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ARTICLES

Assumptions of the Deficit Model Type of Thinking: Ignorance, Attitudes, and Science Communication in the Debate on Genetic Engineering in Agriculture

Marko Ahteensuu

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Abstract This paper spells out and discusses four assumptions of the deficit model type of thinking. The assumptions are: First, the public is ignorant of science. Second, the public has negative attitudes towards (specific instances of) science and technology. Third, ignorance is at the root of these negative attitudes. Fourth, the public's knowledge deficit can be remedied by one-way science communication from scientists to citizens. It is argued that there is nothing wrong with ignorance-based explanations *per se*. Ignorance accounts at least partially for many cases of opposition to specific instances of science and technology. Furthermore, more attention needs to be paid to the issue of relevance. In regard to the evaluation of a scientific experiment, a technology, or a product, the question is not only "who knows best?," but also "what knowledge is relevant and to what extent?." Examples are drawn primarily from the debate on genetic engineering in agriculture.

Keywords Deficit model · Ignorance · Attitudes · Science communication · Genetic engineering · Nanotechnology

M. Ahteensuu (✉)
University of Turku, Public Choice Research Centre (PCRC),
Publicum, Assistentinkatu 7, 20014 Turku, Finland
e-mail: mataah@utu.fi

Introduction

The term "deficit model"[1] was coined by social scientists in the 1980s to highlight assumptions underlying much of science communication.[2] According to the deficit model, the general public's negative attitudes towards modern science and technology are based on ignorance. The proposed remedy: scientists should communicate the facts to non-scientists. In the subsequent academic literature the deficit model was criticized on empirical and theoretical grounds (e.g., Evans and Durant 1995; Wynne 1991; Ziman 1991), which have resulted in its abandonment—at least in the social science literature related to science communication (Einsiedel 2007, 5; see also Royal Society 2004, 11). The old "paradigm" of the Public Understanding of Science (PUS) has been replaced with a new one, namely that of the Public Engagement with Science and Technology (PEST). The latter emphasizes negotiation and two-way communication between scientists and non-scientists as well as the public's real opportunities for participation in decision-making processes. (Gregory and Lock 2008; see also Hails and Kinderlerer 2003, 820–821; Bubela et al. 2009, 514–515.)

Yet the deficit frame seems to remain a common mindset among many scientists and decision-makers. It has reappeared in more subtle forms. Wynne (2006) speaks about continual reinvention of public deficit explanations. He identifies five public deficit models for mistrust of science in his article on public engagement as a means of restoring public trust in science. Sturgis and Allum (2004, 57) argue that "[w]hilst the deficit model (…) is to some extent a simplification, or even something of a 'straw man', it quite evidently underlies many programmatic statements from the scientific community when the misplaced fears of scientifically illiterate public and mass media are bemoaned." In their *Nature Biotechnology* commentary article Bubela et al. (2009, 514–515) note that "[d]espite increasing attention to new directions in public engagement, a still-dominant assumption among many scientists and policymakers is that when controversies over science occur, ignorance is at the root of public opposition." According to Gaskell et al. (1999, 386), it is an ordinary belief that scientific literacy and understanding generate support for (specific instances of) science and technology. (For the view that the deficit model type of thinking shapes views and actions of scientists and policymakers see also Cook et al. 2004, 438–439; Dickson 2005, 2; Hansen et al. 2003, 111–112; Wright and Nerlich 2006, 331; for new deficit models see Gregory and Lock 2008, esp. 1256,1259–1260; see also Brown 2009.)

The debate on genetically modified organisms (GMOs) in the European Union (EU) provides a topical example. The general public's reluctance to and in some cases hostility towards agricultural gene technologies and food products are often

[1] Other phrases employed include "cognitive deficit model of the public understanding of science" (Wynne 1991), "deficit model of public attitudes" (Sturgis and Allum 2004), "deficit model of science communication" (Hails and Kinderlerer 2003; Dickson 2005), "deficit model of public understanding of science" (Sturgis et al. 2005), "deficit model of understanding" (Royal Society 2004), "public deficit models" (Wynne 2006), and "deficit approach" (Bubela et al. 2009).

[2] Instances of the deficit model type of thinking no doubt go further back in time. See e.g., Wynne (2006, esp. 214).

attributed to ignorance of the science behind these technologies, lack of awareness of extensive risk assessments, erroneous beliefs about them, religious beliefs, and irrational fears, especially by scientists and decision-makers. A European Commission funded study *Public Perceptions of Agricultural Biotechnologies in Europe* (PABE) states that the myth of an ignorant public is one of the persistent and entrenched views that are shared by scientists and numerous policy actors, including non-governmental organizations (NGOs) (Marris et al. 2001, 78–79). A flagrant instance of the deficit model type of thinking is the frequency with which a particular response from Eurobarometer surveys is cited. According to the survey conducted in 2005, only 41% of the population appears to know that genes are not exclusively contained in genetically engineered (GE) tomatoes (Gaskell et al. 2006, esp. 59). In the earlier years the scores have been even lower (see Inra 2000; Gaskell et al. 2003).[3] The erroneous belief that non-GE tomatoes are gene-free coupled with the public's opposition to modern agricultural biotechnologies is a perfect recipe for the deficit model type of thinking.[4] Another more particular instance comes from the context of nanotechnology. Currall et al. (2006, 154) recommend that "now is the time to educate the public aggressively with facts about risks and benefits of nanotechnology. Education can prevent opinions from becoming polarized on the basis of misinformation."[5]

This paper begins with a simple characterization of the deficit model type of thinking. I presume that most authors would accept the following statement to capture its core idea: the general public's negative attitudes towards (specific instances of) science and technology are based on the lack of scientific knowledge, which can be remedied by telling them the facts. Actual cases—such as the ones referred to above—no doubt come in many forms. But in order for something to count as an instance of the deficit model type of thinking, it should satisfy at least a qualified form of this characterization. In what follows I will consider the empirical evidence supporting and theoretical issues related to different assumptions implied by the deficit model type of thinking. The aim is to contribute to the discussion about a sound foundation for science communication and public engagement mechanisms. Examples are drawn primarily from the current debate on genetic engineering in agriculture.

[3] One might ask whether the persistently high percentage of wrong answers can be partially explained by the way the survey has formulated the particular question.

[4] A common response to the GMO controversy by many national (advisory) biotechnology boards has been an attempt to educate the public about genetic engineering in agriculture. Sometimes this has taken the form of producing information leaflets one after another. (By this I do not mean that basic informing through leaflets and various other popular science outlets would not be needed. It should also be noted that at least some of these boards have informing and educating the general public as part of their mission.) Certain decision-making practices may also uphold the deficit frame. It has been argued that the current public consultation practices on the deliberative release and placing on the market of GMOs in the EU fail to yield a genuine two-way communication between policymakers and the general public (Ahteensuu and Siipi 2009).

[5] As a response to Bonnie Wintle, Mark Burgman and Fiona Fidler's criticism (2007, 327), Currall et al. (2007, 328) state that they do not take the stance that simply educating the public about science would lead to public acceptance of nanotechnology. For recent discussion about deficit model related ideas in the context of nanotechnology see e.g., Brown (2009), Jones (2008), Kahan et al. (2009); see also Currall (2008),Scheufele et al. (2008a, b).

The Deficit Model Type of Thinking

The logic behind the deficit model type of thinking might seem somewhat simple and appealing at first glance. The public is diagnosed as ignorant of (and lacking interest in) science. The main symptoms of the condition are aversion, anxiety, and mistrust. The prescribed cure: science pills. Directions: swallow facts. It is not only to let scientists (and public authorities) work in peace, but also for the public's own good. Indeed, a scientifically literate and knowledgeable citizenry is a prerequisite for the functioning of a modern democratic society. As scientific developments and technological innovations are increasingly part and parcel of citizens' daily lives, to educate the public about science is to empower them.[6] Only when armed with scientific facts can citizens make informed decisions and effectively engage in public debate on science and technology policy. (See Royal Society 1985;[7] for reasons why care about public understanding of science see also Durant et al. 1989, 11; Irwin and Wynne 1996, esp. 5.)

As too often, the first impression proves wrong. The deficit model type of thinking rests on four interrelated empirical assumptions, all of which invite a host of theoretical issues. First, the public is ignorant of science. Second, the public has negative attitudes towards (specific instances of) science and technology. Third, ignorance is at the root of these negative attitudes. Fourth, the public's knowledge deficit can be remedied by predominantly one-way science communication from scientists to citizens. I will next consider each of these assumptions separately.

The Public is Ignorant of Science

Survey research has indicated the public's scientific illiteracy, innumeracy, and ignorance over and over again.[8] In fact, the awakening to the low levels of science knowledge and concerns about waning interest in science prompted the first science education programs and initiatives—especially in the United Kingdom (UK) and the United States (US)—and the field of study known as the PUS. As Ziman put it, "the striking result of both surveys [an Oxford survey and a national survey in the US] was, of course, how little grasp most adults seem to have of the most elementary items of scientific knowledge" (Ziman 1991, 102; see also Durant et al. 1989). Much of the same still seems to hold today, according to more recent surveys (see e.g., Sturgis et al. 2005; Sturgis and Allum 2004). Eurobarometer studies on modern biotechnology, for example, have repeatedly reported the general public's low levels of knowledge on biology and genetics (Inra 2000; Gaskell et al. 2003, 2006, esp. 57–60).

[6] In this paper I use the term "development" in a neutral sense. It does not imply any evaluative stance or commitment.

[7] The 1985 report from the Royal Society in fact goes even further and suggests that the public understanding of science is vital to the future well-being of society and critical to a nation's competitiveness. Scientist should consider promoting the public understanding of science as their responsibility.

[8] Needless to say science knowledge encompasses knowledge about scientific basis of technologies.

Not all hope is lost. For one thing, there is also some evidence to the contrary. The PABE study goes against the findings of the Eurobarometers and suggests that the general public is informed about issues related to GMOs.[9] As noted, the authors claim that the myth of an ignorant public is one of the persistent and entrenched views that are shared by scientists and numerous policy actors, including NGOs. However, this myth is not supported by their focus group analyses. (Marris et al. 2001; see also Louët 2001.) Besides this opposing indication, the level of general science knowledge arguably increases over time. Eurobarometers on science and technology (see e.g., 2010 and 2005) have reported a clear progress in terms of basic scientific knowledge. The National Science Board's *Science and Engineering Indicators* published every second year (see e.g., 2010 and 2004) reveal the same trend.

It is also worth pointing to the fact that the availability of science information is better than ever before. Many citizens—in the affluent countries—nowadays have access to newspaper science coverage, popular science books, science magazines, radio and television documentaries, science websites and blogs, science fairs, science museums, zoos, aquaria, and botanical gardens. Moreover, the public actually shows interest in science and technology. This was confirmed by the early studies in the field (see e.g., Durant et al. 1989, 11), and recent studies also report that citizens want to know more about particular scientific developments and their technological applications (e.g., European Commission 2010, 156; European Commission 2008a).[10]

Another thing is to draw attention to the distinction between formal and informal knowledge. Even if the public shows low levels of formal scientific knowledge, they may possess a fair amount of informal knowledge that is useful and directly related to their everyday lives. Local knowledge championed by Wynne (1991) is a paradigm. Related to this, an obvious worry—and a common criticism—lies in the way the public's scientific literacy has been approached via quantitative surveys. The knowledge measures employed in Eurobarometers have been claimed to be based on a culturally determined idealization of what should constitute scientific knowledge (Peters 2000 quoted in Sturgis and Allum 2004, 57; see also Sturgis et al. 2005, 33).

What does it mean to be knowledgeable about science? How do we adequately measure scientific literacy? Textbook knowledge offers one possible answer. It is straightforwardly definable and measurable. But probably nobody seriously suggests that that is a sufficient measure. Scientific knowledge surely extends beyond simply memorizing facts. On the other hand, it is not reasonable to set the standard too high either. Many authors speak about a deficit in the public's understanding, not only in their knowledge (e.g., Dickson 2005; Hails and Kinderlerer 2003; Royal Society

[9] In fact, *Eurobarometers* on biotechnology show some, but rather small, increase on the public's knowledge on biology and genetics.

[10] Ignorance is typically closely connected to lack of interest. People do not seek information on issues that they are not interested in. However, the connection is contingent. Even if a person is highly interested in some subject, this does not always result in adequate knowledge or understanding of the subject matter in question. S/he might for example acquire information from sources that are not trustworthy or accurate, or alternatively misunderstand adequate information provided.

2004; Sturgis et al. 2005; Wynne 1991). Knowing facts is a prerequisite for understanding.[11] Facts "tell" us how the world is. We may learn the facts through observation, reason(ing), and communication. Understanding, in its turn, consists of relating the facts together. It presupposes awareness of the explanatory and other connections involved in the subject matter in question. Scientific understanding is commonly taken to presuppose comprehension of the nature of scientific inquiry. It includes awareness not only of the facts, but also of the methods employed and their limitations as well as of the possible applications and social implications. Now, apart from the specialists it may be that no one actually has the facts precisely spelled out and comprehension of the specific methods, limitations, and applications. This carries the implication that only experts really know and understand the issues in question.

Two further remarks on the knowledge measures: First, not all surveys are quantitative. The European Commission's pan-European report *Qualitative Study on the Image of Science and the Research Policy of the European Union* (2008b) provides an example. Second, to the extent that the above criticisms undermine the conclusions of some quantitative surveys on the public's scientific illiteracy, they also do so in regard to the other quantitative studies with more positive results (i.e., results indicating that the public is well-informed).

Another set of questions relates to the identification of the public. To whom does the term "general public" refer? A common approach is to set aside different roles people play in different contexts (i.e., the fact that one person may be a citizen, an activist, a policymaker, a scientist, etc.) and equate the public with non-scientists (e.g., Royal Society 1985). Besides this simplification, there are other issues. Taking some kind of an average as a reference point does no justice to many well-informed citizens. (Nor does it do justice to some ill-informed members of society.) Increasing availability of science results and discussions and the fragmentation of science media have had the effect that some members of the public are very well-informed about what is going on in (a particular field of) science. The fragmentation, however, also means that if an individual lacks interest in science and technology, s/he can easily avoid science media altogether. A related point is that it might be in order, or more accurate, to speak about many publics rather than one. In science communication different publics can be reached by different media. At the very minimum, it should be borne in mind that the distinction between experts and lay people does not correspond with that of scientists and the general public (for discussion on the expert-lay knowledge divide see Evans 2008; Irwin and Wynne 1996; Lidskog 2008; Wynne 1996).

Negative Attitudes towards Science and Technology

A conventional wisdom—especially in the EU—has been that the general public is skeptical about benefits of scientific developments and related technological

[11] Not all epistemologists agree with this. For discussion on the nature of and relationship between knowledge and understanding see e.g., Kvanvig (2003).

innovations, and that citizen's trust has wavered in the last decades (see e.g., Sturgis and Allum 2004, 56). As an example of negative attitudes the Eurobarometer 64.3. reports that GM foods are still "widely seen as not being useful, as morally unacceptable, and as risk for society" (Gaskell et al. 2006, 13–14, 28; for negative attitudes towards biotechnologies see also Bonny 2003; Gaskell et al. 1999; Pardo et al. 2002; see Savadori et al. 2004 for expert and public perception of risk from biotechnology). In regard to the issue of trust O'Neill (2002, 11) notes that

> reported public trust in science and even in medicine has faltered despite its successes, despite increased efforts to respect persons and their rights, despite stronger regulation to protect the environment and despite the fact that environmental concerns are taken far more seriously than they were a few years ago.

The conventional wisdom is not entirely truthful. Several surveys on the public's attitudes indicate rather positive techno-science views and trust. Eurobarometers on science and technology (European Commission 2010, 156–157; see also ibid. 2005; ibid. 2008b) conclude that Europeans' image of science and technology appears clear and positive.[12] (See also National Science Board 2010, ch. VII; ibid. 2004.) The aforementioned Eurobarometer 64.3. in fact states contrary to the conventional wisdom that Europeans have become more optimistic concerning biotechnology in general. Opposition and lack of trust arguably remain, but they are typically concerned with specific scientific developments and technological innovations, not science and technology *per se*. In general, certain technologies—such as genetic engineering in agriculture and hormones in beef—are viewed more negatively in the EU, while this applies to others in the US (see e.g., Whiteside 2006, esp. ch. III; Wiener and Rogers 2002, esp. 322–323). One recent study reported that respondents in the US were significantly less likely to agree that nanotechnology is morally acceptable than respondents in many European countries (Scheufele et al. 2008a).

It is necessary to distinguish between attitudes towards modern science and technology in general, and attitudes towards specific scientific developments or technological innovations. General attitudes towards science seem to be poor predictors of attitudes towards particular areas of scientific study (e.g., Evans and Durant 1995, 70). Related to this is a theoretical issue. The exact object of general attitudes towards science is not clear. Science is surprisingly heterogeneous in its forms—not only temporally speaking. It is neither unitary nor a coherent whole, although there are certain features that all scientific research should exhibit (Hansson 2008). Much of the same applies to attitudes towards technology in general. Whilst the general attitudes may be ontologically dubious, attitudes towards specific instances of science and technology do not share this problem. At its inception the deficit model type of thinking was concentrated more on general attitudes towards modern science and technology, later it was applied to specific contexts of science and technology.

Another two points relate to the negativity of an attitude in itself. What does it mean to have a negative attitude? In the context of the deficit model type of

[12] When compared with the 2005 survey, a minor general shift towards skepticism can be observed.

thinking, relevant kinds of negative attitudes include disquiet, opposition, hostility, and mistrust. Someone's having a negative attitude is considered something that should be got rid of. Interestingly, not many people seem to be concerned about positive attitudes that are based on ignorance. So the deficit model type of thinking expresses a systematic bias towards certain kinds of attitudes. Perhaps more importantly, someone's having a negative attitude does not mean that the attitude in question would be somehow undesirable, misplaced, or wrong. It only implies a relation of non-acceptance or dislike to its object. A rough distinction might be made between reason-based opposition and other (emotion-based) opposition.[13] A person may hold reasons against the object of her/his negative attitudes. Alternatively her/his opposition can be due to mere dislike. In the former case the reasons may be well-founded or ill-founded. They can be concerned with ethical convictions or include other kinds of evaluative stances, e.g., related to acceptable evidence and the required level of certainty about safety. The lesson: negativity does not imply undesirability or wrongness. In many cases non-acceptance is desirable and well-founded. Trust is similarly only *prima facie* desirable. Misplaced trust, i.e., trust in persons who are not trustworthy, is not desirable.[14]

Even if one considers negative attitudes formed in the state of ignorance, it is not reasonable to conclude that they would automatically be irrational or ill-founded. Beliefs with low degree of confidence, extra attention, and caution may present the rational and/or ethical response when one encounters a situation or a thing that s/he does not understand (or know) anything or much about.[15] It is also worth noticing that the view which takes scientific knowledge to be a prerequisite for well-founded normative beliefs and right actions presupposes a specific theory of (meta)ethics.

Mistrust is often coupled with the deficit model type of thinking. Wynne (2006, 211), for instance, speaks about public deficit explanations of mistrust which according to him have been continually reinvented. Mistrust can constitute an instance of either reason-based or other opposition. A person might find it rational to mistrust certain regulatory agencies owing to their previous failures,[16] or s/he may

[13] These kinds of distinctions may be useful for analytic purposes. In most instances of negative attitudes both types of opposition are present to a certain degree.

[14] A proponent of the deficit model might try to respond that relevant kinds of attitudes are concerned only with ignorance-based negative attitudes, not with all negative attitudes. This kind of response however misses the point. Although it may work in regard to the second assumption, the response undermines the explanatory strategy of the deficit model type of thinking. It is detrimental in regard to the third assumption. The response results in an undesirable kind of a tautology: ignorance is at the root of negative attitudes only when ignorance is at the root of negative attitudes. The fact that many explanations—in fact all deductive-nomological and deductive-statistical explanations—are tautologies in the strict sense does not help. If the explanandum (i.e., relevant kinds of negative attitudes) is narrowed down by definition, not made understandable by a reference to a (statistical) non-accidental regularity supported by empirical studies, the tautology in question becomes uninformative and non-explanatory.

[15] Although the argument from ignorance (*argumentum ad ignorantiam*), a fallacy in argumentation, has no direct bearing on the deficit model type of thinking, the normative perspective to ignorance-based attitudes comes close to it. The argument from ignorance takes many forms, and not all of them are problematic (see e.g., Walton 1992).

[16] European Environment Agency's report *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000* (EEA 2001) examines fourteen case studies on taking no precaution in the state of uncertainty, and the serious consequences of this omission.

exhibit paranoid delusions and tendencies as a character trait. Nonetheless, mistrust seems different from other negative attitudes. First, it is unclear whether or not mistrust constitutes a negative attitude—at least in the common usage of the word. Neither do negative attitudes imply mistrust, nor vice versa.[17] Negative attitudes and mistrust have contingent connections, however. A person's distrust of scientists and scientific institutions may for example have the effect that s/he acquires information from other sources, and this can result in negative attitudes owing to exposure to false or polarized views. Second, even if mistrust constituted a negative attitude, the objects of mistrust and other negative attitudes are somewhat different. More precisely, they are only partially convergent. The objects of mistrust may be scientists, producers, decision-makers, products, etc. Negative attitudes, on the other hand, typically concern specific scientific experiments, methods of production, and products. A person might have negative attitudes towards a certain production method. At the same time s/he might however consider people responsible for the method in question trustworthy. Third, mistrust is sometimes employed as an explanatory factor—an explanans rather than an explanandum. According to Bubela et al. (2009, 515; italics added), "the narrow emphasis of the deficit approach does not recognize that knowledge is only one factor among many influences that are likely to guide how individuals reach judgments, with ideology, social identity, and *trust* often having stronger impacts." Sturgis and Allum (2004, 58) also identify trust as an important factor influencing the public's attitudes.

Ignorance as an Explanation for Negative Attitudes

In 1985 a report from the Royal Society[18] committee chaired by Sir Walter Bodmer—usually called *the Bodmer Report*—focused on the public understanding of science as a critical issue for society. It emphasized the role of the scientists in enhancing scientific literacy of the general public. This report and the establishment of the Committee on Public Understanding of Science (COPUS) were based on an assumption that a more scientifically literate public would be more supportive of scientific research programs and technological innovations (Royal Society 2004, 11). A quantitative survey (Durant et al. 1989), which appeared in *Nature*, was interpreted (by the PUS campaigners) as providing empirical confirmation of the claim that higher levels of knowledge correlate with more positive attitudes. Empirical research was quickly coupled with the deficit frame, and it arguably spurred much of its popularity.

It was quite clear from the beginning, however, that the relationship between levels of knowledge and attitudes is more complex than that depicted above. In a later analysis two authors of the *Nature* paper pointed out that different knowledge

[17] It is rather clear that negative attitudes are not always associated with mistrust. I do not like cars, but I experience no mistrust of them. Some kinds of negative attitudes are typically present when someone mistrusts a thing or a person. Yet there are cases in which this does not hold. I might mistrust my friend as I know that s/he is a pathological liar even if I do not have any negative attitudes towards her/him (at least in the common sense of the word).

[18] The Royal Society of London for the Improvement of Natural Knowledge.

levels do not imply any particular attitudes towards specific instances of science and technology, although high levels of knowledge are related to more coherent and discriminating attitudes. They conclude that

> we have discovered some evidence that higher levels of knowledge are indeed associated with more supportive attitudes towards science. This appears to hold both for science in general and for what we have termed 'useful science'. In morally contentious and non-useful areas of research, however, the well informed are more strongly opposed to funding than are the less well informed. (Evans and Durant 1995, 70; see also Ziman 1991.)

This is not the end of the story. More remains to be said about the third assumption, according to which ignorance is at the root of the public's negative attitudes towards (specific instances of) science and technology. The relationship between this assumption and assumptions one and two is somewhat complicated. The third assumption can be wrong even if assumptions one and two hold. Perhaps less evident is that the assumptions about ignorance and negative attitudes may be proven wrong in some contexts or as general statements without necessarily compromising the third assumption. If there is at least one context or a case in which ignorance plays the sole, main or partial explanatory role for negative attitudes, a qualified form of the third assumption can be upheld. Moreover, explanations are often supposed to have contrafactual power, i.e., to apply not only to the actual but also to hypothetical cases. Even if nobody was actually ignorant of science and had negative attitudes towards (specific instances of) science and technology, an explanation suggesting a socio-psychological mechanism or regularities could tell us what kinds of attitudes to expect if somebody was lacking scientific knowledge.

"Deficit explanations" may be explanations in a rather weak sense of the word. Although they are clearly concerned with the question of why a phenomenon X (i.e., negative attitudes) occurred, as such deficit explanations do not draw on any general theory of sociology or psychology. Nor do they propose or describe a well-defined socio-psychological mechanism(s). Furthermore, the suggested socio-psychological regularity (between levels of knowledge and attitudes) is hardly exceptionless.[19] When deficit explanations involve the subsumption of particular states of affairs (an individual's ignorance of and negative attitudes towards an instance of science or technology) under statistical laws (a correlation between knowledge levels and negative/positive attitudes), it is invalid to draw definite conclusions from a change in a person's attitude towards a more positive one even when it is coupled with an increase in the person's knowledge about the particular matter in question. This is because the explanandum is not a logical consequence of the explanans. What might

[19] Many authors who have published on the deficit model use a causal language (i.e., phrases such as "causes," "is at the root of," etc.). It should be noted however that the connection between levels of knowledge and attitudes is not a causal one in the strict sense of the word. It is concerned with the ways in which individuals reach judgment and form attitudes. (Admittedly, causality is often interpreted more loosely in social sciences than in natural sciences.) One related rather an absurd implication of a strict reading of the deficit model type of thinking is that the absence of something (i.e., lack of knowledge) causes something else (negative attitudes).

be the case, nevertheless, is that the explanandum (a positive attitude) was to be expected with a high probability. At the very minimum, the suggested explanans (ignorance) needs to have some statistical relevance. It might be argued that deficit explanations amount merely to claiming that low levels of science knowledge correlate with negative attitudes, and higher levels of knowledge with more positive attitudes. If so, two points should be borne in mind. Correlations themselves are not commonly held to be explanatory. A mere correlation between X and Y only conveys the information that one of the three possibilities is probable: either X causes Y, or Y causes X, or they have a common (unknown) cause Z.

Before considering surveys, which form the main strand of evidence for an explanatory relationship between knowledge levels and attitudes, it may be useful to think about the implications of a strict reading of the third assumption. If ignorance is at the root of negative attitudes, then the public should exhibit the most opposition to specific instances of science and technology where their level of knowledge is the lowest, and conversely most acceptance and promotion where their knowledge is the strongest. An analysis of Gaskell et al. (1999, 386) goes against this as Europeans show more negative attitudes towards GMOs than do people in the US. The mean score in textbook knowledge was found to be higher for Europe. Another implication is that all experts should have positive attitudes towards scientific developments and technological applications related to their fields. As pointed out by Kvakkestad and co-authors, this is not the case in the context of biotechnology. The scientists' opinions vary, especially in accordance with academic discipline and (funding) organization (Kvakkestad et al. 2007; see also Waltz 2009). Nanoscientists are more optimistic than the general public about the potential benefits of nanotechnology, but they have been reported to be more concerned than the public about certain issues related to environmental and long-term health impacts of nanotechnology (see Scheufele et al. 2008b). Lastly, decision-makers and science journalists are presumably typically rather well-informed. Yet they should always accept (/reject) any scientific development or technological innovation to a lesser (/greater) degree than experts do. This is hardly the case.

Much of the recent empirical research on the relationship between attitudes and levels of knowledge has been concerned with modern biotechnology. In Europe, citizen knowledge levels and attitudes have been studied in Eurobarometers and the PABE research project. The Eurobarometers have provided a basis for subsequent more elaborate analyses (e.g., Bonny 2003; Gaskell et al. 1999; Pardo et al. 2002; Pardo and Calvo 2006). Other studies include for instance Sturgis et al. (2005) who estimate what collective and individual opinions would look like if everyone was as knowledgeable as the currently best-informed members of the general public. (See also Midden et al. 2002; Martin and Tait 1992.) All in all positive correlation has been found in many studies (e.g., Eurobarometer 2008; Gaskell et al. 2006), but others report no correlation or an inverse correlation (Marris et al. 2001, 79; Bucchi and Neresini 2002, 261). Strong general conclusions about the relationship between the level of knowledge and attitudes are thus difficult to sustain. It has been suggested, however, that "empirical studies have, on the whole, found the relationship between formal scientific knowledge and attitude toward science to be significant and positive, though moderate in magnitude" (Sturgis et al. 2005, 33).

Two more remarks on the correlation studies. Correlation "explanations" are not sensitive to particular cases of attitude change. If attitudes get more polarized owing to more information as some studies suggest (see e.g., Marris et al. 2001, 79), individuals moving in opposite directions may cancel each other out in correlation studies. Besides ignorance, other factors have been proposed to explain the public controversy over GMOs in the EU. These include worldviews (esp. cultural cognition), sensationalist media, faltering trust in institutions, recent food crises, and actions of certain NGOs (see e.g., Bonny 2003; Gaskell et al. 1999; Pardo et al. 2002). In the light of these analyses it is probable that no single factor accounts for the resistance to food biotechnology, but that various factors are implicated and interrelated.

Although deficit explanations may lack strong empirical support (at least in the context of GMOs) and they appear to be rather unspecific and perhaps untenable in general, ignorance may account correctly to a large degree for opposition and mistrust towards specific scientific developments and technological innovations. If a person opposes GM foods only because s/he believes that they contain genes and that other food products do not, the opposition may be revised by explaining that all food ingredients contain genes. Genes are absent only from some processed food products, such as oils and sugars. This kind of a case is reported by Cook et al. (2004, 438). The moral of the story: there is nothing wrong with ignorance-based explanations *per se*. They presumably hold in many particular cases. In numerous others ignorance provides one relevant explanatory factor.

A more theoretical challenge—which has been stressed in the relevant literature (e.g., Einsiedel 2007, 6)—related to the third assumption is to unpack further the explanans, i.e., our understanding of ignorance. In the context of the deficit model, ignorance equates to the lack of scientific knowledge on a particular issue. This, however, leaves room for different interpretations (or perhaps more accurately possibilities). Ignorance may refer to the fact that a person does not have any factual beliefs in regard to the relevant subject matter. There might be non-conceptualized fears and superstition instead. Or alternatively a person might hold certain non-scientific beliefs, e.g., certain religious or ethical beliefs.[20] Another possibility is that ignorance refers to the fact that a person has unscientific beliefs, i.e., beliefs that go against state of the art knowledge in a particular field of science. These erroneous beliefs may then underpin opposition. Distinctions between factual and non-factual on the one hand, and scientific, unscientific and non-scientific on the other deserve more attention in this context.

Science Communication Remedy

The fourth assumption of the deficit model type of thinking is that the general public's knowledge deficit can be remedied by one-way science communication. In

[20] This is not to say that religious and/or ethical beliefs would preclude factual knowledge. In forming ethical beliefs (X is morally good/bad, right/wrong, desirable/acceptable/prohibited, etc.) the knowledge component is typically considered to play an important justifying role.

particular, scientists should communicate the facts to non-scientists. The aim is obviously not only to replace ignorance with knowledge, but also to mould negative attitudes into positive ones (see e.g., Bubela et al. 2009, 515; Dickson 2005). The assumption is nevertheless concerned more with adequate or effective ways of science communication than with the relationship between levels of knowledge and attitudes. Assumptions one, two, and three are presumed—at least in qualified forms.

This kind of "science pills" panacea to remedy the public's disenchantment with science was what the early critics of the deficit model were worried about. One obvious problem regarding this assumption is that people are not blank slates on whom science can be written. It does justice to cite Ziman (1991, 101) on the way he first put it.

> People do not draw on stable, if fragmented or ill-conceived, "models" of the world, along the lines of textbook accounts of scientific knowledge. The little they retain of what they were taught at school is overlain and supplemented by the diverse representations of science that they meet in the media and in many other aspects of life. What they pick up is not [sic] simply filtered version of formal scientific knowledge: its meaning is actively constructed by the processes and circumstances under which it is communicated and received. (…) The use that people make of formal knowledge in any particular situation depends on the needs of the moment and represents only one element in a complex and varied response. They not only rely heavily on the tacit, uncodified, but highly expert and rational knowledge that is shared in most work communities: they also engage with, select, or construct the scientific elements according to their own interests, involvement, personal and social histories, and other circumstances. (…) People do not accept passively the knowledge presented to them by scientific "experts."

However, as Wynne (1991, 116) further explains,

> the main insight here is that public uptake (or not) of science is not based upon *intellectual capability* as much as social-institutional factors having to do with social access, trust, and negotiation as opposed to imposed authority. When these motivational factors are positive, people show a remarkable capability to assimilate and use science or other knowledge derived (inter alia) from science.

Even if the general public's uptake of science was free from personal histories, interpretations, biases, and other contextual matters, simply educating people with the facts might not present an adequate mode of science communication for several reasons. The deficit model type of response does not appreciate the fact that many scientific facts are not simple, certain, or easily communicated. It also neglects a possible mismatch between what the public expects from science and what a scientist can legitimately tell them. Science typically provides estimates with confidence levels and intervals, i.e., in terms of probability. The public, in its turn, often wants to know whether or not a certain product (e.g., a GM food) is safe, whether or not there are harmful environmental effects related to its production, and if so, what is the exact extent and severity of these effects.[21] It is easy to slip into a conclusion that because the scientists are uncertain, they know nothing.

The attempt to mould attitudes does not seem to fare any better.[22] Whenever the negative attitudes in question are anxiety, hostility, and others with a lesser cognitive component, communicating the facts might not be helpful.[23] Even if I know that a particular kind of a snake is harmless, I might continue to get scared with every sudden appearance of the snake. Slovic et al. (2005) consider risk to be perceived and acted on in two ways. "Risk as feelings" refers to individuals' fast, instinctive, and intuitive reactions to danger. "Risk as analysis" brings logic, reason, and scientific deliberation to bear on risk management. (Ibid.; for the two-system view see Kahneman 2003.) If this holds in regard to negative attitudes (with a lesser cognitive component) towards specific instances of science and technology more generally, an effective way to change or affect these attitudes may require different kinds of science communication depending on the balance between reason-based and other opposition.[24] Certain survey results might be interpreted to provide some, if rather limited, support for this kind of a view. As noted, Europeans show more negative attitudes towards GMOs than do people in the US. Ignorance does not provide a satisfactory explanation for the opposition. The mean score in textbook knowledge was found to be higher for Europe. However, the mean score for threatening images of food biotechnology in the US was lower than in Europe. This might in part explain the opposition. (See Gaskell et al. 1999.)

Even when reason-based opposition is concerned, explaining a scientific development, a technological application, or a product in increasing detail might not be effective. The deficit model type of response misses the point that facts that are relevant for the evaluation of a scientific experiment, a technology, or a product may be different from scientific facts about the experiment, technology, or product in itself. Besides understanding the basics of the experiment or innovation, relevant information may include results of ecological, toxicological, and epidemiological studies, related legislation, surveys of public attitudes, and ethical analyses. The question is not only "who knows best?," but also "what knowledge is relevant and to what extent?." This might come close to what Hails and Kinderlerer (2003, 823)

[21] This mismatch might be a problem especially in the context of the study of complex systems such as GM agriculture and climate change.

[22] It might be useful to distinguish between two types of knowledge, namely "knowledge that" (i.e., propositional knowledge) and "knowing something" (knowledge as familiarity, being able to recognize or identify something or somebody). A fear of the unknown in many forms is common for human beings. (Natural curiosity, however, pulls somewhat the opposite direction.) Now if fears and other opposition are based on "not knowing" in the latter sense, communicating the facts might not be as useful as direct exposure to the particular technological innovation in question.

[23] Anxiety, hostility, and some forms of fear have somewhat lesser cognitive components in them than do other kinds of negative attitudes. Some forms of fear are instinctive, others are more cognitive. As an example of the latter I might be afraid of unemployment if that would result in a failure to pay my monthly mortgage repayments.

[24] It is difficult to say to what extent the public opposition is due to cognitive reasons, and I do not pretend to claim that the public would always be knowledgeable or rational in their opposition. The "yack" factor surely plays a role. Sometimes emotional responses may however provide useful knowledge or advice to us, e.g., as warnings of potential dangers and directing attention.

intend when they conclude that "the science behind GM is highly technical, but it is not necessary for members of the public to have in-depth knowledge of the science to form an opinion on the social and ethical implications." That is a good point, but it might be added that the better one understands the *relevant* facts the better are the premises for an assessment of acceptability of the experiment, technology, or product in question.

Related to this is the point that no purely scientific support or opposition (for a technological innovation, product, etc.) exists. "Scientific arguments" for or against something always include both scientific facts and non-scientific beliefs, specifically values.[25] In consequence they may fail because of getting the facts wrong, because of getting values "wrong," or because of getting both of them wrong. More generally, any rational judgment—i.e., a well-founded reason-based attitude—implies identification and weighing of the relevant facts. This is necessarily based on values.[26] As the deficit model type of thinking says that increase in scientific knowledge results in positive attitudes (which are in effect necessarily cognitive),[27] it presumes an extensive agreement about values that determine the issue of relevance. This is a questionable assumption. It may be precisely the values, not the science, that are the object of disagreements in many public controversies (see Hansen et al. 2003 in regard to food risks; Kahan et al. 2009 in regard to nanotechnology).

The issue of relevance is important not only in the context of public opposition and debates, but also within science in itself. Think about the knowledge of molecular biologists, conventional plant breeders, plant physiologists, evolutionary geneticists, ecologists, and social scientists in the context of genetic engineering in agriculture. In this regard Kvakkestad et al. (2007) analysis of scientists' views on the deliberative release of GM crops offers interesting insights. They report that scientists from different disciplines differ in their perspectives on the level of predictability, on uniqueness of risks, and on usefulness. As a result of this they suggest that it is "crucial that the policy makers include several disciplines when they ask for scientific advice on policies for GM crops." (Ibid., 99.) Sometimes

[25] The term "value" is understood here in a very general sense. Moral judgments—such as the belief that causing unnecessary pain is morally wrong—are one instance of them.

[26] To approach the issue of relevance from the opposite direction, the question is what normative conclusions a certain piece or a body of scientific knowledge grants. For seminal work discussing and questioning the "is"/"ought" gap see e.g., Foot (1958), Frankena (1939), Searle (1964).

[27] The deficit model (type of thinking) does not specify whether or not the basis of negative attitudes is cognitive or non-cognitive. Opposition may be based on reasons or on other factors. Nor does it specify whether the lack of scientific knowledge refers to one's having no factual beliefs on the subject or to scientifically mistaken (i.e., unscientific) beliefs. It is sensible to assume that both are included. Moreover, in its basic form the deficit model does not say anything about the presence or absence of non-scientific beliefs, such as ethical beliefs, certain religious beliefs, and superstition. The deficit model, however, implies that the positive attitudes towards or support for (specific instance of) science and technology arising from uptake of information are cognitive. This follows because it is scientific knowledge that makes the difference. Attitudes change from negative towards positive owing to scientific knowledge. Either (1) scientific knowledge "causes" the change from non-cognitive opposition to cognitive support, or (2) scientific knowledge adds in factual beliefs where there were previously none and results in cognitive support, or (3) earlier scientifically mistaken beliefs are revised in the light of new scientific information and this results in cognitive support.

scientists of a particular discipline dismiss the results or critical comments of their colleagues (from another field) as being irrelevant or based on junk science, false assumptions, and "ignorance." In certain cases this is well-founded, in others it is misplaced. "Rhetoric of ignorance" can be powerful to frame relevant questions and to downplay uncertainties, unfavorable results, and even certain domains of knowledge. In her *Nature* paper on GM crops research Waltz (2009, 27) explains that "[t]hese strikes are launched from within the scientific community and can sometimes be emotional and personal; heated rhetoric that dismisses papers and can even, as in Rosi-Marshall's case, accuse scientists of misconduct."[28] This kind of "deficit thinking" within science may work as a hindrance to interdisciplinary collaboration and advances in fields where co-operation and open discussion between many disciplines are necessary.

Discussion

The deficit model type of thinking seems to be persistent. Despite being continuously discredited (at least by social scientists) and supposedly abandoned (i.e., not many people would explicitly subscribe to it), it remains a common mindset among many scientists and decision-makers. This arguably colors science communication and policies, and it may account for some failures to establish genuine two-way public engagement mechanisms (see e.g., Bubela et al. 2009).

The deficit model type of thinking takes many forms. One obvious question is then to what extent, if any, its different instances share a common core. This analysis identified four interrelated assumptions. Each assumption may vary in regard to its level of generality (or qualifications) and strength. The attribution, connection, or remedy may apply always, most of the time, sometimes, or in at least one case.[29] As noted, what it means to be ignorant and to have negative attitudes can be interpreted in various ways. Etc. A lesson: different instances of the deficit model type of thinking need to be evaluated individually. The four-assumption analysis provides a framework for doing this. Against the common mantra of rejecting the deficit model altogether, this paper points to the need to better distinguish between cases in which these type of explanations and assumptions are warranted and cases in which they do not hold.

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[28] Another issue is that the freedom of scientific research on GMOs may be compromised in an undesirable way by intellectual property rights of industry as suggested by the editors of *Scientific American* (Editors 2009). Some seed companies have veto power over the work of independent researchers on their crops.

[29] The connection between certain assumptions may seem—and in fact be—somewhat contradictory. An example: if one totally lacks understanding and knowledge about something, it might be questioned how s/he could have negative attitudes towards that particular thing because s/he obviously fails to identify the thing in question.

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