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FORUM

Understanding the sciences: a quasi-Wittgensteinian note on NOS

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Abstract
Aragón, Acevedo-Díaz and García-Carmona study prospective biology teachers' understanding of the Nature of Science (NOS). In my comment, I would first like to step back and ask *what it is to understand something*, i.e. the sciences. I will turn to a quasi-Wittgensteinian epistemological tradition and suggest that, contrary to our habit to associate meaning with definitions, to understand something is, in fact, to engage in the normative practices around it. To understand the sciences then, we don't need some definition; we need to engage in their practices. I will then turn to NOS research and suggest that NOS terminology, as well as certain NOS teaching practices, often fail to address two seemingly opposite mentalities, both of which prohibit understanding the sciences: *scientism*, i.e. the implication that there is in fact a definition of *science*; and *relativism*, i.e. the implication that, lacking a definition, *science* is a meaningless term. Both these mentalities could be challenged if NOS incorporated a quasi-Wittgensteinian account of what it is to understand something. In the last part of the paper, I will highlight some promising aspects of NOS research. To be specific, Aragón, Acevedo-Díaz and García-Carmona use the historical case of Semmelweis and childbed fever as a trigger to highlight certain elements of NOS and then facilitate reflective dialogue. Indeed, reflection over particular cases seems to be a promising way to understand the sciences; as a quasi-Wittgensteinian approach would suggest, it allows people to engage in the normative practices of scientific research. In the end, NOS researchers could benefit from such an epistemological account of understanding: avoid misconceptions such as scientism and relativism, as well as provide a strong theoretical background for their recommendations.

Keywords NOS · Scientism · Relativism · Wittgenstein · Family resemblance

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This review essay addresses issues raised in Aragón, Acevedo-Díaz and García-Carmona's paper entitled: Prospective Biology teachers' understanding of the NOS through an analysis of the historical case of Semmelweis and childbed fever, https://doi.org/10.1007/s11422-018-9868-y.

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María del Mar Aragón, José Antonio Acevedo-Díaz and Antonio García-Carmona study future teachers' understanding of the Nature of Science (NOS). NOS, they suggest, should be considered as a key component for citizens' scientific literacy. Indeed, explaining the workings of the sciences seems necessary for engaging the young into this aspect of our collective civilization, cultivating new scientists, nurturing a science educated public, and encouraging a rational way of living in a world where sciences and technology influences with most of our everyday life decisions (Gasparatou 2017b).

In this paper then, I will take it for granted that prospective science teachers should understand how the sciences work and evolve, so that they are able to pass this understanding to their students. But I would like to pause and ask what it is to understand something, i.e. the sciences. Then, I will turn to NOS terminology and suggestions and discuss how they may sometimes hold us back from understanding the sciences. Finally, I will also turn to the NOS researchers' recommendations that do help understand the sciences and put them into a wider epistemological perspective.

On understanding how things hang together

Aragón, Acevedo-Díaz and García-Carmona start their paper, as we all usually do, explaining why what they study is important; they argue that promoting NOS understanding is important for scientific literacy. And I agree with their argument. Nevertheless, I would like to begin this paper in a different way. That is *not* argue on the importance of teaching something *in order* for something else to happen. Paraphrasing Wilfrid Sellars (1963, p. 35), I'd like to suggest that education ought to help us understand "how things hang together", just for the sake of understanding how things hang together. After all, understanding something seems a good start when you want to engage in it.

So, what does it mean to understand something? There is a long tradition in modern epistemology, from Ludwig Wittgenstein (1953) to John McDowell (1996) and Robert Brandom (1997) among others, which roughly claims that in order to understand something one needs to engage in the practices around it and grasp the rules or the criteria that underlie such practices. For the rest of this paper, I will refer to this tradition as a quasi-Wittgensteinian one, and mainly focus on Wittgenstein, since his writings and terminology are the common ground for most followers of this tradition today. Human behavior, according to this tradition, is highly normative; we follow rules even in the smallest bits of our everyday behavior: how to sit on a chair, or how to brush our teeth, how to crack a puzzle, or how to carry out an experiment. We have criteria about what to call an *apple* and what to call a *chair*; about how to ask or how to buy or how to use either. Language-use both enables and depicts our rule-following habits. Rules pass on through language, since language actually mediates *all* our practices. Language is not just what we say, but also what we do. After all, to say something is to do something (Wittgenstein 1953, §1–38). So language includes all our symbolic and commutative, verbal and nonverbal, activities. Wittgenstein's quote echoes this idea: "to imagine a language is to imagine a form of life" (Wittgenstein 1953, §19).

Understanding something then, does not amount to having a mental representation or definition of some referendum, but rather to grasping the rules around it. To understand what *eight,* or *apple* means, I don't have to recall a definition of eight or an apple; I ought to be able to actually use *eight* or *apple* to do stuff: articulate a syllogism about $2+2+4$ apples, make suggestions about how many apples one should eat per day, give advice on whether to put my eight apples in the fridge or on the table, etc. The same goes with more abstract practices. For example, to understand that an ostensive definition is not (just) to put a mental link between the proposition "this is red" and a red object, but rather to grasp the whole set of rules around the practice of giving ostensive definitions: the gesture of how to point, where to look when one is pointing, where to focus—that is, focus on the color and not the apple this time. It is *because* I have grasped the practice of ostensive definition that I understand the link between the term *red* and red objects (Wittgenstein 1953, §1–5). And I know I have grasped it because I can follow the rule: actually look at the end of one's finger, right at the red color when I hear the utterance "this is red", and then use *red* to refer to red objects.

Meaning lies in the ability to use. To understand a term, you need to understand the *language-games* or practices, in which this term is used: grasp and follow the rules that govern such practices (Wittgenstein 1953, §1–38). Rules are often implicit; they may differ when the same word is used in different practices; and they are all subject to change; in fact, they do change all the time (Wittgenstein 1953, §138–242). Note however, that to change a rule means to replace it with a different rule; it does not mean there are no rules. However, since rules are often implicit, overlapping and changing, it is very difficult, even futile, to insist on a complete, explicit list of such rules when trying to explain the meaning of a term. And more importantly, trying to make such a list might actually inhibit understanding in the long run (Gasparatou 2008). For changes may have occurred (Gasparatou 2017a).

What is criticized here is an old and traditional view of meaning and understanding, together with a traditional habit of ours to think of understanding as *giving definitions* (Wittgenstein 1953 §1–38). To understand, for instance, what a *game* is, is not to give a definition of the term. It is very rare that any definition could actually include all the uses of a term, and even if we could find such a definition, it would stand only for a while. And anyway, to understand is not to open a dictionary. I understand the term *game* because I can grasp the *family resemblance*, the sometimes obvious, and sometimes vague, overlapping similarities, between all the practices we call *games*. So, I can use the term *game* to talk about monopoly and baseball, chess and golf, but even when talking about dating or parenting at times, or even about our human practices as *language-games*.

Now, *science* is a term. And in order to understand the sciences, one needs to grasp the family resemblances between them (Erduran and Dagher 2014). Many have already argued that science is a family resemblance term (Irzik and Nola 2011). And adopting the idea of family resemblances among the sciences can actually enable us to challenge two sets of mentalities, which interfere with our understanding of the sciences: *scientism* and *relativism* (Haack 2003). Let me briefly comment on my use of these terms.

Scientism is "an exaggerated kind of deference towards science" (Haack 2003, p. 47); an excessive admiration towards science, together with a tendency to impose its method to all questions (e.g. Pigliucci 2013). The basis of this admiration however, is the belief that *there is such a thing called science*; that the term refers to certain properties, that make a universal definition possible. In its extreme form, scientism sees science and scientific method as a single, context-free, non-speculative calculus, which, if applied to the world correctly, will give us true/false answers on any question. It is not by chance then, that *science* is used in the singular when suggesting that it will bring the answers to every legitimate question. We often don't even name which sciences are implied by *science* here. It must be physics; biology; chemistry even; perhaps geography or geology. But we do assume there is a referendum there; a referendum defined as a more or less context-free, rational thinking method, which the natural sciences collectively follow.

Extreme scientism is a problematic stance for it prohibits the very skills that promote scientific research and literacy: critical thinking, patience with history, open-mindedness, tolerance (e.g. Kitcher 2012). And the slippery slope begins with oversimplifications. It is simplistic to assume that all sciences employ the same method (Thurs 2015). Physicists and biologists do not employ the same methods; in fact, even two physicists may work very differently (e.g. Nola and Irzik 2006). For example, an experimental physicist and a theoretical one, probably use very different tools and thinking strategies. A zoologist works differently from a molecular biologist who works very differently from an evolutionary one, and so on. Scientism misses many of the particularities and the context of scientific research. So, scientism, while implying that there is such a thing called *science* in the singular, it can offer no valid definition accommodating adequately even all the so-called *natural* or *exact* sciences.

Relativism, on the other hand, assumes is that there is no real meaning attached to the term; that *there is no such thing called science*. Relativism lurks whenever it is implied that whatever works for different people in different contexts, deserves to be called *science*. For example, some western medicine works well in the western world, while other forms of therapy, voodoo or acupuncture, may work well in different context, thus all deserving to be called *medical science*. Relativism also lurks whenever it is implied that a theory is called scientific just due to some historical circumstance; for example, just because the rhetoric or the context or some power play between scientists came its way, quantum theory got to be called scientific whereas homeopathy did not. Even though context is relevant in all human endeavors though, there are always certain criteria about what kinds of things we call by a name. Moreover, among the family resemblances that the sciences share is this quest to find as rigorous and universalizable thinking strategies and methodologies as possible. If we give this quest up, it becomes very difficult to find arguments that resist pseudo-science, pseudo-medicine, and the like; we give up some of very goals of sciences. It makes concepts like *truth, verification* and *falsification,* or *methodological validity* seem empty, up to the point that they are not even considered viable pursuits. Especially in an educational setting, to teach there are no real similarities between the sciences; no common rules, no methodological commitment, no common purpose or anything, may lead students to the slippery slope of relativism. And in its extreme form, relativism may treat the sciences as mere opinions. And this is a mistake also. More than that, it is dangerous. It promotes a total disrespect for the sciences and the scientific findings.

Now, there are many varieties and shades of scientism and relativism, from very nuanced to really extreme ones (Haack 2003). And there are also many ways in which those terms are being used today in philosophy and in popular culture. And it is fine to respect science; just like it is fine to realise there is no one rigid on/off criterion by which to differentiate science from non-science or pseudoscience. But the fact that there are reasonable variations of scientism and relativism does not make its extreme versions less plausible or dangerous. A vague relativism is partly at work in popular culture symptoms today: whenever people refuse to be vaccinated; whenever people believe fake news and conspiracy theories; whenever people think facebook is as good source of information as any. And a relativistic attitude towards norms like truth, verification or expert opinion can deprive us of the means to address such symptoms (Nola and Irzik 2006). Today also, we hear voices of extreme scientism: science will point out the ways to be happy (Seligman 2004); science will find us the perfect romantic match (Fisher 2008); our moral problems will be answered by science (Harris 2011). Sometimes scientism is in fact, a reaction to the relativistic stance. Science denial seems to discredit all the ideals of the scientific enterprises, ideals like rationality and methodological validity. In their quest to defend such ideals, many philosophers and theorists end up taking extreme pro-science stances (Rosenberg 2011). So in a sense, extreme relativism feeds extreme scientism. And vice versa, in some ways, scientism opens up the road to relativism (e.g. Kidd 2014). Scientism implies there is such a thing called science even though it cannot adequately define it. Moreover, scientism's insistence that science holds the true answers on everything, might turn one's admiration for science to its total discredit, in a world where everything changes, including many mainstream scientific stances on public matters. Scientism and relativism can entrap us in an ongoing loop.

It is not just about *science,* though. We often go from looking for a definition of any term all the way to the opposite end of assuming there is no meaning attached to it. Sometimes the very realization that it is so difficult to give a definition about anything really, takes us to absolute relativism. One way to escape this twofold risk is to see understanding, not as definition giving or seeking, but as grasping the implicit, complicated, overlapping rules around whatever we are trying to understand. The *family resemblance* idea resists the idea that we need a definition in order to understand something, or even that we can give an explicit, complete list of all the similarities. However, it also suggests that *there are* such similarities, and that we are in a position to grasp them. And such similarities are normative; they point to the *criteria* by which we use a term in certain contexts, to the *rules* of the practices attached to the use of a term. For *there are* rules that govern the use of a term, even if such rules are difficult to make explicit at times.

It is not just about science then, and yet, if the NOS literature really wants to address the many misconceptions around the sciences, it should get behind such an account of meaning and understanding. For as it stands now, even though NOS discussions do contribute to science education, they can easily be hijacked by either the scientistic or the relativistic mentality; or even both at the same time. In the next sections, I will address the weak spots of NOS and also make some suggestions about how to overcome them.

NOS and the tightrope between scientism and relativism

NOS discussions aim at correcting a simplistic view of science. NOS researchers insist there is no universal method for the sciences, no autonomous reading of the data (e.g. Lederman 2006); they emphasise the many factors that interfere with our interpretations and explanations: methodological, social, individual, cultural and historical (Lederman and Lederman 2014). Most of them suggest an explicit teaching of the many factors that the Nature of Science (NOS) includes; and many make lists of all the features that point to the true *nature of science*.

Now, terms carry their meaning and they deserve some attention. When talking about the *nature of science*, as the NOS acronym suggests, *science* is again used in the singular term; once more, it refers to the natural sciences, them alone, collectively under one name. So, it is possible to assume that there must be something in common that these very sciences share; and that the rest of the disciplines do not. Some kind of methodology perhaps, or some specific kind of genius needed or whatever. What might be expected next then, is that a definition will follow. And in a way it does follow. But before I get to that, let me note that, to be fair, there is some debate today about which acronym is best and how to use it (e.g. Kampourakis 2016a). Nature of Scientific Knowledge (NOSK) or Nature of Scientific Inquiry (NOSI) have been proposed to replace NOS (Kampourakis 2016b). The K or I in the acronym might make some difference, since the focus now turns to more abstract concepts: our collective scientific knowledge or our collective inquiry practices. And turning the focus away from the collective *science* might have helped. But there are deeper problems.

NOS enthusiasts develop lists of characteristics and propose their explicit teaching. Students are taught that science is *(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.* The above *(a–f)* is just one draft list summarizing the minimum elements of the many proposed NOS-lists (Kampourakis 2016b). Aragón, Acevedo-Díaz and García-Carmona also take for granted what NOS aspects are, just like most relevant research does. And even though lists do point out to some general important features that may influence the sciences, the very idea of relying on pre-determined lists, or even worse teaching students explicit lists, bullet by bullet, today attracts some criticism, partly because it directly implies that each of the characteristics of the list must be true in order for something to count as a *science* (Irzik and Nola 2014).

To make matters worse, while NOS-researchers explicitly deny that sciences share *one method*, they seem to have no problem suggesting that they share *one nature*. But then, there is no way around it, we are definitely getting a *definition*. And it is not just a conventional definition, a definition society agreed upon just for the sake of speedy communication, but rather a list of *necessary* natural properties. For the implication behind the term *nature* is that science is a *natural kind* of sorts, such as gold or water, whose nature is to be discovered. And just like for something to be a *water* molecule, it would have to have two atoms of hydrogen atoms and one of oxygen, for something to be *science,* it would have to have (a–f) features, or whatever else is on the list. This is an essentialist view of science (Eflin, Glennan and Reisch 1999) that echoes the very root of scientistic ideology. Thus, some propose we talk about *features* -not *nature*- of science (Matthews 2012).

Even so however, it is often implied that science is great *because* it has those very features. Students need to clear certain misunderstandings away, and learn about the many features of NOS *in order* to appreciate science. For example, William McComas (1998, p. 68.) writes: “Only by clearing away the mist of half-truths and *revealing science in its full light,…, will all learners appreciate the true pageant of science*…”. Italics are mine, for they seem to imply that science is so great *because it is,* say, (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. And while the quote might be interpreted to echo the scientistic stance that science is great because it qualifies under such characteristics, it may also be interpreted to echo absolute relativism, as well. For it begs the question as to what happens with the rest of human practices. Indeed most human practices are *social, creative, tentative, human products, that involve many different methodologies, none of which relies on an automatic processing of data*. Art, theology, carpentry and knitting, for example, can easily pass the test. And if, on top of that, we put a bit too much emphasis on the *social* and *tentative* features of the list, relativism grows even stronger.

Some authors propose we use *history of science* (HOS) to teach NOS. The suggestion that science education should include *HOS* (e.g. Matthews 1988) relies on the rationale that learning the history behind theories, experiments or terminology can make students realize, for example, what a great influence communal practices and norms have on scientific pursuits; how important collaboration is at times; how the imagination, the creativity, even the passions of certain people produced new insights; and it can show how many different interpretations of similar observations have been given over time. HOS then, can give historical examples that emphasise certain aspects of NOS. On the other hand, too much emphasis on the socio-historical context of scientific enterprise in an educational environment may open the road towards relativism. For, while the sciences rely on the socio-cultural and historical context, within their normative aspirations is the ideal to draw as many generalizable explanations, conclusions and predictions as possible. Scientific communities have always tried to build self- and other-correcting strategies in order to promote this ideal. One of the goals of each and every scientist is to protect their research from total context dependence. Even if futile, this ideal is among the normative family resemblances of our scientific practices.

So, if a teacher over-emphasises historical and social influences in the development of the sciences, and within an overall simplifying educational culture, students may end up seeing science as a totally context-dependent term. And it is easy to over-emphasise context, even without realizing you do so, because it is just easier to explain the socio-historical aspects of scientific research than the methodological ones. It might take just a couple of historical examples to get students to see that society influences scientific research: point to some states that financed certain research projects while neglecting others; show how certain technological advancements made an observation possible in a certain era; or say that religion stopped some kinds of studies. It is just easy to grasp. It takes much more than narrating a couple of examples for students to actually grasp the struggle of coordinating data with theory in different scientific research areas; to grasp the many different strategies scientists employ in order to do so; to grasp how the scientific community tries to built mechanisms that ideally correct such strategies. If we want students to be able to play the game, they need to see for themselves the underlying, overlapping, common rules of the game, the normative aspect of science, the quest for some sort of criteria for what counts as science, *ideally* independently of context. Especially in an era when students have all kinds of information literally in their pockets, it important that education helps provide some kind of criteria for assessing this information, or at least help have such an ideal in mind when processing this information. So, when including HOS, and in order to not over-emphasise context, science teachers should rely on many different stories, discuss about them, accompany them with other kinds of activities, and work on engaging the students in the methodological aspects and goals of the sciences, as well as the socio-historical ones. It may be risky then, to use *one* anecdotal case to promote what you already think the general aspects of NOS are. In the case of the Aragón, Acevedo-Díaz and García-Carmona study for example, the very particular example of Semmelweis research is supposed to elicit quasi-generalisable conclusions about NOS. The participants in this study are adults and already have a background in the sciences, so the danger is minimal. But as a general teaching strategy, if you present just one case emphasising its flaws and handicaps, you may allow students to unconsciously infer the flawed and handicapped nature of science and open the road to relativism. Just like if you present an anecdotal case as bulletproof research, you may allow students to unconsciously infer the bulletproof nature of science and open the road to scientism. You may not even intend to do either. Education happens not only by what a teacher explicitly says, but also by what a teacher implies and allows, as well as what students infer (Gasparatou 2016a). One indeed needs to be very careful when employing anecdotal cases in NOS teaching, as many, including Aragón, Acevedo-Díaz and García-Carmona, have suggested (e.g. Numbers and Kampourakis 2015).

Yet, the same goes for any teaching of NOS anyway; it can easily strengthen either scientistic or relativistic ideas. We try to correct myths about science, but such myths seem to have very deep roots in our minds and our culture. And while confused, explicitly teaching NOS-lists needs caution. The acronym does not help at all. The N does most of the damage, but the S is not innocent either. Perhaps without the acronym or with a different acronym we would do better. However, again it is our mentality that is mostly confused. And perhaps we are confused for a good reason; all this is rather baffling stuff.

On reflection

So, why not use this bafflement to teach about the sciences? Aragón, Acevedo-Díaz and García-Carmona used the story of Semmelweis and childbed fever in order to highlight certain NOS features, and then they facilitated reflective discussion about the case to promote NOS understanding even more. And they suggest that the participants' understanding of most NOS features improved significantly after the discussion. I will like to argue that, independently of the specific study and its results, reflection over specific triggers seems to be a promising method if we want people to understand how things, including the sciences, hang together (Gasparatou 2016b). Reflective dialogue over particular cases enables us to embrace confusion and learn how to rely on self- and other-correction strategies in order to work through it; just like a scientist—or any other rigorous thinker—ought to do. So, if we want to educate future scientists or a science educated public or just a community that is able to think rigorously, we ought to leave shortcuts aside, and start collectively reflecting on things (Levinson, Kent, Pratt, Kapadia and Yogui 2012).

And this is what Aragón, Acevedo-Díaz and García-Carmona do; they use the story as a trigger to facilitate reflective discussion within a group of peers. The trigger might be a story, like in this case, or a hands-on activity, or even just a question. Reflective conversation over any particular trigger however, is important because of the very mentality it encourages. Facilitating dialogue on particular scientific cases helps students engage in the actual workings of the sciences (e.g. Ergazaki and Zogza 2005). It creates a community of inquiry, helps students exercise their argumentation skills, reflect on different views and interpretations, and witness the community's correction strategies. And this is what most NOS researchers suggest we do (e.g. Taber 2017). In fact, reflection over particular cases is the most highly recommended practice in science education research these days (Levinson 2006), just like the *hands on–minds on* motto suggests. Yet, all relevant research would benefit from putting this suggestion within the context of an overall view about *what it is to understand something*. Such a context would give science education researchers a strong theoretical background for their recommendations, as well as help them pay more attention to terminology and methodological details and avoid misinterpretations.

Within the quasi-Wittgensteinian view I summarised above then, reflective dialogue is the appropriate method because it helps students grasp the rules—the *criteria*—of the very practice they are supposed to learn; the scientific practice (Gasparatou 2017a). And one can begin grasping the rules of any practice only by actually engaging in the practice itself. Of course we won't learn, for example, human biology just by engaging in reflective dialogue about this or that case, or about this or that activity we performed in the classroom. Neither will we learn the rules of the scientific practice at once; just like we don't learn the rules of ostensive definition all at once. It takes time and exposure. And this is why we need more than just one reflective intervention now and then. One reflective discussion, even a great one, cannot get students accustomed to the rules of the scientific practice. We need to regularly employ lots and lots of reflective strategies over concrete cases in science education: expose students little by little to the many ways the scientists perform data-theory co-ordinations, and to the many dimensions and problems of scientific research. Moreover, if enough classes include reflective dialogue, students might intuitively grasp the family resemblances among the sciences. And to see that, even though *science* might resist a strict definition, there are important similarities among the sciences, similarities that boil down to the rules that govern such practices. And indeed, not just the sciences, but many other human practices may follow some of those rules. To explain, to decide, to argue for or against something, to make a representation are all language-games that the sciences, as well as many other human practices, include. And such games share certain rules, while they differ in others.

Things hang together. Our ways of thinking may not be entirely different whether we think about a math problem, the Big Bang, or where to put our eight apples. And it is because things hang together that, if we learn to be sensitive to the many uses of apples, we may end up realising there are indeed *criteria* for what we call an *apple*. There are also criteria for distinguishing apples from oranges, as well as for mingling apples and oranges. Contrariwise, if I decide to teach about the *nature of apples*, I will probably either oversimplify about what it is to be an apple, or end up wondering if there is such a thing as an apple, anyway. For sometimes it is the way we present a problem that makes us stray. Attending to how we talk and what terms, or acronyms we use, is important because language can easily produce false images. Science and science education is one more victim of our habit to use language carelessly and to oversimplify in our attempt to make sense of things quickly. And to overturn this habit, we need to learn to take notice of the normative similarities and dissimilarities of our practices, while engaging in them and reflecting on them. However difficult and time consuming, however slow the progress, however frustrating the students' scores, there is no shortcut in understanding.

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