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Pseudoscience and the end of dialogue

How and why are science and pseudoscience so different and what does it mean for science engagement?

| Estimated reading time: 22 minutes.

We live in an age of science and technology, and yet, many people still adhere to all sorts of weird beliefs such as homeopathy, creationism, and conspiracy theories. As a philosopher of science who wants to make a contribution to the public understanding of science I am fascinated by the question of why these beliefs remain persistently popular. Why do people adhere to such nonsense? How do these weird beliefs spread? Why don't people simply trust scientists? An important part of the answer lies with human cognition. Weird beliefs spread because they are somehow contagious. They seem to jump quite easily from mind to mind. If we want to explain how pseudoscience and related false beliefs emerge and spread, we have to understand what exactly makes them contagious. Identifying the factors and processes that underlie the dissemination of pseudoscience – about which I will tell more below – has been a major part of my research in recent years. I am also very much interested in what an understanding of these factors and processes entail for the relation between science and pseudoscience. I was kindly invited to present some of my work at the 2018 Ecsite Conference in Geneva, after which the Spokes Editorial Committee asked me to share some of my ideas on this issue in their magazine with this article as a result.

In this article I want to focus on the role of reasons in science and pseudoscience. A common assumption is that science is rational and pseudoscience is irrational. Only science relies on reasoning whereas pseudoscience emerges from unreliable sources such as intuitions, emotions and various biases. Or so the story goes. The truth, however, is a bit more complicated. On the one hand, scientists often rely on their hunches and feelings when engaging in scientific practices. On the other, purveyors and adherents of pseudoscience often provide reasons for what they believe, so pseudoscience seems to involve at least some kind of reasoning. But if both science and pseudoscience depend on intuitions, hunches, and reason, how and why are they so different?

The answer is that science emerges from a dialogue in which people can freely produce and evaluate reasons, whereas pseudoscience does not. In fact, pseudoscience is the end of dialogue. To make this point clear, I start from Susan Haack's (2003) notion that science is "common sense, only more so." Science relies on ordinary capacities of inquiry but that become supported with all sorts of 'helps'. One such ordinary capacity is reasoning, the production and evaluation of reasons. Science shapes and constitutes the conditions under which this social everyday process – a dialogue – tends to result in true beliefs. Purveyors of pseudoscience, however, often complain that scientific communities adhere to dogma that blinds them to the truth of their alternative theories. However, it is they who are unwilling to surrender their beliefs after their pet beliefs and the reasons they were giving for them have been razed

to the ground. They step outside, and thus effectively put a halt to the dialogue. As a result, pseudoscientific beliefs tend to be supported by bad reasons. Nevertheless, these reasons and the pseudoscientific beliefs they support can become quite popular. In this article I identify some of the survival strategies that such successful beliefs and reasons tend to develop. I then discuss the implications of the role of reasons for the irrationality of pseudoscience and for the demarcation between science and pseudoscience. I conclude by providing some suggestions as to how science and natural history museums and other science engagement organisations can improve the public understanding of how science works and help to tackle pseudoscience.

How does science work?

What is science? Providing an answer to this question belongs to the core tasks of philosophers of science. At first, philosophers assumed that science owed its success to a particular formal method that accounted for the rationality and objectivity of scientific beliefs. However, the search for the scientific method failed – indeed, there is no such thing as the scientific method – which opened the door to postmodernism and relativism. According to members of this tribe, science only provides us with one perspective on the world, next to many others such as religion and art. The truths that science allegedly discovers, they claim, are only true relative to its perspective and so science does not and cannot say anything about the world itself. Furthermore, they argue, what the dominant perspective within science is and whether one adopts the scientific perspective or not, depends not on good reasons, but on subjective or cultural preferences and political power struggles. If you want to understand how science works, you have to take a close look at the strategic manoeuvring and the rhetoric that scientists employ in order to have their pet views become part of the consensus. Scientific knowledge is, hence, nor objective, nor rational. Postmodernism has become very popular in certain academic circles despite the fact that the position is hopelessly self-undermining: all knowledge is relative except the claim that all knowledge is relative. Postmodernism is a dead end when we want to understand science (for a critical discussion of both the search for the scientific method and the postmodernist response, see Haack 2003).

What we need then is an approach that does not aim to anchor the explanatory power of science in an imaginary formal method. We also don't want an approach that questions the very idea that science constitutes a uniquely reliable way of generating true beliefs. How can we explain why science is so successful in accounting for the world without resorting to any of these two options? The answer lies in selecting the best out of the two approaches. Yes, science provides us with an extraordinary tool to attain true beliefs about the world. However, in order to understand what makes science so special, we do not have to search for an abstract scientific method, but examine how scientists in real life generate scientific beliefs (Boudry and Pigliucci 2018).

Scientists are no superheroes with extraordinary intellectual powers. They are ordinary people with ordinary minds. This means that scientists too suffer from the constraints that we all face as human beings. From the very beginning of science philosophers such as Francis Bacon and David Hume realised and emphasised that we needed to have a good understanding of our cognitive make-up if we want to know how we generate reliable beliefs about the world. Only then would it be possible to find and develop the means to overcome our limitations and build on our truth-tracking capacities (Blancke, Tanghe, and Braeckman 2018).

HAACK: SCIENCE AS "COMMON SENSE, ONLY MORE SO"

Philosopher Susan Haack (2003) describes science as "common sense, only more so". This slogan, as you will, beautifully captures the idea that science builds on ordinary cognitive processes that become supported by a whole range of helps. We scaffold our inferences by using mathematics, statistics, and logic; we expand our observational capacities by using instruments such as telescopes, microscopes, scans, and the Large Hadron Collider. We employ formulae and well-defined concepts to improve communication. And so forth.

Science as a dialogue

Perhaps most importantly, scientists rely on their peers. Not only do they stand "on the shoulders of giants", as Isaac Newton once quipped, building on and arguing with the works of the generations of scientists before them. They also depend on their colleagues to spot and expose the errors that they make and that they are unable to detect by themselves. As all people, scientists suffer from my-side bias, the tendency to only have eye for (interpretations of) facts and arguments that support one's own position (Mercier and Heintz 2014). This does not necessarily have to be a bad thing, as it induces scientists to make the strongest case possible. It can also blind them, however, to the errors in their beliefs or the ways that they develop them. Luckily, people are more critical when it comes to other people's beliefs. They will happily point out where things went wrong. This explains why peer review is such an important part of the scientific process. It enables scientists to constantly correct and adjust their beliefs and the methods that they use to acquire them. This process, in turn, leads to the development of the best possible knowledge about a particular domain. The result is what we call scientific knowledge.

The recently developed interactionist theory of reasoning by Hugo Mercier and Dan Sperber (2017) makes clear why the reliance on others is an instance of Haack's "common sense, only more so". According to these cognitive scientists, the evolved function of reasoning is not to improve our beliefs about the world by thinking individually. It is to produce and evaluate reasons in a social context. Reasons come in two types: as arguments to persuade others and as justifications for our beliefs and behaviour. We thus look for and use reasons that suit these purposes, which explains why the production of reasoning is lazy and biased. If we can get away with a simple, but not so good reason, why bother to look for a better, but more complicated one? And if I want to make my case, why would I look for arguments that go against it? In other words, the my-side bias is a built-in design feature of our reasoning capacities, not a bug that our reasoning tries to overcome.

MY-SIDE BIAS: A BUILT-IN DESIGN FEATURE OF OUR REASONING CAPACITIES

Fortunately, things improve considerably at the receiving end, where people evaluate the reasons of others. When people would too readily accept the reasons of others they might end up being misinformed which makes them vulnerable to deceit and manipulation. And if I am not sufficiently sceptical about other people's justifications, they might get away with behaviour that negatively affects my wellbeing. This explains why people tend to be far more critical and more objective when they examine the reasons of others than when they produce reasons themselves. The outcome is that the producers have to come up with better reasons.

Humans constantly produce and evaluate reasons. When my youngest wants to go to the fairground she tries to convince me by saying that she will pay for it. And when she is still not asleep at 9pm, she explains this by complaining about the weird light that falls through the curtains. Science builds on these ordinary cognitive and communicative processes but provides the conditions by which they lead to true beliefs. More specifically, science constitutes a space in which individuals who are motivated in finding the truth, can freely express and evaluate the reasons for belief (Longino 1990). These reasons include facts and methods, for which, in turn, they can provide reasons to account for why certain data counts as facts and why this or that method is trustworthy. Science thus takes shape through constant negotiations in which reasons take central stage and thus forms a particular "space of reasons" (Sellars 1963, Rouse 2015). This constant dialogue results in a consensus when the reasons for a particular view on or opinion about the world manage to persuade the majority of scientists within a particular domain.

SCIENCE IS INHERENTLY SOCIAL - IT STRENGTHENS, NOT WEAKENS, ITS EXPLANATORY POWER

This does not imply that the people or groups with the strongest argumentative or political skills solely determine the course of science. Because of continuous mutual criticism scientists arrive at the concepts and theories for which they have the strongest reason for belief. These concepts and theories form the truth. As philosopher C.S. Peirce (1878) eloquently put it: "The opinion which is fated to be ultimately agreed to by all who investigate is what we mean

by truth and the object represented in this opinion is the real." The fact that science is inherently social does not undermine the explanatory power of science; it actually provides strong support for it (Boudry and Pigliucci 2018, Dawes 2018).

The end of dogma?

Despite the fact that the social character of science enables us to acquire true beliefs, there are quite a few people who question and challenge the scientific consensus and claim to have better alternatives. Purveyors of pseudoscience such as creationists, homeopaths, conspiracy theorists, ufologists, climate change deniers, antivaxxers and opponents to genetically modified organisms (GMOs) pretend that science has it all wrong. Scientists can uphold their pet theories because they form some sort of sect or a religion that refuses to surrender its scientific dogmas. If only scientists would be willing to open their eyes and their minds, they would see the light. They would acknowledge that evolution did not shape life on Earth over millions of years, but that God created it six to ten thousand years ago. They would realise that homeopathy cures many diseases, that vaccines cause autism, and that the use of GMOs is bad for our health, the environment, and the small farmers in developing countries. It would become obvious to them that the government is responsible for 9/11 and hides the remnants of aliens who visited our planet. And scientists would certainly have to accept that climate change is a hoax or, at least, that it is not caused by human activities. If only scientists would listen. But until then, pseudoscientists complain, they are undeservedly excluded from the scientific community.



Anti-vaxxers do not adjust their position in response to the scientific consensus on the safety of vaccines and thus dogmatically stick to their beliefs. Here: protest in Melbourne, Australia, 14 September 2017. Pic by Alpha.

The Intelligent Design (ID) movie *Expelled! No intelligence allowed* constitutes one long elaboration on this argument. Intelligent Design is a modern variety of creationism that purports to have scientific evidence for the activities of an intelligent designer – ID proponents claim not to know who the designer is, but they obviously think that it is the Christian god. The bacterial flagellum, for instance, is so complex according to ID proponents that it could not have evolved through a natural process. Hence, it has to be designed. However, this is only a reformulation of the ancient argument from design, which is the very argument that Charles Darwin (1859) undermined with his theory of evolution by natural selection. We now have a perfectly good idea of how biological complexity arises by purely natural causes and have no need for an intentional designer whatsoever. Since Darwin, the evidence has only accumulated in favour of naturalistic evolution in various disciplines including genetics and palaeontology. We have very strong reasons for believing that evolutionary theory is true.

Nevertheless, in the movie, ID adherents complain about the "maltreatment" that they had to suffer in the hands of their scientific peers after having disclosed their ID sympathies. The movie starts with images of the communist regime building the Berlin wall, so the message is clear: the scientific community is constructing walls to keep out the freethinkers of ID in order to protect the naturalistic evolutionary doctrine. But nothing could be wider off the mark. The reason why ID proponents are not taken seriously is that they do not or no longer engage in the scientific dialogue. They defend beliefs for which there are no good reasons (left) according to a majority of scientists. If ID sympathisers are unwilling to abandon their ideas after the reasons for them have been criticised to shreds, then they themselves step outside of science, even though they continue to pretend that science is on their side. We can find the same rhetoric among climate change deniers, homeopathy lovers, and other purveyors of pseudoscience. Pseudoscience is not the end of dogma; it is the end of dialogue.

Bad reasons

Purveyors of pseudoscience do not partake in the scientific dialogue; this means that they do not adjust their reasoning in response to the criticisms that they receive from others. As a consequence, the reasons that purveyors of pseudoscience resort to, tend to be of poor quality. One would expect then that pseudoscientific beliefs would soon be weeded out and replaced by better beliefs. Yet, that is not what we observe, since pseudoscientific beliefs are quite resilient and remain popular. What explains this persistent popularity?

Successful pseudoscientific beliefs and the reasons that people use to support them tend to adopt certain strategies that enable them to spread widely. It might sound weird to think of beliefs and reasons as developing strategies as beliefs and reasons obviously have no intentions. Nevertheless, biologists tend to talk in similar ways about organisms adopting certain survival strategies. They claim, for instance, that frogs adopt camouflage colours in order to deceive their predators. The frog, however, did not choose to wear those colours; the animal is not even aware of them. Nevertheless, we humans can grasp what Daniel Dennett (2017) calls "free-floating rationales", the reasons for which the frog's skin evolved a particular pattern. Similarly, we can understand why beliefs and reasons take on a particular form without the need for intentions. It is because that form enabled them to survive the onslaught of human communication better than other beliefs. Furthermore, the focus on strategies of beliefs rather than of people allows for the fact that successful beliefs can be quite detrimental to the individuals who hold them (Blancke, Boudry, and Pigliucci 2017, Blancke, Boudry, and Braeckman 2017, Boudry, Blancke, and Pigliucci 2015).

What are the strategies that pseudoscientific beliefs tend to adopt? One important consequence of the fact that pseudoscientific beliefs do not change in response to criticism, is that they do not sit well with reality. Instead, they take on forms that do not adapt to the world, but to human cognition. We are born with intuitive expectations about how the world functions. For instance, young infants already know that an object will not disappear at once, that it will not move on its own and that it tends to move in a straight continuous line until it exhausts its force (Spelke 1990). These intuitive, unreflective beliefs are part of our folk physics. We also hold intuitive expectations about the biological world, our folk biology. For instance, we spontaneously assume that an organism contains an unobservable, immutable core (an "essence") that determines the development, behaviour, and the identity of that organism (Gelman 2003). Furthermore, we have an inclination to teleological thinking, i.e. to explain the existence of natural phenomena in terms of their goal or function, for instance that rain exists to water the plants (Kelemen 1999). Our intuitive beliefs about the minds of other people constitute our folk psychology. We automatically explain other people's behaviour in terms of their mental states such as intentions, desires, and hopes (Dennett 1987). When I smash the door, you might infer that I am angry, or when I buy a burrito from a food truck you assume that I am hungry or that I have a craving for Mexican food, and so forth. We are an exceptionally social species, so this type of thinking comes very naturally to us. In fact, it is so easy for us that we also spontaneously apply it to natural objects. We get mad at our car when it breaks down on our way to a job interview or curse our computer when it crashes the moment we are about to finish writing a twenty-page article.

Although these intuitions are present for good evolutionary reasons, they sometimes make us effectively "scienceblind" as cognitive psychologist Andrew Shtulman (2017) puts it. Pseudoscientific beliefs and the reasons for them however tend to tap into these intuitions to further their cultural success. Indeed, pseudoscientific beliefs are

intuitively appealing. Examples are not hard to come by. Psychological essentialism is reflected in the creationist beliefs that the "kinds" like dogs and birds have remained stable since creation. They definitely did not evolve from other species (Blancke and De Smedt 2013). We can also detect the impact of psychological essentialism in the opposition to genetically modified organisms. For instance, many people wrongly believe that a tomato inserted with fish DNA will taste like fish. Anti-GMO campaigns warn that companies make crispy cereals by inserting scorpion DNA into corn (Blancke et al. 2015). Teleological and intentional intuitions make us vulnerable to belief in aliens, UFOs and conspiracy theories that posits the actions of agents where none are there (Boudry, Blancke, and Pigliucci 2015).



This 'Frankenfood' protest sign reflects an intuitive teleological understanding of nature that underlies the opposition to GMOs. 2014 March Against Monsanto, Washington DC, USA, 24 May 2014. Pic by Stephen Melkisetian.

Another strategy that pseudoscientific beliefs adopt is science mimicry. In our modern-day world science is generally regarded as a trustworthy source of information. However, people might not have a clear idea why science deserves its reputation. Under these conditions it pays off for irrational beliefs to adopt the trappings of science, and hence to become pseudo-science. As such, pseudoscientific beliefs create the false impression that they provide reliable information. Hence, we can observe how purveyors of pseudoscience will tend to boast their academic credentials, publish books in academesse with footnotes and an extensive bibliography, and engage in debates with actual scientists. They will also try hard to get published in academic journals or with academic publishers and point at these publications to back up their claims ad nauseam, even after scientists have completely demolished the content of these publications (Blancke, Boudry, and Pigliucci 2017).

PSEUDOSCIENTIFIC BELIEFS: INTUITIVELY APPEALING, MIMICKING SCIENCE, IMMUNE TO CRITICISM

A third strategy for pseudoscientific beliefs is to immunise their content against criticism. Pseudoscientific beliefs might be intuitively appealing, but they do have one major weakness and that is that they are untrue. This renders them vulnerable to falsifiable evidence and rational criticism. Hence, if pseudoscientific beliefs want to stand a chance in the struggle for cultural success, they have to develop ways to avoid these challenges. For instance, people who claim to have telepathic talents tend to lose their supernatural powers after having agreed to a scientific experiment. Usually, people do not give up their beliefs but maintain that their powers do not function under critical scrutiny.

Pseudoscience also often relies on vague concepts and claims that can be understood in multiple ways and thus function as moving targets. Horoscopes, for instance, often contain imprecise predictions that are open to various interpretations. Or, they predict that things might happen so that, whether the event actually occurs or not, their prediction always bears out (Boudry and Braeckman 2011).

SCIENCE AND PSEUDOSCIENCE

People who believe and spread pseudoscience are not irrational in the sense that they have no reasons for their beliefs. As any other humans, they bring in reasons as justifications and as arguments to persuade others. They are irrational because they produce reasons that are no longer accepted within the scientific community as good reasons (Blancke, Boudry, and Braeckman in press). What counts as a good or bad reason is not something one can establish by using a universal reason-evaluator that works under all circumstances. It depends on the social interactions and rounds of mutual criticism within the scientific community. From these interactions it becomes clear which reasons are acceptable and which ones are not: No, you cannot argue that climate change is a hoax because it exceptionally snows in May. No, homeopathy cannot work, because water has no memory. No, one cannot read a person's character from one's skull as phrenologists maintained, because personality traits are not linked to particular brain regions, nor does the skull reflect the individual brain in sufficient detail to enable mindreading. And so on. And so on. Of course, scientists – often intuitively – use criteria such as evidence, explanatory power, consistency, coherence, parsimony, and elegance to evaluate beliefs and the reasons for them. However, how scientists apply them and what weight they attribute to them, depends very much on the issue and the domain at hand. A newly suggested theory might not cohere with the consensus, but it might be solving a problem the consensus cannot and therefore seem very promising. Or a theory might have little evidence in its support, but seem to be more consistent than its predecessors.

The distinction between science and pseudoscience, therefore, is not as clear-cut as we would like it to be. Pseudoscientific beliefs are often incoherent with scientific beliefs, but, sometimes, so are scientific theories. Pseudoscientific beliefs have little evidence in favour of them, but sometimes, so do scientific theories. Because of the complexities involved, some philosophers have given up the demarcation project altogether. However, others have only surrendered the idea of finding a list of sufficient and necessary criteria that neatly distinguishes science from pseudoscience. Instead, they have resorted to the notion of "family-resemblance", introduced by the philosopher Ludwig Wittgenstein. This approach acknowledges that we cannot clearly delineate science from pseudoscience. It starts from the assumption that typical instances of science such as the kinetic theory of gases and of pseudoscience such as creationism display certain characteristics that we do not find in the other category. We can then use these characteristics in order to determine whether and to what extent a theory or belief system is more like a science than a pseudoscience or vice versa – so what family it resembles the most (for an introduction to the current debates about the demarcation problem, see Pigliucci and Boudry 2013). The typical characteristics of science do not necessarily have to apply to the epistemic traits of the theory under consideration such as coherence or parsimony; it can also include the ways in which a theory has originated (for instance, was it developed by a critical social community, see also Dawes 2018) or the attitude of its proponents (to what extent they are willing to give up the theory when the theory continues to remain incoherent with a firmly established consensus, to what extent they acknowledge a theory's inconsistency, and so forth).

FAMILY-RESEMBLANCE: A TOOL FOR THE DISTINCTION BETWEEN SCIENCE AND PSEUDOSCIENCE

One important advantage of the family-resemblance approach is that it enables us to handle the subtleties involved in navigating the border between science and pseudoscience. It takes into account that bold hypotheses are not as scientific as well-established theories such as evolutionary theory or genetics, but that these are not pseudoscience either. For other theories, the jury might still be out as they hover over the twilight zone between science and pseudoscience. To which side these theories will fall depends entirely on the reasons (such as facts and arguments)

that their proponents will manage to gather in their support. In the course of that process, some theories might be moving towards pseudoscience, whereas others might be on their way to becoming part of the scientific consensus.

PURVEYORS OF PSEUDOSCIENCE INVEST CONSIDERABLE EFFORT IN PRESENTING THEIR BELIEFS AS FRONTIER SCIENCE

Clearly, one of the areas where the distinction between science and pseudoscience becomes the most blurred and is therefore also the most contested is frontier science. It is no wonder then that purveyors of pseudoscience try to take advantage of the situation and invest considerable efforts in presenting their beliefs as frontier science. They purport to present new and daring challenges to the scientific consensus and claim that they are in the midst of a scientific controversy. In the case of frontier science, however, the status of a newly developed theory is still undecided, and new reasons for or against it are expected to determine its fate. In contrast, the reasons that purveyors of pseudoscience deliver in support of their beliefs have been discarded. This is exactly what makes their beliefs a pseudo-science. Hence, we do not use the label of "pseudoscience" to set aside any theory we do not like a priori. We employ it to categorise theories that make a claim to the best available knowledge in a particular domain, but for which there are simply little to no good reasons (left). Pseudoscience is not an argument, but a conclusion.

Foster the dialogue!

In the United States one of the slogans that Christian fundamentalists use in support of their attempts to introduce creationism into public schools is "Teach the controversy!" When you engage in a scientific controversy, your belief system forms a worthy competitor in the frontier of scientific progress, where scientific debates rage at full strength to determine what will become science and what not. In the case of creationism, however, there is no controversy; there is not even a dialogue. Nevertheless, the pretence of pseudoscience might confuse lay people and lead them to accept information from people who falsely claim to be their experts in their field. Scientific theories are often complex and abstract, which makes it difficult, if not impossible, for lay people to evaluate their content. Hence, they have to decide which people they can trust as experts. In response to this challenge, philosopher Alvin Goldman (2001) suggested a number of heuristics that lay people can employ to detect the most reliable source of information. For instance, you can check his or her academic credentials (does the person have a PhD in a relevant field or not?) or to what extent other experts endorse her or his expertise (how many scientific awards did she win? How many citations does her work have?). As Goldman emphasises, his guidelines do not provide a bulletproof defence against nonsense, but they might help to heighten one's vigilance towards frauds. Museums can build on these insights to empower visitors to detect and ward off unreliable sources of information and, as a result, train their critical thinking skills (Gomes da Costa 2017).

FOCUS ON WHY PEOPLE SHOULD BELIEVE IN SCIENCE

An effective way to implement a proper and nuanced understanding of science and pseudoscience is to "foster the dialogue". Often, science is presented as information that people have to believe without questioning, as if science truly delivers dogmas. Little attention is devoted to explaining the reasons why people should believe it. Why is science a reliable source of information? Why can we usually trust scientists who defend the scientific consensus? The solution is to inform lay people that science emerges from the interaction of scientists who freely propose and evaluate hypotheses and the methods of developing and testing them. Make clear to people that science is a constant dialogue and why this dialectical process does not undermine science, but actually explains why science tends to result in trustworthy and true beliefs. Science comprises beliefs that are supported by the best possible reasons at a

particular time.

LET VISITORS PERSONALLY EXPERIENCE HOW SCIENCE WORKS

Perhaps the best way to instil such an understanding of science is to let visitors experience personally how it works: confront them with problems and let them find out how engaging in a dialogue is key to finding the solution. Give people the opportunity to develop hypotheses and provide reasons for them, and to criticise in a fair manner the hypotheses and reasons of others. Have them engaged in dialogues with scientists who can then, in their turn, learn about and respond to specific beliefs, reasons for belief, and concerns of members of the public (Lehr et al. 2007, McCallie et al. 2009). Through such experiences, people will come to appreciate the role of dialogue in scientific development and improve their reasoning and critical thinking skills (Kuhn 2019, Mercier et al. 2017).

Conversely, one can employ the same approach to expose pseudoscience as the end of dialogue. Supporters of pseudoscience use reasons and thus pretend to engage in the dialectical process of science. This creates opportunities to let people understand how bad the reasons for pseudoscience actually are and to make them realise why scientific explanations constitute better explanations. One can provide people with the means to check whether a certain pseudoscientific beliefs properly explains what they observe, examine whether and to what extent an argument supports a pseudoscientific claim, and compare the explanatory power of a pseudoscientific with that of a scientific theory.

COMPARE THE EXPLANATORY POWER OF SCIENCE AND PSEUDOSCIENCE

To explain how the scientific dialogue results in true beliefs is to engage in a dialogue with the public (Lehr et al. 2007, McCallie et al. 2009). One provides people with reasons for why science is a trustworthy source of information, but also with the means to critically evaluate them. As such visitors will not only learn about science, but they will have done so on the basis of the very dialectical process that is central to it.



This 'Frankenfood' protest sign reflects an intuitive teleological understanding of nature that underlies the opposition to GMOs. 2014 March Against Monsanto, Washington DC, USA, 24 May 2014. Pic by Stephen Melkisetian.



Anti-vaxxers do not adjust their position in response to the scientific consensus on the safety of vaccines and thus dogmatically stick to their beliefs. Here: protest in Melbourne, Australia, 14 September 2017. Pic by Alpha.

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