminology could develop habits of self-correction and data-theory coordination (Burgh and Nichols 2012).

I would like to add one final proposal here: include the teaching of the social sciences, such as psychology, social anthropology, and sociology, under the *science education* branch. This could help students widen their perspective of *science*; see it as a family resemblance term. Just like the term *game* can adequately characterize many different activities, from monopoly or baseball, the term *science* should be seen as an umbrella term that brings to mind the many, graded, vague similarities that the many sciences share (Wittgenstein 1953; Irzik and Nola 2011). Including the social sciences would emphasize the pluralism of scientific methods; it could facilitate links among the sciences and the many ways different sciences may address the same issues. Giving students more insight and more diverse instances of scientific thinking could help them engage with different ways of theory-data coordinations. But again, the mere inclusion of the social sciences under the umbrella of science education would not automatically escape the scientistic trap; many branches of the social sciences today also promote a naive image of scientific research by trying to copy the so-called scientific method. Educational research is often a good illustration of how hastily the educational sciences try to mimic the so-called hard sciences (Bridges and Smith 2007). Any inclusion of the social sciences should again then be accompanied with methodological and epistemological discussions.

At the end of the day, no strategy can help if the reasoning of its supporters or practitioners, consciously or unconsciously, relies on scientism. Whenever an educator submits to the scientistic rationale, they will probably pass it on, explicitly or implicitly. Here I summarized some of the best strategies science education research has put forward so far. I believe that all of them can help disable scientism, especially if they are used to *explicitly* address its misconceptions. In any case, the inclusion of more sciences under science education courses, reflective discussions over social, and methodological and epistemic criteria in the context of authentic educational environments may be a good start.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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