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Abstract

The aim of this article is to propose a methodological externalism that takes knowledge about science to be partly constituted by the environment. My starting point is the debate about extended cognition in contemporary philosophy and cognitive science. Externalists claim that human cognition extends beyond the brain and can be partly constituted by external devices. First, I show that most studies of public knowledge about science are based on an internalist framework that excludes the environment we usually utilize to make sense of science and does not allow the possibility of extended knowledge. In a second step, I argue that science communication studies should adopt a methodological externalism and accept that knowledge about science can be partly realized by external information resources such as Wikipedia.

Keywords

cognition, cognitive extension, cognitive technology, deficit model, knowledge, philosophy of science communication, web science, Wikipedia

Since the end of the 20th century, traditional accounts of cognition have come under increasing criticism by an externalist movement that argues that human cognition extends beyond the organism and can be partly constituted by the environment. According to externalists, philosophers and cognitive scientists have been misguided by the idea that human cognition is entirely located in the brain and have been blind to how reasoning, problem solving, and other abilities are entangled with and dependent on the environment. The aim of this article is to utilize the externalist framework to formulate an approach to science communication that rests on an extended concept of knowledge. I argue that a thorough externalism has a far reaching impact on science communication, as it implies that external information resources such as Wikipedia or Google can constitute extended knowledge about scientific issues. Furthermore, I try to show that a reformulated and extended concept of knowledge fits the needs of science communication better than traditional accounts of knowledge and scientific literacy.

Proponents of extended cognition claim that cognitive processes can extend beyond the boundaries of the organism and often illustrate their position with a large variety of examples that involve very different kinds of cognitive processes. One popular example is the use of a pen and paper to

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perform long multiplication (e.g. Wilson and Clark, 2006). When using a pen and paper for long multiplication, a lot of cognitive labor is transferred from the brain to external processes. For example, all the intermediate results that add up to the final result are not stored in the biological memory but on a sheet of paper. Proponents of extended cognition argue that we should think of the cognitive process of multiplying as being composed of processes that are internal as well as external to the organism. There is no reason to think that only neural processes can realize cognitive processes.

While externalist accounts usually try to defend the concept of extended cognition with respect to very different kinds of cognitive processes, this article will focus almost exclusively on knowledge. The most discussed example of extended knowledge in contemporary literature is a thought experiment with Otto who suffers from Alzheimer's and relies on a notebook as a substitute for his lost biological memory (Clark and Chalmers, 1998). According to externalists, Otto uses the information in his notebook in much the same way as people with a healthy brain use their biological memory, and we should accept his notebook as an extended memory.

The main claim of this article is that science communication will benefit from a thorough externalism and a robust notion of extended knowledge. The potentially radical consequences of this proposal become clear when we move from thought experiments such as Otto's notebook to large information resources such as Wikipedia. If we take externalism seriously, external information resources such as Wikipedia may become storages of external knowledge. In one of his popular 'xkcd' webcomics, cartoonist Randall Munroe provides a nice illustration of this possibility by describing the effects of Wikipedia's server outages on his problem-solving abilities (see Figure 1). While he is usually able to impress other people with detailed knowledge of obscure topics, the disrupted access to Wikipedia makes him incapable of dealing with even the simplest problems.

The title of his comic-strip, 'The Extended Mind', refers to the theoretical context of externalism and suggests that Wikipedia is not only a helpful cognitive tool but literally part of his cognitive system. The aim of this article is to take this radical hypothesis seriously and explore its implications for science communication. I will argue that a radical extension of knowledge through

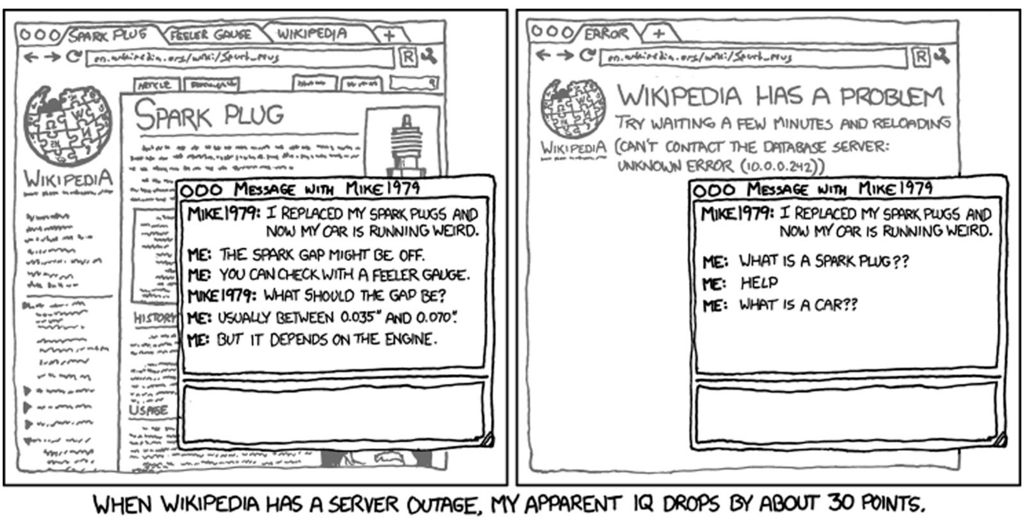

Figure 1. 'The Extended Mind' by Randall Munroe (CC BY-NC 2.5 License).

external and digital media is actually more plausible than it may appear on first sight and offers a methodologically attractive interpretation of the impact of modern technologies on our cognitive economies.

1. 'Knowledge about science'

Although science communication can serve a large variety of purposes, there can be little doubt that one of its core functions is to increase knowledge about science. While the general claim that science communication should increase knowledge about science may be a truism, the question of what constitutes knowledge about science remains highly controversial. A cursory look at the recent history of science communication studies reveals a large diversity of concepts, and the aim of this first section is to briefly introduce some influential accounts that will help to put the externalist proposal into context.

While science communication is arguably as old as the professionalization of science, it has only more recently become a topic of distinct scholarly interest. Walter Bodmer, one of the pioneers of contemporary science communication, argues that, for most of the 20th century, popular science was not only irrelevant but even potentially harmful for the careers of young scientists: 'It was, presumably, more or less acceptable for a Fellow [of the Royal Society] to be a populariser, as this could hardly any more tarnish his or her scientific reputation, but for younger scientists, perhaps aspiring to election to the Royal Society, the fear of opprobrium was a definite disincentive to becoming too popular' (Bodmer, 2010: 152).

This situation changed profoundly in the 1980s, partly triggered by a research report of the Royal Society, today known as the 'Bodmer Report' (Bodmer, 1985). In 1982, the Royal Society set up a working group to evaluate the public understanding of science and strategies of an improved science communication. Published in 1985, the Bodmer Report stressed the duty of scientists to communicate their results and the public understanding of science was presented as an important element in the promotion of national prosperity, the quality of private and public decision making, and richness of the lives of individuals (Bodmer, 1985).

As a consequence of the Bodmer Report, many social scientists began to study scientific literacy and public knowledge about science. Two of the most influential studies were carried out by Durant et al. in the UK and Miller et al. in the USA. The results of both studies were published in *Nature* (Durant et al., 1989) and discussed two kinds of knowledge: knowledge about *basic scientific facts* and methodological knowledge about *processes of scientific inquiry*. Knowledge about basic scientific facts was tested through questions such as *Does light travel faster than sound? Does the liver make urine? Do all insects have eight legs?* Methodological knowledge about processes of scientific inquiry was tested by asking subjects questions in which they were supposed to identify the correct answer in a list. For example, they were presented with the case of a drug against high blood pressure that is suspected of not working well and asked how scientists would approach the problem. Subjects who chose 'Give the drug to some patients but not others. Then compare what happens to each group' from a list of possible answers (*Talk to the patients* …) were taken to have at least tacit knowledge of the importance of the experimental method in scientific inquiry.

The results of the studies were widely received as showing an alarmingly low level of public knowledge about science. For example, Durant et al. found that 'only 34% of Britons and 25% of Americans appeared to know that the earth goes around the sun once a year, and 23% of Britons and 25% of Americans knew that antibiotics are ineffective against viruses' (Durant et al., 1989: 11). Given Bodmer's case for the importance of public understanding of science and the apparently widespread misunderstanding of even the most basic scientific facts, there seemed to be an urgent need for a public understanding of science movement.

Although the public understanding of science movement deserves credit for making science communication a topic of wide academic interest, it soon became criticized as being based on an insufficient 'deficit model'. According to its critics, public understanding of science efforts focused too much on the lack of factual knowledge and were often blind to the importance of critical engagement with the role of science in society. Furthermore, the deficit model was accused of 'selling science' and presupposing that public skepticism towards scientific and technological innovations was based on the public ignorance towards science (Wynne, 1992).

The 'contextual model' of science communication emerged as an alternative to the 'deficit model' and aimed at a critical engagement with science and its role in society (Miller, 2001). This alternative also implied new conceptual strategies. For proponents of the 'deficit model', knowledge about science was defined as knowledge about scientific facts and methods. Proponents of the contextual model suggested a broader account that not only included knowledge of 'the formal contents of scientific knowledge; the methods and processes of science' but also 'its forms of institutional embedding, patronage, organization and control' (Wynne, 1992: 42). As the public understanding of science movement was only concerned with the first two kinds of knowledge, proponents of the contextual model argued that it ended up with narrow minded and insufficient concepts of knowledge about science.

The debates about the 'deficit model' and 'contextual model' of science communication have led to large variety of accounts of knowledge about science that still constitute the framework of many theoretical debates about science communication (Bubela et al., 2009; Nisbet and Scheufele, 2009; Sturgis and Allum, 2004). Despite the obvious differences between these accounts, I want to argue that many of them share an assumption that is the focus of criticism of this article. The assumption I want to challenge can be summarized as the idea that knowledge is something entirely *internal* to the organism and that knowledge about science has to be tested independently of the environment we usually utilize to make sense of science. Contrary to this *internalism*, I want to propose an *externalist* account that accepts externally stored information as a potential part of someone's knowledge system.

One way of illustrating the difference between internalism and externalism in science communication is to consider different ways of testing knowledge about science. Internalists will rely on test designs that systematically exclude the cognitive environment of the subject. During the test, participants won't be allowed to consult Wikipedia or a specialized dictionary, to 'Google' a key word, to call a friend, to use a notebook, and so on. Ideally, an internalist test of knowledge takes place in the controlled environment of a laboratory where all of these 'confounding factors' can be systematically excluded. An externalist account of science communication is based on the idea that this way of testing knowledge about science is not helpful and should be replaced with an account that incorporates at least parts of the cognitive environment as relevant for a subject's knowledge.

The externalist proposal challenges most studies of public knowledge about science. The public understanding of science studies of the 1980s focused on basic knowledge of scientific facts and methods without considering the environment as something that could legitimately constitute a part of a subject's understanding of science. The same is true for more recent studies that combine aspects of the contextual model with quantitative accounts. Sturgis and Allum's (2004) study, for example, offers an account of contextualist knowledge by combining traditional measures of knowledge about scientific facts and methods with studies of political knowledge. For their 'measure of political knowledge, [they] use a six-item scale tapping respondent knowledge of the policy stances of the main political parties in Great Britain' (2004: 62). While this political knowledge is obviously not identical with contextual knowledge about science, Sturgis and Allum argue that it 'will likely act as [a] reasonably good prox[y]: people who are knowledgeable about political parties and the issue positions they endorse, are also more likely to be familiar with existing forms of scientific regulation, government committee structures, and the nature of links between science, industry, and government and so forth' (2004: 60). Sturgis and Allum's account also clearly presupposes an internalist framework: contextualist knowledge is not defined through the often heavily environment-depended strategies that people use to make sense of science in society but through a test that systematically excludes cognitive strategies that rely on the environment.

Similar points can be made with respect to studies of *scientific literacy*. Although the debate about the concept 'scientific literacy' is as complex as the debate about 'public understanding of science' (see DeBoer, 2000), the conceptual framework of the 2006 PISA test offers a good and often used example of contemporary accounts of scientific literacy. The PISA test defined scientific literacy as an individual's (OECD, 2006a: 23):

- Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen

While this is clearly a quite complex model, the PISA test also measures scientific literacy in an internalist framework, as students are required to answer questions in a standardized test environment that excludes helpful resources of the students' normal cognitive environment – cellphones, friends, books, computers, parents, magazines, teachers, and so on. Although the PISA test also asked students about their social context, the test was carried out in a controlled environment that only provided 'pencils, erasers, rulers, and in some cases calculators' (OECD, 2006b: 28).

Contemporary science communication studies offer heterogeneous conceptual frameworks as the different but closely related concepts 'scientific literacy', 'public understanding of science' and 'public knowledge about science' illustrate. Furthermore, these concepts are often interpreted in different ways along the distinction between a deficit model and contextual model. However, it still seems that at least a majority of them rely on an internalist framework that excludes the normal cognitive environment of subjects.

If the majority of quantitative studies relies on an internalist framework, one may assume that externalist approach is somehow generally opposed to attempts to measure 'scientific literacy', 'public understanding of science' or 'public knowledge about science'. Does the externalist alternative imply that we can only approach these topics with qualitative case studies? I don't think so and will argue in the following sections that one of the main reasons for adopting externalism is that it will actually lead to more meaningful test designs. In next section, I introduce extended cognition as it is discussed in contemporary philosophy and cognitive science.

2. Extended cognition: Metaphysical and methodological issues

Recent debates about extended cognition are strongly influenced by Andy Clark and David Chalmers's landmark paper 'The Extended Mind' (1998) that argues that human cognition literally extends beyond the boundaries of the organism and is partly constituted by the subject's environment. Consider, for example, Clark and Chalmers's now famous example of Otto, who suffers from a mild case of Alzheimer's and uses a notebook as a substitute for his lost biological memory. Otto wants to go to the Museum of Modern Art (MoMA) in New York, so he consults his notebook and goes to 53rd street. Compare Otto to Inga, who also wants to go to the MoMA but has a healthy biological memory and does not need a notebook to remember the address.

It is tempting to describe the difference between Inga and Otto as a difference between knowing and not-knowing: Inga actually knows the address of the MoMA because she has the information stored in her biological memory and can access the information when she needs it. Otto does *not* know the address until he looks it up in his notebook – the notebook is not a literally a part of his memory but rather a tool for his cognitive system. But why is the spatial location of the information storage so important? Why does Inga's biologically stored information constitute knowledge while Otto's external information storage does not constitute knowledge until he looks the information up and makes it part of his biological short-term memory?

Clark and Chalmers argue that the location of the information storage is actually not that important and that the cases of Otto and Inga are not as different as they may appear at first. Otto uses his notebook in a very similar way to how Inga uses her biological memory, and both cases are systematically analogous in important aspects: 'First, the notebook is a constant in Otto's life – in cases where the information in the notebook would be relevant, he will rarely take action without consulting it. Second, the information in the notebook is directly available without difficulty. Third, upon retrieving information from the notebook he automatically endorses it. Fourth, the information in the notebook has been consciously endorsed at some point in the past, and indeed is there as a consequence of this endorsement' (Clark and Chalmers, 1998: 17).

So what is the reason that we consider Inga's biological memory a *part* of her cognitive system while many of us would consider Otto's notebook a *tool for* his cognitive system but not a genuine part of his memory? According to Clark and Chalmers, there is no systematic justification for this distinction and the idea that human cognition must be limited to what goes on in the brain is a prejudice we should give up in favor of a more adequate picture of extended cognition.

Clark and Chalmers's externalism raises metaphysical questions and worries that are usually of no concern for science communicators: Does it make sense to claim that human cognition and the human mind *literally* extend beyond the brain and even the body? What is the metaphysical status of cognitive states that are partly constituted by external media such as notebooks? (For a discussion of these issues in the context of modern technologies see Smart, 2012 and Smart et al., 2010.) However, Clark and Chalmers's discussion also raises methodological issues that directly affect science communication studies: Is it helpful to think of knowledge about science as partly constituted by the environment? Should tests designs in science communication studies reflect an externalist concept of knowledge?

The main goal of this article is the justification of a *methodological* externalism in science communication as I do not want to suggest that science communication scholars must endorse a specific metaphysical theory of the mind. At the same time, the metaphysical and methodological questions are obviously not entirely independent of each other and it will be helpful to consider how methodological issues in science communication relate to the metaphysical issues in contemporary philosophy of mind. In the following sections, I will argue that we should endorse an externalist framework because the internalist concept of knowledge undermines the very possibility of successful science communication. Internalism sets the bar for knowledge so high that it becomes impossible for anyone to have a sufficient amount of knowledge about science. This argument can be interpreted in two ways. According to a *strong interpretation*, this argument has metaphysical implications: if internalism undermines the prospects of a consistent concept of knowledge about science then at least some cognitive states (i.e. knowledge about science) must literally extend beyond the organism. According to a *weaker interpretation*, the argument only shows the methodological benefits of an externalist concept of knowledge without having any metaphysical implications: maybe externalism is just a pragmatically useful model in science communication that turns out to be insufficient from a metaphysical point of view. Or, to formulate the weak interpretation in terms common philosophical labels: maybe we need some fictionalist, or instrumentalist, or quasi-realist account of extended knowledge that acknowledges its usefulness in science communication without actually being committed to the existence of extended cognitive states.

Although I sympathize with a stronger interpretation of my argument, I want to restrict the following discussion to its methodological aspects in order to base the case for externalism in science communication on as little controversial assumptions as possible. And even if methodological externalism does not have radical metaphysical consequences, it still turns out to be radical in other ways. This becomes evident when we consider how externalism in science communication changes what kind of knowledge we ascribe to subjects. Let us first return to Clark and Chalmers's example of Otto and assume that Otto also often visits the American Museum of Natural History (AMNH). His notebook includes information on every exhibition room of the AMNH (e.g. biographical data of naturalists and basic facts about species) and Otto always consults his notebook when he visits the museum. Internalists assume that Otto does not actually know the information he has stored in the notebook, as the information is not stored in his biological memory. Externalists, however, argue that the notebook qualifies as a part of Otto's cognitive system if it is used in a specific way: if the access to information through the notebook is functionally analogous to the access to information in the biological memory (e.g. the access is quick and reliable) then the information in the notebook should also count as part of the belief and knowledge system.

The example of Otto's notebook illustrates how internalism and externalism can come to different conclusions regarding someone's knowledge about science. At the same time, the implications do not seem very radical, as the example is limited to very specific and uncommon circumstances of someone using a notebook as a substitute for normal biological memory.

However, there are also examples that promise more far-reaching implications. Imagine Otto's (or someone else's) use of a cell phone with internet access. While strolling through the ANMH, Otto uses his cell phone to retrieve information from Wikipedia. Often, he quickly checks basic facts on species, geologic periods, biographical data of scientists, and so on. Does Otto's quick and reliable access to information from Wikipedia mean that he actually knows all of these things? This would be a truly radical implication of externalism, as the incorporation of information from Wikipedia into Otto's belief system would imply a staggering explosion of knowledge. For example, Otto would know the biographical data of tens of thousands of scientists and have at least basic information on hundreds of thousands of species. He would also know millions of geographical coordinates. And so on.

Some externalists try to avoid this explosion of knowledge by adding additional criteria that exclude Wikipedia and similar online resources. Clark and Chalmers, for example, suggest a 'prior endorsement' criterion that would exclude many external information resources by requiring that externally stored knowledge has to be 'consciously endorsed at some point in the past' (1998: 17; cf. Clark, 2008: 80). Although externalists may be able to avoid an explosion of knowledge by adding additional criteria such as a 'prior endorsement' criterion, I will focus on a thorough externalism that accepts this surprising consequence. In the next section I argue that the explosion of knowledge is actually an important asset for externalism and the *very reason why* science communication studies should accept an externalist framework. The assumption of an explosion of knowledge is actually methodologically beneficial, as it solves the 'problem of cognitive overload' of the next section. This methodological benefit would vanish if we added criteria that restrict extended knowledge in a way that external information resources such as Wikipedia are excluded.

3. The argument from cognitive overload

In this section, I present a simple argument in favor of an externalist framework in science communication. I argue that internalism sets the bar for knowledge so high that a sufficient level of public knowledge about science becomes outright impossible. As science communication scholars should avoid conceptual decisions that undermine the very possibility of successful science communication, they should employ a more liberal externalist concept of knowledge.

The most controversial premise of this argument is the claim that internalism sets the bar for knowledge so high that it undermines the prospects of successful science communication. In order to justify this premise, I first want to discuss what kind of knowledge is necessary for successful science communication. As already shown in the last sections, the public understanding of science studies of the 1980s focused on two kinds of knowledge: on the one hand, knowledge of basic scientific facts such as knowledge that the earth moves around the sun, that antibiotics are not effective against viruses or that light travels faster than sound; on the other hand, basic methodological knowledge such as the importance of experiments in scientific inquiry. Furthermore, I have already presented the contextualist criticism of these studies that insisted that successful engagement with science in modern societies also requires knowledge about the social embedding of science and the role of science in society. Occasionally, these different kinds of knowledge have been taken to imply two rivaling and incompatible accounts of science communication represented by the deficit model and the contextual model. However, there is no reason to think of these different kinds of knowledge as opposed to each other and many more recent accounts of science communication consider them complementary instead of rivaling (e.g. Bauer et al., 2007; Sturgis and Allum, 2004).

And indeed, if we turn to concrete examples of public engagement with science, all three kinds of knowledge seem necessary. Consider simple examples such as a radio debate about the future development of the gross domestic product (GDP) or an article on the dangers of nuclear energy on a science-blog. To make sense of these issues, one certainly needs some *factual knowledge*. For example, one will not understand a radio debate if one has no idea what a GDP is. In the case of the blog article, one needs at least a very basic understanding of what nuclear energy is and what dangers it implies. Although some factual knowledge is necessary, it certainly isn't sufficient. Often, adequate understanding requires some *methodological knowledge* as well. In the case of a debate about the future development of the GDP, it seems necessary to have a basic understanding of what a forecast is and how it differs from other scientific statements. The commentary on the dangers of nuclear energy may make claims about the likeliness of a nuclear catastrophe that require some grasp of probability statements. And so on. Even if the contexualists are right that knowledge about facts and methods is *not enough*, they are often clearly necessary to make sense of scientific issues that affect the public.

At the same time, the examples also show that we often have to go beyond factual and methodological knowledge. Economic forecasts and evaluations of the dangers of nuclear energy are tremendously complicated and even informed citizens will have to rely on external resources. This dependency on the expertise of others is one of the main reasons why knowledge about the social embedding of science is such an important factor in the public engagement with science. Given the complexity of scientific issues and their interactions with other aspects of society, we almost always rely on the expertise of others. And when we rely on the expertise of others, it is often indispensable to know something about their social and institutional embedding. Debates about the economic policies or comments about nuclear energy are clear examples as claims regarding these issues require some contextualisation through knowledge about the media platforms, about the experts or their institutional embedding.

If we look at individual examples of public engagement with science, the internalist framework does not seem to create many problems. Of course, one can acquire sufficient (internally realized) knowledge about the dangers of nuclear energy or the GDP even if we employ a complex model that includes knowledge about scientific facts, methods and the social embedding of science. The problems of the internalist framework become apparent, however, if we move from individual examples to the diversity of scientific issues that are of public importance in a way that they require informed decisions by the society at large. There are different ways in which scientific issues can require these kinds of decisions. First, scientific research can make technological applications possible that require a democratic evaluation and legitimation. Many typical examples of science communication such as nuclear energy, genetic engineering, nanotechnology or neuroenhancement fall in this category. Second, scientific research can also presuppose decisions that need to be evaluated within a society. Examples include scientific endeavors that require large financial investments such as space exploration or particle accelerators but also research that needs to be evaluated in the light of our moral beliefs such as research based on animal testing or embryonic stem cells. Third, scientific research can also come to conclusions that make decisions by the entire society necessary. Obvious examples include research on climate change or declining biodiversity. Fourth, one could also argue that there is a lot of research that does not require immediate action by a society but is still of importance for the self-understanding of individuals. Consider, for example, basic research in the human sciences that does not have any immediate applications but raises fundamental questions such as the nature of consciousness, free will, or the social and/or biological foundations of personality.

My sketchy list of scientific topics that affect society in important ways could easily be extended. However, I think that the main problem is already apparent: Even if we restrict ourselves to scientific issues that affect society at large, we are still facing an enormous amount of complex and highly diverse topics. If science communication aims at factual, methodological and social knowledge regarding all of these topics, we seem to set the bar so high that it becomes hard to see how science communication *can be successful at all*. The point of the argument is not that most people do not have this kind of complex knowledge about science. This would not be a surprising claim, as many studies have found a low level of public knowledge about science. The point of the argument is that we seem to undermine *the very possibility* of successful science communication given the complexity of required knowledge. Even under ideal circumstances, we could not expect the public to have sufficient level knowledge. This problem of a cognitive overload seems to be caused by a combination of three claims:

1. *Complex model*: Science communication should aim at sufficient knowledge about scientific facts, methods and the social embedding of science regarding issues that are important for a society at large.
2. *Internalism*: Only information that is represented internally in the brain qualifies as the basis of knowledge.
3. *Achievability*: The goals of science communication are actually achievable.

The three claims constitute a trilemma in the sense that the endorsement of two claims implies the rejection of the third claim: If we accept the complex model and still insist that the goals of science communication are achievable, we have to reject internalism. If we want to keep the complex model and internalism, we have to conclude that successful science communication is actually not achievable. If we insist on internalism and achievability, we have to formulate a less ambitious model of science communication. I think that we should react to this dilemma by dropping internalism. The persuasiveness of this strategy largely depends on the availability of a viable alternative. In the remainder of this article, I want to outline why externalism may provide a viable and actually quite attractive alternative.

4. Reshaping the concept of knowledge

In the last section, I argued that internalism threatens the very possibility of successful science communication. Given the large amount of knowledge that is needed with regard to very heterogeneous scientific topics, a restriction to information that is stored in the biological memory seems to lead to a cognitive overload for everyone who attempts to understand enough about scientific issues to successfully engage with the role of science and technology in society. Furthermore, it seems obvious that externalism reshapes the concept of knowledge in a way that allows new strategies to deal with this problem. If external information resources can serve as part of subjects' memory, external devices can play a decisive role in extending public knowledge about science and enabling public engagement with science. This is especially evident in the case of basic factual knowledge, as it has been tested by most public understanding of science studies. Given the internalist design of these studies, subjects are not allowed to utilize their cognitive environments – they are not allowed to look up an answer in a notebook, ask a friend, use Google or Wikipedia, and so on. It is obvious that the results of externalist tests would show more optimistic results – especially, if the tested persons have online access to resources such as Google or Wikipedia.

While the argument from cognitive overload may make an externalist concept of knowledge attractive, there are also some rather obvious objections. First, there seems to be an intuitive case against externalism that insists that it would be simply *absurd* to extend someone's memory and knowledge beyond their biologically constituted cognition. The intuitive objection appears especially pressing in the light of examples such as the utilization of Wikipedia as an external memory. Access to Wikipedia allows access to literally millions of simple facts such as biographical data, population numbers, geographical coordinates, and so on. Doesn't externalism imply that a person with quick and reliable access to Wikipedia has all of this knowledge because it is available in their cognitive environment? And wouldn't it be absurd to accept this consequence?

Although these worries are understandable, I think that they are ultimately misguided. An 'explosion of knowledge' through external information resources is actually not as absurd as it may appear on first sight and can provide a helpful account of how digital media and mobile technologies change our cognitive economies. People who make mobile access to online information resources such as Wikipedia and Google part of their second nature alter their cognitive routines profoundly, and externalist accounts provide an interpretation of this process. Furthermore, even a thorough externalism has limits and cannot include all parts a subject's cognitive environment. For example, an externalist may claim that a person knows the biographical data of Albert Einstein because of their quick and reliable access to Wikipedia. However, that does not mean that mobile access to the Wikipedia article on Einstein's theory of relativity ensures understanding of that theory.

Recall that I have introduced externalism through a contrast with internalist studies that test knowledge about science without allowing subjects access to their normal cognitive environment. The basic idea of externalism in science communication is to reshape the concept of knowledge by removing the internalist restrictions of typical test designs. If we remove these restrictions, studies will evidently come to different results, but they will also indicate limits of extended knowledge. A few examples can clarify the situation. Let us start with the knowledge of some simple facts such as *Charles Darwin was born in 1809*. Internalists assume that a person knows that Charles Darwin was born in 1809 if *and only if* this information is stored and available in their biological memory. A internalist test would therefore not allow any external help in answering the question of Darwin's birth year. Externalists allow people to access their normal cognitive environments and therefore allow the possibility that a person knows Darwin's birth year even if they haven't stored it in their biological memory. Recall the example of Otto who has a lot of information including Darwin's biographical data stored in his notebook and therefore has reliable and quick access to this information. If we do not exclude the cognitive environment, Otto will pass the test with the same ease as someone who has the information stored in their biological memory. The same is obviously true of everyone who has reliable and quick mobile access to Wikipedia and can retrieve the biographical data online.

However, even radical externalists will be happy to acknowledge that many people do not know Darwin's birth year because they do not have a sufficiently robust access to this information. The most obvious possibility is that someone has no access to the information at all – not through a notebook, laptop, smart phone, print encyclopedia, or any other external information storage. In other cases, the information may be available in the cognitive environment but not accessible in a sufficiently robust way. For example, someone may only be able to access the information on a computer at work or at the local library. In both cases the information is only available at a specific location at a specific time and therefore the access is not reliable enough to constitute knowledge. The externalist test condition should reflect this restriction by only allowing the reliably available cognitive environment when testing knowledge about science.

Another limit of external knowledge becomes apparent when we move to more complex issues than birth years. Consider, for example, knowledge of complex scientific theories. It would be absurd that a person with quick and reliable online access knows everything that is published in an open access journal, simply because the information is accessible online. The obvious reason is that genuine knowledge must be readily available for further consideration while the extraction of knowledge from scientific publications requires considerable time and cognitive effort. Again, the externalist reinterpretation of typical test of scientific literacy and knowledge reflect this limitation: We should ascribe someone knowledge about an issue *only if* appropriate information is readily available for further consideration. However, a lot of complex scientific information in a scientific open access journal is usually not readily available for further consideration because its retrieval requires considerable time and cognitive labor.

The suggestion of reshaping the concept of knowledge about science by removing the internalist restrictions of typical tests of knowledge leaves many questions open. For example, I have talked about 'quick and reliable access' without offering any suggestion of how to operationalize these conditions. Although this is a serious methodological issue, it is not entirely unique to externalist approaches. *Any* attempt to test knowledge about science will face similar methodological problems. Internalist tests will also have to deal with situations where information retrieval is somehow inconsistent, only available in specific contexts or requires a lot of time. Although I do not want to downplay these issues, I assume that the main point of the externalist proposal is independent of them. We can approach studies of knowledge about science in two crucially different ways. On the one hand, we can restrict knowledge to information that is stored in the biological memory. Although this approach matches traditional, internalist concepts of knowledge, it runs into trouble because it creates the problem of cognitive overload that threatens the very possibility of successful science communication. On the other hand, we can reshape the concept of knowledge in a way that it includes quickly and reliably available information no matter whether it is stored in the biological memory or external information storages. This proposal requires some bold conceptual moves but also provides a conceptual framework that fits the needs of science communication studies better than traditional internalist accounts.

5. Conclusion: Technological optimism and its limits

In this article I have argued that we should abandon internalism and instead adopt an account that accepts externally stored knowledge if it is quickly and reliably accessible in the cognitive environment of a subject. This reconzeptualization of knowledge has important methodological consequences, as it suggests different test designs that allow the utilization of the cognitive environment. Furthermore, the externalist account may also lead to a normative reevaluation of science communication strategies and efforts: if external information resources realize externally stored knowledge, both access to and the quality of these information resources becomes of crucial importance for successful science communication.

For example, externalism may provide a reason for science communicators to join forces with computer education/access programs that try to close the digital divide (e.g. Norris, 2001; Warschauer, 2004) between groups that have reliable access to online sources and groups that do not have this kind of access or at least not the media competence to use it efficiently. Given the argument from cognitive overload, we may even go a step further: *only* societies that are able to bridge the digital divide can hope to achieve a level of scientific literacy and knowledge about science that allows informed democratic decisions at the intersection of science, society and policy making.

So far, I have told a mostly optimistic story about the extension of knowledge through modern technologies: by creating quick and reliable access to external information resources, we also create externally stored knowledge that can play a crucial role in science communication efforts. Although this is indeed an encouraging story, one should certainly not slip into an uncritical technological utopism that misunderstands external information resources as a simple solution to all problems in scientific literacy and public engagement with science.

Important limitations of extended knowledge become obvious when we look at the public understanding of complex scientific issues. As discussed in the last section, the complexity of scientific information sets limits to extended knowledge. No one has knowledge of everything that is published in an open access journal because the retrieval of most of the information requires considerable time and cognitive labor. A second limitation of externalism becomes apparent when we employ a more ambitious concept of understanding. Consider the case of evolutionary theory and the question to what extent access to Wikipedia articles such as ‘Evolution’, ‘Adaptation’, ‘Population Genetics’, ‘Evo-Devo’, ‘Evolutionary Psychology’, ‘Creationism’, and so on ensures understanding of issues in evolutionary theory or even issues such as the implications of evolutionary theory for human self-understanding. Access to Wikipedia articles is clearly not sufficient for an understanding of these issues. One reason is their complexity – although Wikipedia contains a lot of information, much of it is not readily available for further consideration and its retrieval requires too much time and cognitive labor to constitute knowledge. However, I do not think that the complexity of the information is the only reason why we think that access to these Wikipedia articles does not grant understanding of complex issues regarding evolutionary theory and its implications.

Instead, I want to suggest that we often use the term ‘understanding’ in a more ambitious way than ‘knowledge’. In order to truly *understand* a complex issue, we not only need propositional knowledge but we also need to be able to consistently integrate this knowledge in our system of believes, values, and actions. Of course, complex scientific issues are often dominated by the division of cognitive labor and externalists can point out that we always rely on the work of others when we evaluate these issues and integrate them with our beliefs, values and actions. However, even the most radical externalist will acknowledge that this process cannot be entirely external, as it also requires integration with internally realized believes and values. Externally stored knowledge can be an important part of the understanding of complex scientific issues but a more ambitious concept of understanding will still set limits to externalism by also requiring consistent integration of externally stored knowledge with internally realized cognition.

In addition to these limits in understanding complex scientific issues, there are further reasons that should make us suspicious of an overly optimistic technological outlook. In this article, I have focused on how external information resources can realize extended knowledge. However, external information resources can contain all kinds of information, no matter whether it is accurate, biased or outright wrong. Externalism claims that external information resources can constitute parts of people's belief systems. This also means that all kinds of ideology and misinformation can become part of belief systems simply by being present in the external information resources people rely on. To use a more drastic formulation and example: By editing a Wikipedia article, one can literally *edit* the belief systems of millions of people. By adding false or biased information to a Wikipedia article, one can add false or biased information to the belief systems of millions of people.

Externalism implies not just great opportunities for science communication but also new challenges. The growing importance of external knowledge resources in our cognitive economies creates the need for improved media competence as a crucial part of public engagement with science. This not only requires a shift in science communication practice but also theoretical reflection of the ideological power of external and digital information resources. In this sense, externalism provides an opportunity to reflect the dramatic changes that digital and mobile technologies enforce on our cognitive economies.

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