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Putting Sociology First—Reconsidering the Role of the Social in 'Nature of Science' Education

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Abstract Contrasting two examples from 2005, a creationism-trial and a recent textbook, the article shows two different ways of employing social considerations to demarcate science from non-science. Drawing conclusions from the comparison, and citing some of the leading proponents of science studies, the paper argues for a novel perspective in teaching nature of science (NOS) issues, one that grows out of sociological and anthropological considerations of (scientific) expertise. In contrast to currently dominant epistemic approaches to teach NOS, this view makes it possible to incorporate epistemic and social norms in a unified framework that can alleviate presently problematic aspects of NOS modules, and can help students appreciate science as a privileged form of knowledge-production without becoming scientistic. A pilot module to carry out the above is presented and assessed, showing that a broad sociological starting point is closer to the lifeworld of students, and that traditional epistemic considerations need not be compromised.

The paper argues for the embedding of epistemic goals in Nature of Science (NOS) education in a sociological framework (Sect. 5), and describes as well as evaluates one such module (Sects. 6, 7). Before outlining the objectives and the rationales for this approach, however, I will show that sociological considerations play an increased role in court decisions concerning the status of creationism (Sect. 1), and that recent textbooks fail to utilise this asset when teaching NOS (Sect. 2). Although in the science education literature sociological approaches elicited little positive response (Sect. 3), recent trends in science studies and in the sociology of science provide frameworks which display an attitude towards science that should be welcome even by researchers and educators who stress traditional considerations in NOS (Sect. 4).

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1 Prelude: Lessons from Creationism

The 139-page-long argument supporting John E. Jones III, District Judge's decision in the Kitzmiller/Dover case (from now on referred to as KD),[1] the most recent of a series of trials on the teaching of creationism in the USA, is a highly significant example of philosophy of science in practice. In the document different views on the Nature of Science (NOS) are explicated. Reading it carefully, one can draw some important lessons concerning NOS issues that have relevance for teaching about science in the classroom.

As with creationism-trials generally, the question again was whether creationism, or intelligent design (ID) in its new disguise, is (a) a religious movement and/or (b) a scientific enterprise. In US Court rulings the main issue is usually (a), and the religious nature of the movement is used to dismiss creationism. For the present paper—and for science education in general—the second question is of greater importance. As in many similar cases, expert witnesses differ in their views concerning NOS, so these trials provide excellent opportunities where different views on science and on what counts as science (i.e. demarcation criteria) can be explicated and evaluated under significant pressure. What positions should or could expert witnesses testifying about the nature of science take?

To better appreciate Judge Jones' decision, below I contrast the recent KD case with the earlier, 1981 Arkansas Creationism trial,[2] focusing on the role of social criteria in demarcating science from non-science. During his 1981 hearing, expert witness Michael Ruse listed a number of epistemological desiderata (and no social ones) that distinguish science from non-science. These included the use of law to effect explanation, the ability to predict hitherto unknown phenomena, and the claims that a theory should be testable, must be falsifiable, and has to be tentative by necessity (Ruse 1982). Going through the criteria, Ruse confidently stated that creationism is not science, as it fails to live up to the criteria he listed. The Judge in this "balanced treatment" case decided against the creationist side, but the testimony was not received unanimously by other experts. Although similar criteria for demarcation surface in textbooks even today (see more in Sect. 2), already in the 1980s many found Ruse's position unacceptable and unsupported by empirical studies on the development of science.[3]

One of the critics, Larry Laudan claimed that as creationism made many testable statements, and the theory changed at several points, Ruse's position was untenable. After listing a number of criticisable moves, he concluded that creationism is not non-science, but simply bad science. As he summarised the case:

> The victory in the Arkansas case was hollow, for it was achieved only at the expense of perpetuating and canonizing a false stereotype of what science is and how it works. If it goes unchallenged by the scientific community, it will raise grave doubts about that community's intellectual integrity. … No one familiar with the issues can really believe that anything important was settled through anachronistic effort to revive a variety of discredited criteria for distinguishing between the scientific and the nonscientific. … this time, the pro-science forces are defending a philosophy of

[1] *Tammy Kitzmiller, et al. v. Dover Area School District, et al.* 2005 WL 578974 (MD Pa. 2005). For the memorandum opinion see: http://www.pamd.uscourts.gov/kitzmiller/kitzmiller_342.pdf.

[2] *McLean v. Arkansas Board of Education*, 529 F. Supp. 1255 (E.D. Ark. 1982).

[3] While I only analyse Laudan's response, other critics included Richard Burian, Phil Quinn, and Ernan McMullin, the latter reportedly stating during the trial that "Ruse is setting our case back twenty years" (Hull 2001, p. 429). These views were seen outdated by many already a quarter century ago.

> science which is, in its way, every bit as outmoded as the "science" of the creationists (Laudan 1982, p. 19).

Thus epistemic criteria to decide what science is and what it is not have already been criticised in the aftermath of the 1981 trial.[4]

As opposed to the 1981 trial, in the recent KD case social considerations played a significant role in grounding the Judge's decision. Judge Jones went further than listing decontextualised, purely epistemic criteria, and relied on social criteria, too, to argue for the position that creationism is not science.[5] Where he argued that ID is not science (KD, pp. 64–89), sociological considerations played a surprisingly significant role in differentiating science from non-science—contrary to earlier rulings. The judge cited statements made by NAS and AAAS, major scientific organisations in the USA. Without critically investigating the claims these organisations made in support of their position concerning ID, the judge relied basically on the status of these institutions in society. This meant that the judge took their views for granted due to the NAS being the "most prestigious scientific association in this country" (KD, p. 69), and the AAAS the "largest organization of scientists in this country" (KD, p. 70). Not only *ad verecundiam*, but also *ad numeram* arguments have been used: "an overwhelming number of scientists, as reflected by every scientific association that has spoken on the matter, have rejected the ID proponents' challenge to evolution" (KD, p. 83).

What is more, a significant part of the reasoning was closely connected to social factors, as the Judge investigated "out of an abundance of caution and in the exercise of completeness" additional arguments (KD, p. 71). Investigating the nitty-gritty details of one of the most important books on ID, *Darwin's Black Box* by Behe (1996), the judge again and again, whether discussing the bacterial flagellum or the blood-clotting system, referred to articles that (1) contradict Behe's argument, and (2) are peer-reviewed.

The same issue reappears in the final section of the argument: "A final indicator of how ID has failed to demonstrate scientific warrant is the complete absence of peer-reviewed publications supporting the theory" (KD, p. 87). To cite a crucial passage in extenso:

> Expert testimony revealed that the peer review process is "exquisitely important" in the scientific process. It is a way for scientists to write up their empirical research and to share the work with fellow experts in the field, opening up the hypotheses to study, testing, and criticism. In fact, defense expert Professor Behe recognizes the importance of the peer review process and has written that science must "publish or perish." Peer review helps to ensure that research papers are scientifically accurate, meet the standards of the scientific method, and are relevant to other scientists in the field. Moreover, peer review involves scientists submitting a manuscript to a scientific journal in the field, journal editors soliciting critical reviews from other experts in the field and deciding whether the scientist has followed proper research procedures, employed up-to-date methods, considered and cited relevant literature and generally, whether the researcher has employed sound science. The evidence

[4] Similar issues have been raised in the debate over Steve Fuller's expert testimony in the KD case. See for example the debate on his testimony on the HOPOS list server: http://www.listserv.nd.edu/archives/hopos-l.html, which was the major focus of the November 2005 discussions.

[5] Obviously arguments that can be considered epistemological or even ontological have not been dropped completely. Thus the unscientific notion of supernatural causation and other religious aspects of the movement were highlighted, like Behe's statement that "the plausibility of the argument for ID depends upon the extent to which one believes in the existence of God" (KD, p. 28). But these were mostly used to argue that ID is religion, and less to support the claim that ID is not science.

> presented in this case demonstrates that ID is not supported by any peer-reviewed research, data or publications (KD, p. 87, leaving out the references in the original).

Let's see what the scientific method is for the Judge, according to which ID is *not* a science. The traditional epistemic criteria, like the ones that abounded in Ruse's testimony, play a less significant role. Instead, the Judge mentions a number of social norms (that serve epistemic goals as well). These leave scientists, members of the scientific establishment (a social institution), to decide upon what counts as "proper" procedures, "up-to-date" research methods, etc. in science. The social and historically developing, emergent norms of the scientific establishment are "exquisitely important"—yet are not explicated. What appears in peer-reviewed journals, what is endorsed by leading scientific organisations, is science. Movements and ideas that fail to meet these criteria are not scientific. What science is or what it is not is decided on the basis of demarcation criteria that are primarily sociological, and not upon criteria that directly utilise epistemological or traditional methodological considerations. This stress on the sociological aspects of science and on norms becomes even more pronounced in the concluding part of the argumentation in this section:

> After this searching and careful review of ID as espoused by its proponents, as elaborated upon in submissions to the Court, and as scrutinized over a six week trial, we find that ID is not science and cannot be adjudged a valid, accepted scientific theory as it has failed to publish in peer-reviewed journals, engage in research and testing, and gain acceptance in the scientific community (KD, pp. 88–89).

Why does the judge rely on these criteria and not on well-known epistemic criteria like falsifiability, predictivity or explanatory power, criteria that served well (though were heavily criticised) in the 1981 trial?

One possible answer is that the use of these criteria became problematic, as they have been used by *both* parties in the rhetorical arms-race that characterised the last decades. Intelligent design, as a *Nature* editorial has stressed "was itself designed, in large part, to get around earlier court decisions that barred creationism from the classroom" (Editorial 2005).

Let us see how a few years back Michael J. Behe, one of the most well-known proponents of ID wrote about ID. "Some reviewers of *Darwin's Black Box* [his book, (Behe 1996)] have objected that intelligent design is not falsifiable. I will argue that it is. … In fact, intelligent design is open to direct experimental rebuttal" (Behe 2001, pp. 695, 697). Worse still, epistemic criteria are often turned against mainstream science: "The point here is that ID could potentially be falsified by the results of a single series of rather straightforward experiments … Darwinian evolution can't. … A strong point of intelligent design is its vulnerability to falsification. A weak point of Darwinian theory is its resistance to falsification" (Behe 2001, p. 698). Behe also claimed that "any explanation which rests wholly on empirical evidence and basic logic deserves the appellation 'scientific'…. Therefore, I consider design to be a scientific explanation (whether ultimately correct or not)"[6] (Behe 2001, p. 702). Such views, appearing in peer-reviewed journals, show the possible dangers of court-room decisions based on these much debated epistemic criteria.

A second possible answer is that epistemic criteria put an unreasonable burden of proof on science, if the decision is based on them. As has been known for a number of decades, even "proper" science fails to clearly live up to these criteria. And this leads to the third possible answer. In spite of sustained efforts, good science or science in general does not seem to be

[6] Here Behe utilises what Popper himself has said about Darwinian evolution, i.e. that it is a "metaphysical research program" rather than a scientific theory (Popper 1988, p. 147). This nicely illustrates how decontextualised demarcation criteria become rhetorical resources.

clearly separable from bad science or non-science, based on epistemic criteria. The individual epistemic criteria (like Popper's criterion of falsifiability) have long been neglected. More recent attempts either operate with a loose list of epistemic desiderata (Bunge 1982; Thagard 1978) or incorporate historical and/or sociological criteria, too (Derksen 1993). While many hold that satisfactory lists of demarcation criteria are still in principle attainable, and that in due course the scientific community as well as the group of experts studying scientific knowledge-formation (historians, philosophers, sociologists) could agree on such a list, after a few decades of desperate search many experts abandoned their quest, believing that it is not possible to provide a set of sufficient and necessary conditions that could demarcate science from non-science. As yet no consensus has been reached on either the "epistemic-social-psychological profile" of the pseudo-scientist or pseudoscience.[7]

These three reasons can explain why it was a good choice to rely heavily on sociological criteria to define what is science and what it is not. To repeat, as the KD case shows, if one publishes in peer-reviewed journals, carries out research and testing that is accepted by the scientific community, then one does science. Surprising as it may sound, to defend the boundaries of science, sociology can be a useful ally—at times more than traditional epistemology, with its outdated notions of falsification, and vague definitions of simplicity, explanatory power, or testability.[8] This does not mean that epistemic criteria are valueless, or that the social norms referred to have no epistemic significance.[9] It simply means that the epistemic norms are embedded in a social system. They are guarantees that science as a social institution can produce knowledge.

2 Sociology in "Nature of Science"

Is this great potential of sociological insights utilised in courses that teach students about the nature of science?[10] To contrast the 2005 trial, I first investigate in some detail a book

[7] In recent decades attention turned from proclaiming what the true demarcation criteria are (or should be) to investigating how they become (in a certain period and for a specific audience) criteria that are seen as separating good from bad science. Studies have shown the enormous flexibility of these boundaries and of the use of resources. For examples see Gieryn (1999), Mellor (2003), Taylor (1996), Wallis (1979). Importantly, while I argue that "sufficient and necessary conditions" for something to qualify as science cannot be found using epistemic criteria, I do not claim that such expectations can be met using purely social criteria. Given enough time and effort, mimicking most of these desiderata seems also possible. Also, on a closer look, sociological approaches for demarcation face similar problems as epistemic ones (McClenon 1985). Any attempt to define terms like "science", "religion", or even "chair", will either include items generally thought to be excluded or (and) the other way around. Instances of what we call science stand in relations of—*pace* Wittgenstein—"family resemblance". What I argue for is that a broad set of criteria needs to be employed, and these should include social ones.

[8] Needless to say, the recent interest in creationism also resulted in novel approaches to epistemological problems or even in novel philosophical insights: Elliott Sober has given an exemplary approach to such questions in Sober (2000), or in his recent contribution to Dembski and Ruse (2004), and this attitude is applauded in Lewens (2006).

[9] Importantly, however, many of the 'old-fashioned' epistemic criteria are *independent* of empirical success, so if the *differentia specifica* for science is empirical success (differentiating it from e.g. pseudoscience), the use of these criteria becomes problematic. As a result, when analysing theory-choice, authors like Solomon group simplicity etc. among the non-empirical decision-vectors (Solomon 2001).

[10] That this ruling is of interest for science education has clearly been recognized e.g. in Bottaro et al. (2006), but that article only investigates the special place immunology played in the trial, and not the social criteria to demarcate science. Also, as there are many arguments not to teach creationism at all and few in support of it (Pennock 2002), In line with the majority of educators, I will not consider the case where creationism is to be taught *as* science.

published the same year. The textbook "Theory of Knowledge" was written by van de Lagemaat (2005) and published by Cambridge University Press. It prepares 17–19-year old students for the International Baccalaureate examination, a worldwide network of schools with an examination centre in Geneva.[11] A separate chapter on natural sciences discusses what is generally considered suitable and adequate teaching material in a nature of science course, including philosophical, epistemological, and sociological considerations. The sequence of subheadings, however, shows where the author's preferences lie. Science and pseudoscience are the first topic tackled after a short introduction. This is followed by a few pages each on the scientific method, problems with observation, testing hypotheses, the problem of induction, falsification, finishing with science and society, and science and truth. I investigate in more detail the part on pseudoscience, and the one on society.

The book clearly stresses that demarcation criteria are needed for distinguishing science from pseudo-science (van de Lagemaat 2005, p. 223). The demarcation that "distinguishes a pseudo-science is that it claims the status of science while lacking its substance". This recalls attempts like Bunge's: "pseudoscience is a cognitive field advertised as a science though failing to be one" (Bunge 1982, p. 378). However, instead of listing the rich and detailed set of criteria that characterise Bunge's work (or other attempts from recent decades) to operationalise this definition, the writer falls back on testability as the main criterion, and stresses that pseudo-science protects its statements from testability by being vague and/or using ad hoc explanations.

Needless to say, testability as the demarcating criterion is inadequate—one simply has to look at the history and philosophy of science. Darwin's theory of evolution failed to provide anything but utterly vague mechanisms for the emergence of variations, and the Bohr model of the atom used ad hoc assumptions concerning the shape and positions of the molecular orbits. Moreover, one can recall Behe's claim, mentioned in Sect. 1, that ID *is* testable. Even if these examples are found wanting, it has clearly and forcefully been argued that no sufficient or necessary epistemic criteria of demarcation can be given (Laudan 1983). None of the sociological criteria surface in this part of the chapter that clearly play an eminent role in Judge Jones' argument. The contrast is telling. The position on demarcation is closer to the view put forward by Ruse in 1981—and found wanting already at that time by the scientific community. So where does the social dimension appear in this approach, and how is it employed to enrich the students' understanding of science?

After introducing students to inductivism and falsification, and showing that they cannot "give us an adequate account of the nature of science", a third perspective is introduced, that of Thomas Kuhn,[12] and issues in science and society are discussed here. The problem of rationality in the Kuhnian framework is investigated, and social and individual (i.e. psychological) factors are listed. These include "ambition, vanity, envy, … public recognition, … the military's desire for power and big business's desire for profit" (van de Lagemaat 2005, p. 242). We also learn that "ambitious scientists may be attracted to areas in which there is plentiful supply of money to fund research", etc. Individual and social factors are not seen as epistemically important resources and as assets, but as at the least only directing research interest, and at the most hindering progress. The only "positive"

[11] The IBO was founded in 1968, and has around 1,600 schools (August 2005) in 121 countries (more than 1,300 teach the Diploma Programme to approximately 200,000 students).

[12] The division of science into normal and revolutionary is fairly correctly described, but a figure (8–10 on van de Lagemaat 2005, p. 241) is used to show "reality according to Kuhn", with time on the X and progress on the Y axis, where the smooth slope of progress during normal science is interrupted with vertical lines (no time, huge progress) standing for revolutions. This is certainly not what Kuhn believed, as it is exactly between paradigm-shifts that progress is an empty concept.

role for a broadly viewed "social" element is the self-correcting mechanism of science—the cases mentioned are the Lysenko affair and cold fusion. Apart from these, however surprising it may appear, the realm of the social and of the epistemic seem to have no intersection.

Assessing Kuhn's position, the writer falls back to a pre-Kuhnian view of science. A long quote from Popper is cited on the discussion of normal science. It stresses that we ought to be sorry for the "'normal' scientist" and that he "has been taught badly". But what is the aim of this quote? It can hardly be used to argue that Kuhn's view is wrong. It seems that the evaluation of the whole Kuhnian challenge is sidestepped. In his assessment of scientific revolutions, the writer asserts the continuity of scientific development, by claiming that Newtonian mechanics is a special case of Einstein's theory of relativity. As for the rationality of paradigm-choice, he states that "we should distinguish between the *origin* of a belief and its *justification*. For the origin of a belief is not of any great relevance to science. All that matters is that the belief should be *testable*. If it is confirmed by experiment, then we provisionally accept it; if it fails then we reject it" (van de Lagemaat 2005, p. 244). The Kuhnian lessons thus seem to be obscured rather than accepted or properly criticised, and the problematic discovery-justification dichotomy is established in a very naïve form (Schickore and Steinle 2006).

The structure of the book by van de Lagemaat is not untypical of the genre. To take another example, Woolman, the writer of another recent textbook, ends his introduction with the following sentences "Much has been written by scientists, historians of science and philosophers about the nature of scientific knowledge. The 'scientific method', the process by which scientific knowledge is acquired, has been scrutinised so intensively that every attempt to define it has led to counter definitions and redefinitions and reservations" (7.1). In spite of this, three subchapters follow on 'The scientific method'. These discuss popular views and inductivism, falsificationism, and finally, scientific revolutions (Woolman 2000). Even though the demarcation problem is not in focus, this sequence (starting from epistemic considerations and ending with Kuhn and the social dimension) does not seem to show a radically different approach to NOS. In fact, it is hard to find high school textbooks with radically different structures. A comprehensive analysis of Nicholas Alchin's work (Alchin 2003a, b) is given in Zemplén (2007a), and more books could be listed and analysed in detail—*ad nauseam*.

In fact, there are many more problematic examples: the ones I picked are well-written and well-organised textbooks. I do not intend to evaluate these examples, but I hope the above short description suffices to support the conclusion that the insights from the last 40 years of sociology of science, of social studies of science, and of the sociology of scientific knowledge are not present and utilised. And not only in the specific question of demarcation are they neglected, but their potential for a better understanding of the NOS is also overlooked. Instead, the social dimension is introduced because the simplistic criteria of falsification, induction, and deduction are found wanting. But when it comes to evaluating e.g. a Kuhnian approach, the writers often return to the very view of science (a badly distorted type of positivism) that they themselves found inadequate and which necessitated the introduction of a sociological perspective in the first place.

3 Is Upside Down the Right Way Up?

Section 1 showed that in today's courtroom sociological considerations play an important, and, if compared to earlier trials on creationism, an increasingly important, role.

The textbook examples, on the other hand, illustrated that these insights are generally not utilised in the context of the demarcation problem and fail to surface in courses or modules on the nature of science. Looking through a number of courses, there is a noticeable trend. They generally start with "philosophical" or epistemic criteria, stress some simplified "scientific method", and the social considerations only emerge at the end of the chapters or courses, where they are usually used to *weaken* claims on the applicability of the method. "…let us not forget that scientists are humans" (Alchin 2003b, p. 22). So epistemic criteria are not embedded in the social, but are rather juxtaposed to it. Sociology in these books is used to distance the normative view of science from a descriptive perspective, the "how science should work" from "how science really works in our society". Thus, naturally, seeing science as a primarily social phenomenon and subscribing to a social constructivist view are generally seen as moving away from the pristine clear norms of science and entering the messy politics of knowledge-production. Stressing the importance of the social for these writers seems to imply relinquishing the hope of demarcating between science and non-science, and (at the end of this slippery slope) endorsing relativism.

This last mentioned fear of extreme relativist positions motivates many of the negative views about the possible role of (constructivist) sociology (of science) in the classroom (Irzik and Irzik 2002; Izquierdo-Aymerich and Adúriz-Bravo 2003, p. 28; Kragh 1998; Solbes and Traver 2003). One such sceptic is Slezak, whose criticism is mostly based on the sociology of scientific knowledge, i.e. the Strong Program (Slezak 1994). But is this really a valid concern? The ID court case suggests that embracing at least some social criteria by no means equals endorsing relativism. And Douglas Allchin has already argued that it is possible to escape the "monstrous Scylla of unbridled scientism" as well as the Charybdis of relativism when using sociology of science, and that it "should be rated E: Essential for Everyone" (Allchin 2003). While not following Allchin's classification of sociological approaches,[13] I will argue in the next section that the often still prevailing "bad press" for sociological approaches among science educators—which might be due to the distorting transmission process that controversial ideas often fall prey to—is not warranted. Such distortion has been well documented for the case of logical positivism by Matthews, where he observes that "The embrace of Thomas Kuhn by science educators is as shallow and uninformed as the community's rejection of positivism" (Matthews 2004, p. 31). Above, I have also shown one example of Kuhn's mistreatment. But for the problem of demarcation criteria, Matthews's conclusion can easily be rephrased: the embrace of outdated epistemic criteria in NOS is as problematic as the community's rejection of and disregard for sociological insights.

As an increasing number of researchers from the community of science-studies and sociology of science explicitly state, sociology should not be considered as opposing science or the scientific world-view. I will show through a number of recent examples that even for writers who for long have been involved in the critical appraisal of scientific

[13] Here and in the following I will use the term "sociological" in a rather loose sense. The reason is that the rather limited form in which these insights can appear in the classroom does not necessitate the strict separation of the very different streams in sociology. But it will be quite evident from the context which movements are implied in the discussion. Another reason why the traditions are not separated is to avoid "gut-feelings" and the general attitude that approves of structural functionalist or Mertonian sociology and automatically rejects e.g. SSK approaches (Solbes and Traver 2003).

achievements, the tides have turned.[14] Based on these views, in Sect. 5. I investigate the possibility of a sociologically-focused module on NOS, and will argue that it is a viable alternative to the ones discussed previously. Before this, however, let us take a look at the positions of some of the leading figures in the science-studies movement: historian Steven Shapin, sociologist Harry Collins and science studies whiz-kid Bruno Latour.

4 Turning Tides, Waves and Shocks in Science Studies

Bruno Latour is certainly one of the most influential and controversial figures of the science-studies movement, a varied and loose movement that emerged after the "Kuhnian revolution". This historical turn, which of course was involved more people that I could list here (among them Toulmin, Polanyi, Hanson, Lakatos, Feyerabend, and many others) resulted in, among other things, the emergence of sociological approaches that also attracted many traditional historians of science. Following this social turn, science studies became a diverse and flourishing field, and after the naturalised Strong Programme in the Sociology of Knowledge (Bloor 1976, 1991), the floor was open for more and more radical social constructivist and relativist approaches. As the attention shifted from the traditional interest in scientific knowledge towards the study and exploration of scientific practice, the researchers were 'overwhelmed' by what they found. Important debates tackled the possible approaches to the epistemological issues in science-studies (see e.g. the "epistemological chicken" exchange), a good summary of which can be found in Part 2 of Pickering (1992). As a result, to use Pickering's term, a more radical 'posthumanist' approach detached itself from the traditional, sociology based 'humanist' tradition. This new approach put much more weight on the study of material culture, as irreducible to either knowledge or social relations (nonhuman agency was thus seen as playing an important role), and treated the social roles and relations themselves as constituted and transformed in scientific practice (Pickering 2007).

Latour's work belongs to this more radical strand of science studies. And while his position constantly changes—a fact that he applauds and critics condemn (Bloor 1999; Latour 1999)—and his language verges on the bombastic, his recent writings show a markedly positive attitude towards scientific achievements, and a conscious distancing from the "debunking" that science-studies is often purported to be guilty of. To quote Latour's "The last critique", his recent views are explained as follows:

> I am not trying to reverse course, to become reactionary, to regret what I have done. My argument is that a certain form of critical spirit has sent us down the wrong path, because of a little mistake in the definition of our main target. The question was

[14] Of course an obvious counterexample is Steve Fuller's testimony in the Kitzmiller–Dover case, as witness to the creationist side. But there are several reasons for not dealing extensively with this in detail: (1) most of the HPS and STS community did not approve of Fuller's decision (Cole 2006, p. 857; Edmond and Mercer 2006, pp. 849–851; Lambert 2006, pp. 839–840; Lynch 2006, pp. 823–824); (2) Fuller's main aim was not to legitimate creationism, but to legitimize (his view of) science studies; (3) Fuller himself states that "I decided to participate simply after having read the expert witness reports as filed by the plaintiffs' lawyers. These struck me as based on tendentious understandings of the nature of science that would not have survived scrutiny on an informed listserv such as HOPOS-L, let alone the peer review process of a relevant journal. My critical eye was clearly informed by knowledge gained from the science studies disciplines, since I am not a known advocate of - or expert in - either IDT [Intelligent Design Theory] or Neo-Darwinism" (Fuller 2006, p. 827).

> never to get away from facts but to get closer to them, not fighting empiricism but, on the contrary, renewing it (Latour 2004, p. 18).

While his heralding of a "second empiricism" might feel like a more or less empty rhetorical move for some, one thing is clear: when it comes to defending scientific values from recent (all too often fundamentalist) critiques, Latour clearly positions himself and the discipline he contributed so much to. Discussing recent relativist movements, he states: "This is why, with some bias, I consider this field [science studies] so important; it is the little rock in the shoe that might render the routine patrol of the critical barbarians more and more painful" (Latour 2004, p. 19).

In the present situation—brought about not only by the Science Wars, but also by the creationist upsurge—, Latour sees his discipline as a legitimate and possible ally of science in the newly emerging tension between those working towards the scientific understanding of our natural and social environment and those pressing for wars, let they be cultural, science, or against terrorism (including those who aim to add 'deconstruction to this destruction'). The science studies scholar fighting hard for the recognition of science—this is certainly not what many educators or philosophers today think of when they hear about the discipline. But Latour's position is not unique.

From the other side of the science-studies divide, the more traditionally sociology-driven Harry Collins states something strikingly similar to Latour's ideas. Collins is well-known for his methodological relativism, but this by no means amounts to devaluing science: to see that not all relativism is all that bad, consider (Harré and Krausz 1996).

When announcing the "third wave" of science studies (Collins and Evans 2002), the authors start with a painfully pressing question for modern democracies: "Should political legitimacy of technical decisions in the public domain be maximized by referring them to the widest democratic processes, or should such decisions be based on the best expert advice? The first choice risks technological paralysis: the second invites popular opposition" (Collins and Evans 2002, p. 236). This question motivates their search for an approach that can give decision-makers well-argued answers—and is not all that far from the problem of demarcation. As decisions need to be made, sociology has to go beyond the convenient and canny strategy of giving pure descriptions of scientists' activities, and has to develop a normative edge.[15]

When Collins and Evans look back on the track record of the sociology of science movement in a somewhat rough history, they call their enterprise the "third wave". While the first wave was the "old" sociology that served the scientific establishment and did not dabble in epistemological questions, taking the knowledge-claims of science at face value without questioning its authority, the second wave focused nearly exclusively on the "extra-scientific factors", as "scientific method, experiments, observations, and theories are not enough" (ibid., p. 239). The second wave also aimed to dissolve categories that differentiated scientific knowledge and other forms of knowledge. *This* is the type of sociology of science that has met with strong criticism, anger, and intolerance from many scientific circles, denounced as relativist, deconstructivist and aimed against the scientific establishment. Already this reaction is, for Collins, the result of misunderstanding the aims of the sociologist of science. In other writings he observes a strange asymmetry when comparing the vehement reactions to a sociological explanation of scientific views (which society values highly) with a similar sociological explanation of a rejected group (e.g. the

[15] See Pels (1996), Scott et al. (1990) on how avoiding normativity has been seen as problematic for quite some time within the science-studies community.

belief and actions of Nazis before and during World War II). The first is portrayed as an attack, the second as a defence of the views to be explained.

> Whether a sociological explanation is seen as an attack on or a defense of a set of beliefs and actions is itself relative to the valuation of those beliefs and actions within the group considering the explanation. Sociological explanations are seen as attacking those who hold positively valued beliefs and engage in the corresponding actions and defending those who hold negatively valued beliefs and engage in those corresponding actions (Collins 2001, pp. 157–158).

So already much of the "second wave" sociology of science is, as Collins claims, not guilty of many of the charges that have repeatedly been brought up against the movement.

But the third wave goes further. Collins and Evans leave behind the purely descriptive aims of the second wave, and pursue active participation in decision-making: "and this will allow prescriptive, rather than merely descriptive, statements about the role of expertise in the public sphere" (Collins and Evans 2002, p. 240). Therefore, even though sociological approaches have been equated with an attempt to *replace* epistemological questions with social ones, the third wave is thoroughly sociological yet brings back epistemological considerations. It attempts to lay the foundations for a *normative* theory of expertise. This is partly employed by Collins and Evans to find a new place for sociology of science. In this envisioned approach scientists are experts that interact with other groups of experts and the public. At the same time, sociologists and other analysts of science are also experts in areas that at times can help in public and technical decision making, and can provide prescriptive statements about the nature of expertise.[16] To show that this approach is by no means untypical today, it is enough to cite the editor of one of the leading journals of the field. As Michael Lynch stated recently: "I believe that it is fair to say that there is a strong trend in S&TS [science and technology studies] circles toward advocating some sort of normative engagement in techno-scientific politics" (Lynch 2006, p. 820).

While Latour is willing to put to use his resources in the fight against "critical barbarians", Collins offers the expertise of sociologists to develop a normative theory of expertise that can secure the positions of science in society without being scientistic. But is it important to accept the friendly hand from sociology of science and science studies? Even if sociologists are willing to take sides and support scientists against movements like ID, do scientists and science educators need this friendly hand?

Let me give an example where underestimating the significance of the social leads to shallow results or even blunders, depending on how one judges the—at times near desperate—attempts to be able to say "something true" about science. Recall the expert consensus statements that include "truths" like: "Scientific knowledge while durable has a tentative character", "Scientific ideas are affected by their social and historical milieu.", "The history of science reveals both an evolutionary and revolutionary character" (see e.g. McComas et al. 1998, p. 513). The ambiguity of these statements has been pointed out in science education literature (Good and Shymansky 2001), and they have been called "irresponsibly vague, if not self-contradictory" (Allchin 2003). But to my knowledge a crucial (and further) problem has not yet been addressed in these discussions: the social dimension.

[16] For a critique see Jasanoff (2002). Her critique, however, does not rule out using the approach in science education. Even if simplified (Jasanoff's critique rightly points to this weakness), the model is one of the few approaches that take into account political factors and the role they play in decision-making, yet appreciate scientific consensus-building as an epistemically different activity.

Whatever list of statements an expert community in science or science education can come up with, different social groups, e.g. members of a scientific organisation, advocates of creationism, faith-healers or theoretical physicists can use them for very different purposes, to convey different ideas. As humans, we use our social skills to evaluate statements: acceptance of a statement seems to be dependent on *who* states something about science, the context and *the people stating them* can radically change what the statement is believed to imply. To show this, let us turn to our third example from science studies.

The social historian of science, Steven Shapin dramatically illustrated in a mini-hoax (Shapin 2001) that even scientists use their social skills when evaluating statements about science. Shapin collected a number of statements, this time not ones that are believed to be true, like the statements of the expert consensus, but ones that are generally treated as "antiscientific". The list included statements like: "There is no such thing as the Scientific Method", "Scientists do not find order in nature, they put it there", "New knowledge is not science until it is made social", and others, generally associated with constructivist and sociological approaches (Shapin 2001, pp. 99–100). Sentences like these have often been cited to argue for the dangerousness of social constructivist views. Shapin, however, after the provoking list on the nature of science discloses his informants: they include Nobel-prize winning physicists, biologists, such as Peter B. Medawar, Albert Einstein, Niels Bohr and others, but none of the feared social constructivist sociologists or postmodern theorists who have been blamed as responsible for much of the anti-science sentiment among the public. Shapin used the examples to show and argue that

> it cannot be the claims themselves that are at issue, or the claims themselves that must proceed from ignorance or hostility. Rather, it is *who has made* such claims, and what motives can be attributed – plausibly, if often inaccurately and unfairly – to the *kinds of people* making the claims (ibid., p. 101).

As very few people see Einstein or Medawar as responsible for the spreading of anti-science views, the example highlights the importance of social considerations when evaluating *any* statements about science. No expert committee can decide who will cite their statements and for what reason. So while Shapin's list contained sentences that looked unsuitable until the informants were disclosed, a committee's list of suitable statements on science—prepared with the best intentions—can easily appear unsuitable when used by certain groups. In fact, many similar statements have already been used by ID supporters in their fight against evolutionary theory.

So far I have shown the increasing role social criteria play in a legal case concerning the boundaries of science and that this potential has not been recognised and utilised in teaching students about the nature of science. I also showed that sociological approaches need not be seen as devaluing science and scientific achievements: Instead they can be used to form the basis of a well-informed view about science. The playful but meticulously documented hoax by Shapin drew attention to the general neglect of taking social facts into consideration when the nature of science is discussed. Needless to say, very little of these insights have entered the Science Wars, and, even more importantly for the present purposes, the area of science education. This is true not only for textbooks and classroom-exercises, but also for publications in science education. To put an end to this neglect and answer the question asked earlier in this section, science educators should take the hand offered by social-studies of science. Once it is accepted that the role of the social deserves more attention in NOS than is generally seen today, the question emerges: is it doable? Are high school students ready for this approach? And how successfully can it be done? The following section argues that even for high school students the approach is viable, and that a number of common objections can be sidestepped when the social and epistemic considerations are combined.

5 Objectives of and Rationales Behind a Sociological Approach to NOS—Putting Sociology First

Demarcating science from non-science is not necessarily a part of every NOS curriculum. Currently, however, it is often included in NOS modules. I hope previous sections showed that if textbook writers on the nature of science do take demarcation to be an important issue, they should utilise social criteria as well as epistemic ones. Trying to rely solely on the epistemological aspects is hampered by the fact that, as Behe's case shows, recent strategies by movements like creationism include the mimicking of epistemic norms like testability or the notion of crucial experiments. I deliberately say 'mimicking', as a closer study usually finds these claims hollow, but clearly explicating the fallacies in these claims is by no means trivial and easy to explain to high-school students.[17] Therefore, as students are unfamiliar with the intricacies of the specific scientific field, they can easily consider certain movements as real alternatives to scientific views. It is, however, much more difficult to mimic social desiderata, like the general acceptance by other scientists or publishing in peer-reviewed publications. Here defence of ID has to rely on some form of conspiracy theory—and the problematic nature of these explanations can easily be shown. Once the social aspects—quite transparent and readily grasped by students—are also taken into account, it is easier to understand why creationism is not a science. In the courtroom and the classroom the "strict" epistemic criteria do a worse job demarcating various social group practices than the more obviously contingent social ones.

But NOS education should not just focus on the demarcation problem—if at all. How can the social starting point be proved to be beneficial for the other equally important aspects of NOS education? Why should a sociology-centred sequence be considered as an alternative to the currently dominant curricula? First, I argue that it solves certain conceptual problems that often arise in modules on NOS. Second, I show that epistemic considerations are not neglected by this. Following this, I investigate and reject the claim that a social starting point would be more difficult for students than the commonly used inductivist-fasificationist-Kuhnian sequence, generally seen as basic to NOS education. After countering these counterarguments I argue on a more positive note that a social starting point is closer to the lifeworld of students than has been heretofore recognised. And even though this view is generally not utilised in NOS education, it is also closer to a realistic view of science. While this section discusses some elements of a sociologically based pilot module on NOS, the next sections give a more detailed description and an evaluation of the module.

A major problem with current treatments of the nature of science in the classroom is the separation of "philosophical" from historical cum sociological insights. The discussion on the method of science all too often boils down to simplistic logical insights focusing on

[17] One major problem is that many of the epistemic criteria used as argumentative tools in debates on what is good science are not empirical. Though a detailed analysis can show the weakness of ID claims, these debates are much more sophisticated than the general understanding of science among high school students. So while such an analysis clearly can be done—for the issues of observational consequences, testability and supporting evidence in favour of ID see Sober (2007)—, for the classroom use the inclusion of the social aspects seems more viable.

white swans and the like (even in textbooks) when a module on NOS starts with epistemic criteria. More significantly for the current article, starting with epistemic considerations does not allow for the natural introduction of social factors, which at some point need to be mentioned. The rather negative role social considerations generally play in NOS modules as a result was illustrated in Sect. 2. The alternative suggested here, on the other hand, embeds the epistemic in the social. Science is portrayed as a social institution, and as all institutions, science also has norms. The necessary existence of these norms is investigated and their role in maintaining the proper functioning of science as an expert system both in knowledge-production (i.e. epistemic norms) and in the proper functioning within society is stressed.

The aim of the social starting point is therefore not to replace the epistemic considerations, but to find place for them. The epistemic norms are not shown as decontextualised, abstract criteria, but rather as the results of historically contingent developments that gave rise to a very special social institution in Western Societies starting from the 17th century, an institution that is the primary knowledge-producing organ of these societies. Science, while still often portrayed as an isolated enterprise in search for pristine knowledge, is in fact an embedded system that has specific functions in modern societies. Once this social starting point has been established, norms of science can be discussed—some ethical, some epistemic. Even from this short description it becomes evident that as opposed to the prevailing textbook conventions, the approach proposed here reverses the order (the social comes before the epistemic) but does not dispose of the epistemic criteria.

A general objection to this approach is that first a “simple” view of science should be given, and more complex, social considerations can come into play at a later stage to modify earlier views.[18] An unrecognised problem with this view is that it treats earlier, mainly logical positivist and Popperian views as unproblematic and easy to grasp. It implicitly endorses the ‘statements view’ of science, where the job of the scientist is to come up with statements that have certain characteristics (can be verified, falsified, corroborated, reduced to other types of statements, etc.). For most students, however, this is a non-trivial view of the natural sciences. Not only is this alien to what and how they learn in science classes, but also alien to most science teachers, generally little educated in the philosophy of science.[19] Further, this statements view requires non-obvious notions of truth, truth value, etc., and therefore can hardly be considered a “natural” starting point. For most students these notions are not “at hand”. And one need not consider the most technical papers by Carnap and Co. to see that most positivist (as well as Popperian) views are built on a very specific view of language, one that has strict requirements about syntax, mostly idealised views about semantics of the language, with almost total neglect of pragmatics. The scientific method, if introduced in this framework, seems simple on the surface, but in fact implies views that are not at all easy to grasp for high school students.

[18] Examples include referees’ comments, and a response to the earlier article (Zemplén 2007a) by Nicholas Alchin, stressing that the historical development of NOS ideas should be used to determine the sequence of the views taught (See http://www.springerlink.metapress.com/content/311231425022664n/?p=87c7d0cd9e934a60a151abe9481dd199&pi=0, Alchin, Nicholas, *Zemplén on Theory of Knowledge*, Science and Education, online first).

[19] While there have been some improvements due to innovative educational methods, like Nott and Wellington (1998), probably many of the disconcerting findings (e.g. that even a number of the assessment instruments to assess teachers’ knowledge about NOS are poorly constructed) discussed in works like Lederman et al. (1998) still hold true in many countries. There is even less work on and attention devoted to what students should know about NOS, and how one should measure that.

Not only is the epistemic starting point more complex than is believed by many of its supporters in science education, it is also more remote from the students' lifeworld than a social starting point. In science classes students directly face (some of) the complexities of laboratory work, they see instances of error handling, and are accustomed to trust their teachers, when e.g. she explains why a specific experiment did not work the way it should have. They are also faced with science as a socially embedded institution in television news, hospital encounters, or when they see experts arguing for specific positions in open scientific controversies. These are readily available resources that are generally neglected when NOS modules focus nearly exclusively on testability criteria and the like. Yet they could easily be utilised when the social dimensions are given a greater role, as the approach outlined here shows.

A short "expert game" can demonstrate this in class. By asking students in a class to list people who can help them do their physics homework, find parties, or help in an emotional crisis, they quickly see that already in their school environment they treat each others as "experts" in specific situations.[20] The school environment can also be used to discuss how these informal experts become organised and how social institutions emerge, and for what aim. School counsellors, student organisations and occasional teacher-evaluations make obvious how certain roles and expertise are institutionalised and how these institutions develop their own norms.

These relations are easy to grasp, as from early childhood on students have experienced different social relations. It is probably fair to say that students generally have a social-functional approach to science. They see the division of cognitive labour in society, that experts are asked to repair TVs, cure people, etc. Through these insights the complex processes of knowledge-production—something that students have little experience with—can be introduced. This way the social will not be seen as necessary but all too often detrimental to knowledge-production, as it still too often surfaces in textbooks, but as constitutive to it. The students realise the difficulty of organising systems of expertise in society to achieve certain goals (in the case of science, a major goal is knowledge). They are therefore more open to pluralistic approaches, more open to appreciate the historically changing and contingent development of the scientific method. The scientific method will be seen as result of a societal need to base decisions on reliable knowledge about the external world, and this provides the context for the otherwise decontextualised epistemic desiderata.

At the same time the social framework allows for the discussion of changing societal needs, of the power-struggle between different social groups, where scientists have their own agenda and aims. This way socioscientific issues can easily be connected to NOS insights. A comparison with school life can be revealing, and can show both the positive and negative aspects of social institutions. This can lead to a balanced view on the NOS, escaping both overenthusiastic scientism and destructive relativism. It also helps to show how students are influenced by science as a social institution, and to reflect upon how science is communicated to them.

When asked to compare their primary and secondary school education to what they know about university and post-graduate education, students generally clearly see the gradual move towards the "inside" of science from the "outside", even though the names of subjects have stayed the same during their education. In primary school, science had for them an unquestionable authority, but during the latter years of high school education they

[20] The game described here was the opening class of a pilot module for NOS, the details of which are available in Zemplén (2007b), and which is summarised in Sect. 6.

meet more and more of the intricacies of scientific activity. As their knowledge of science increases, the extreme complexity of the issues becomes clearer and clearer. These discussions can be an enormous help to students in evaluating the often contradictory messages they receive concerning science and the status of scientific knowledge. In short, their own experiences concerning the public understanding of science and the popularisation of science can be reflected upon. As students progress in their studies, their position is constantly changing, and this change needs to be addressed and explicated, especially in courses that focus on the gradual development of reflective thinking and responsible citizenship, not only narrower NOS issues.

Once conflicting claims can be investigated in the broader social context (remember Shapin's playful hoax about *who* makes a particular claim), it becomes clear that 'black and white' attitudes help little when a decision is to be made or action is to be taken concerning a specific complex problem. Just as in the case of demarcating science, local arguments are much more helpful, but this is hard to show unless the resources in a social approach are utilised.

This approach leaves one ample space to investigate different communities claiming to do science. The changing boundaries of science, pseudoscience and fringe science can be discussed. Also, the historically developing and changing "scientific method"—with special emphasis on the logical structure of inductivism, deductivism, and falsification—are not eliminated. Instead, they find their place in the broader historical and sociological framework. These norms are connected to science's constant strive to eliminate or at least control different sources of error. They are contingent and malleable guarantees, but still the best guarantees that we have. This framework allows for the connection of NOS issues to the students' lifeworlds, to the objectives of the educational system, and to their own science education (that this move could be welcome when teaching about science, see Donnelly (2002)).

Not only is the social starting point closer to the lifeworld of high-school students, it is also closer to much recent research on how knowledge is produced and transmitted, as I hope will become clear in the next paragraphs. Instead of moving away from reasonableness and rational decision making, this starting point offers a more realistically grounded notion of reasonableness.

Let us take a rather remote and esoteric form of knowledge, cutting edge research in today's laboratories. As has been argued by Hardwig and generally accepted by philosophers of science, in most research areas epistemic dependence is present and a necessary phenomenon of contemporary scientific practice (Goldman 2001; Hardwig 1985). And this does not only mean reliance on the literature and on the expertise of other laboratories and the trustworthiness of their findings, but dependence also exists within a laboratory and co-authors of an article. Even the most reliable scientific knowledge today (and *especially* that) is produced in a way where researchers often have no direct and detailed overview of their co-workers work. Instead, they rely on trust, a usually well-supported belief about the expertise of their colleagues. Science, well known and well advertised for its vigilant scepticism can only function in communities that are founded on and held together by a high degree of trust (Polanyi 1958; Shapin 1994). The resulting epistemic dependence is not something to hide or be ashamed of, but a realistic starting point from which notions of rationality and reasonableness can de developed. A normative account should not disregard the way we can achieve knowledge ("ought implies can"), and therefore, as the production of scientific knowledge is a necessarily communal enterprise, it should take the communal aspects into account.

Science is often portrayed as an enterprise where empirical data and reasoning are used to find regularities in nature. Rational decision making means choosing a position from a variety of possible standpoints based on reasons, i.e. picking theories that are best in accord with the empirical evidence at hand, etc. However, for rational reasons (like time constraints), we do not check each claim, redo all experiments. That is, we take much of the empirical evidence for granted, the existing theories as they are passed down to us through professors, textbooks, and journals. Sociologists have noted that even if a group of scientists work together, they often make judgements based upon their assessment of the other's credibility, and not on the assessment of the evidence (Collins 1985). So in many cases, reasonable and reasoned decision-making primarily means the rational picking of good experts as opposed to bad ones. Previous research, academic position, institutional background can all help the picking of experts. These categories are, however, social categories—science is a cooperative game.

The product of this cooperation is then submitted to journals, where again the editors pick the reviewers based on their position, role in the scientific community, track-record in science, and ask them to review the article in the light of what they consider sound science. The results appear in journals that are ranked according to how other experts cite them for their own work. The epistemic guarantee is the result of a social process—this explains why I referred to peer-review as a(n epistemically significant) social norm in Sect. 1. It is unwise to deny the fact—even for pedagogical reasons—that often choice is not made between knowledge claims themselves (as the knowledge required to make these decisions is also not at hand in most cases) but between the experts/institutions standing behind these knowledge claims.[21]

If this is the case in research, and science-in-the-making, the knowledge of students is even more affected by epistemic dependence. For school science to be successful, it has to rely on much that is not well-argued for, but accepted: it is "immersed in a rhetoric of authority" (Izquierdo-Aymerich and Adúriz-Bravo 2003, p. 33). Also, while students can be expected to make reasoned choices in their picking of experts, they can hardly be expected to pick reasoned positions in complex fields like science.

This is especially true for cases where even expert opinions differ. Much of the science communicated in the media is "controversial science", and the number of such controversial cases is increasing. Recognising and drawing attention to this fact does not mean that rationality is sidestepped. Instead, a more tenable and useful attitude can be presented to students than the still dominant idealised view in science curricula. Such an attitude has relevance not only for NOS, but for the development of critical thinking skills as well, an acknowledged goal of science education (Bailin 2002). As this goal is in the focus of a number of curricular developments fostering reflective thinking, responsible citizenship, and the like, social insights and ways to rationally pick experts have even further reaching consequences.[22]

[21] One might call this type of selection 'vicarious selection', as Allchin (1999) does about the scientific community, but it *is* a selector. Today one of the gravest problems in the public appreciation of scientific issues is that certain organizations pretend to claim scientific expertise where they are only spreading ideologically motivated messages. Creationism is one group, but similar (and even more successful for distorting public opinion in the US), politically motivated groups deny climate change, etc. The point that choice is made based on trust in institutions is underlined by the fact that in these cases the most efficient way to combat pseudoscientific claims is to disclose the funding structure, manipulative techniques, life-histories of organizations, as in the case of the Marshall Institute in denying climate change (Oreskes 2007). A highly interesting issue—not discussed in detail here—is that a justifiable and strong critique is in fact an ad hominem type of argument, generally considered to be fallacious.

[22] From a more traditional epistemological position, similar conclusions have been found in Smith and Siegel (2004), see 4.2 on p. 576.

As science develops and its complexity increases, laymen and students are less and less likely to make informed decisions as to what is sound science and what is not. The Royal Society's motto, "Nullius in verba" (On the words of noone), is not a fruitful approach in a period where scientists themselves have to rely on the words of others. Current emphasis in NOS is still on "Robinson Crusoe" epistemologies; but by giving the rightly deserved attention to social considerations in teaching students about science, we can better prepare them to find the right expertise and thus reliable knowledge in our society.

6 The Module

In the following I describe and evaluate a 6-week module (weekly 90 min, approximate net teaching times given in brackets) on the nature of science in a Theory of Knowledge (TOK) class, a compulsory course of the International Baccalaureate Organization (IBO) Diploma Programme. The module was developed in 2006 (15 students in one group) and after slight modifications it was assessed in the coming year (22 students in one group). A few words about the course. TOK was launched in the IBO Diploma Programme in 1999. It is an interdisciplinary requirement with at least 100 h of teaching time during the programme's 2 years. The aims are to bring students to appreciate different perspectives and "to stimulate critical reflection on the knowledge and experience gained inside and outside the classroom. The course challenges students to question the bases of knowledge, to be aware of subjective and ideological biases and to develop the ability to analyse evidence that is expressed in rational argument".[23]

The subject is structured around the so called TOK diagram with strong focus on the knower(s), surrounded by four ways of knowing (Reason, Emotion, Language, Perception), and six areas of knowledge (Natural Sciences, Human Sciences, History, The Arts, Ethics, Mathematics). Provided that all "areas" and "ways" are treated with equal emphasis, approximately 10 contact hours are left for discussing and studying the nature of natural science. Earlier I have introduced the programme in more detail and showed potential conflicts between the general approach taken by the critical-thinking skills oriented TOK and traditional science subjects, and have also highlighted some possible solutions (Zemplén 2007a). The structure of the module of six double lessons and some preliminary findings were discussed in significantly more detail in the proceedings volume of the 6th ICHSSE meeting held in Oldenburg, 2006 (Zemplén 2007b). Here the main focus is to outline how a sociologically based module can incorporate NOS issues, and to assess the particular module (Sect. 7). At points where the two modules differed, I describe the 2007 module, as this is more relevant for the evaluation in the next section—the reason for some of the changes made was to allow for a better understanding of students' understanding.

6.1 Describing the Module

As opposed to prevailing textbook practice (see Sects. 2 and 3), the particular module designed in 2006 and evaluated in 2007 attempted to incorporate epistemic issues and the traditional NOS material in a sociological framework. This naturally meant that less time was devoted to traditional NOS issues (demarcation criteria, the scientific method, induction, deduction, falsification), as nearly half of the module was spent on grounding

[23] http://www.ibo.org/ibo/index.cfm/en/ibo/programmes/prg_dip/prg_dip_cv.

the sociological starting point. Thus, not only is the module novel in bringing the social to the fore, it is also an attempt to restructure the (more or less traditional) epistemic aspects in a way as to utilise resources available to students, thus to decrease teaching time devoted to these elements.

6.2 Grounding the Social

The module introduced the concepts of expertise, expert systems, and social institutions. The first double lesson started with a setting resembling a quick in-class test, common to many school systems, but the answers were not graded (30 min). This included mini-essay questions (1. Does science provide us with better, more reliable knowledge for important questions than everyday knowledge or other traditions do? 2. If yes, why and where (e.g. healing, physics, environmental issues, risk management, etc.)? If no, why and what *does* provide us with the most reliable knowledge in your opinion?) and a number of questions on expertise within the class (the little expert-game was discussed in Sect. 5). While one student added up the results of the expert-test, the class discussed their response to the mini-essay questions in small groups. This was turned into a frontal discussion, and key concepts (social institutions, expert systems) were introduced (15 + 10 min). After this the results of the "expert-game" were discussed (15 min). This showed that students have expertise in a number of areas, and they treat each other as experts in social, educational, and various other matters. The form of the game was used to contrast "knowledge" that school-tests usually test and other forms of knowledge important for the students' everyday lives. After this, the formal and informal ways experts can be picked were contrasted, a short introduction was given to the development of science, and the gradual institutionalisation of science was presented through examples. The class gave a rough classification of how experts gain acceptance, which was similar to Weber's tripartite grouping of the nature of legitimating into 'charismatic', 'legal', and 'traditional' (15 min).

The second lesson focused on the difficulty of constructing expert-systems, the many ways social institutions can fail, and how norms are instrumental in these systems for their proper functioning (35 min). The class in groups had to devise their ideal expert system (made up of fallible humans) for knowledge-production. (It was not hinted at that science as a social institution *is* one such system, and none of the groups actually attempted to describe what they thought was the functioning of science.) The groups had to present their findings and defend their views (40 min). During what turned out to be one of the best classes (and included some heated discussions) the students recognised in each proposal the difficulty of finding (a) motivation for experts to go after knowledge (as opposed to cheating, etc.) (b) means of control (and control of controllers, etc.), (c) ways to increase the significance of the most successful experts without turning the system into a despotic oligarchy (i.e. to balance both the meritocratic and the democratic elements of science).

As homework, students were (1) asked to list five different scenarios (as diverse as possible) that can hinder "scientific understanding", and where science/the scientist can go wrong (HW 1). They also had to (2) think about the following question "Why do we follow extremely complex scientific methodologies, even in cases where much simpler methods could yield similarly (im)precise answers? Is this good practice or not?" (HW 2).

The third lesson (after a school break) started with discussions on the homework (65 min). Depending on their position in HW 2, the class was split into two groups, and both groups had to present their strongest arguments in 3 min. The short speeches were debated, and the teacher highlighted key elements in both positions.[24] On the *con* side the financial costs of maintaining expert-systems (as opposed to spending money on other issues), and the difficulty of having civil control over them were highlighted. On the *pro* side these included the recognition that we need to tolerate (and pay for) science in areas where it is not too successful (at present) to allow for the development of these fields [chance for developing expertise], and that we have to trust the people who are best at something to do as they see fit in certain cases [epistemic dependence]. Homework 1 was discussed in small groups, and students were asked to provide a typology of error sources into which all their examples could be meaningfully integrated. This exercise was used to introduce the problem of *norms*. The lesson was also used to recap earlier ideas and discuss any problems encountered so far. As homework, students were asked to read a one-page subversive text with the title "Economics meets science" (McErlean 2000, p. 205),[25] where induction and deduction are displayed as simply different strategies to obtain grants (HW 3).

6.3 Incorporating the Epistemic

The fourth lesson started with a discussion of the previous homework. Most students found the text funny, and as some already had vague ideas about induction and deduction, a very simplified answer was given as to what the two terms "really" mean. (These were later discussed in lessons 5 and 6). After this, students were asked why they found the text funny. Soon they pointed to the discrepancy between what scientists should (and they say they) do and what they really do; how methodology is used on the one hand to gain knowledge, and on the other to create an image of the scientist that legitimates her in the eye of the public. So issues of ideology, self-image, and public image were raised, and students were asked to formulate what they thought the communicated image of science was, and what the actual aims of the scientists were. After collecting ideas, the students were asked to figure out how society (including the group of scientists) can ensure that the individual scientist does what is expected of him by society or by the scientific establishment. This discussion revised some of the findings of the previous lesson. The notion of norms, already mentioned on the last lesson, served to bridge the two tasks, in the following fashion (reduced version of blackboard-image, with the teacher "converting" some of the suggestions, and thus introducing the terminology):

Communicated task	Science as a social institution to guarantee that actual practice to guarantee that actual practice is as close to expectations as possible	Actual task of scientists
("Ideally")	NORMS	Utility, fame, truth
"Truth" production	Methodological	New questions, failure
Privileged source of knowledge in society	Ethical (Mertonian, anti-Mertonian)	Money, conspiracy

[24] The exercise was also used to rehearse concepts that the students had met earlier in a module on reasoning and argumentation (for both classes, this was the first module of their TOK course). This took up some time, but as following lessons of the module built on logical fallacies, this excursion seemed necessary. Students were reminded of the notion of strategic manoeuvring and the balancing of rhetorical and dialectical aims of an argumentation. The arguments were analysed both as to how "strong" they were (i.e. were there any fallacies, can the arguments be used to make reasoned choices, etc.) and also as to how "effective" they were (the rhetorical aspects of persuasiveness, the questions of target-group and audience were discussed).

[25] Originally from Weller (1985), see also http://www.besse.at/sms/smsintro.html.

Once science had been located as a historically developing social institution and a system of experts and expertise, the historically changing borders of science were discussed. In a frontally coordinated discussion the class was to list branches and modes of knowledge production, and was asked to classify them. Accepted and rejected science, pseudoscience, and fringe-science were suggested as categories.[26] Well-known examples like astrology and other divinatory techniques were mentioned, and the historically and culturally changing position of these modes of knowledge-production in the given scheme of classification was pointed out. Radical shifts (introduced as paradigms) in norms were mentioned, their effects were considered, and this flexibility was contrasted with the relative stability of the tasks of science as a social institution.

The discussion on the norms led to the introduction of methodological and ethical (Mertonian) norms. The "scientific method" was introduced as an historically changing set of methodological norms, which were seen in different periods as describing successful knowledge-gaining procedures.[27] Once the epistemic elements of NOS were thus embedded in the social, the end of this lesson as well as the last two lessons were used to cover the more traditional material on induction, deduction, falsification, etc. The first side of a worksheet (on the Wason-task) was handed out to students as homework (see Appendix, HW 4).

The fifth lesson, one of the most demanding 90 min in the module, started with a pair-work, where the first side of the handout was completed by the pairs (this included checking and correcting each other's responses and solving the other's problems) (20 min). The students were reminded that the right solutions (p and $\sim$q, i.e. to check the other side of the first and fourth card) coincided with the logically valid forms. With this the possibility of errors in reasoning was highlighted.

The same pairs together filled in the second side of the worksheet (30 min), and the results were discussed with the class (30 min). The class was introduced to 'the scientific method' in this indirect way, with the teacher frequently referring back to the formalisation of the Wason-test and the truth table of the conditional. Deduction was shown as moving from hypothesis (H) to observation (O), while induction as moving from observation to hypothesis. The earlier formalisations were used to highlight the 'problem of induction', and the fact that falsification is a deductively valid method (i.e. a *modus tollens*). The students were asked to write a 2,000-character-long descriptive essay based on the class work and their individual research with the title: "Compare induction, deduction and falsification. Summarise the method, the potential benefits and pitfalls. Try to give one-one real life example" (HW 5).

During the sixth lesson, after recapping the conclusions from the previous lesson (25 min), the problem of underdetermination was introduced still using the same basic forms of conditional arguments. The conditional $H \supset O$ was extended to include auxiliary hypotheses: $(H\&A_1\&A_2\&A_3\& \ldots \& A_n) \supset O$, and students were asked to give specific scientific test-situations and explicate what is to be tested, and how underdetermination is

[26] Rather simplistic differences between pseudoscientists (mimicking the norms of real science) and fringe scientists (striving to conform to the norms of science) were proposed. This is in line with recent interest in the pseudoscientist as opposed to pseudoscience (Derksen 1993). In addition the problems of the approach were also hinted at.

[27] These were consciously not separated. Both classes had to read an excerpt from Rudner's famous article (Rudner 1953), and one class had to comment on the last sentence: "How sure we need to be before we accept a hypothesis will depend on how serious a mistake would be", reprinted in McErlean (2000). This was to underline that even for the purely epistemic considerations one should not disregard the social.

significant in the given situation (20 min). As underdetermination is often perplexing for students, they were introduced to some simplified ideas of Duhem, Neurath, and Quine.[28]

The rest of the lesson was spent on revising the topics of the previous lessons, according to whether they belong to the "inside" or the "outside" of science (see a short discussion in Sect. 5). Problems of methodology and controlling error sources were grouped under the "inside" heading, while the picture of science in the media, complex interactions of science, society, policy-makers, etc. under "outside". These two headings helped students to categorise their experiences concerning the popularisation of science, as well as arguments they were already familiar with—either strongly supporting the scientific establishment (scientism) or strongly critical of it and seeking alternatives ("Romantic" attitudes). The weaknesses of both extremist positions were discussed. The discussion also helped students to see in a new light the personal trajectories they were taking—some moving more and more "inside" science, and planning to continue their studies at university science faculties, others remaining "outside", but in any case facing science-related issues every day.[29]

The aim of the lesson and the discussion on the "insider" and "outsider" views of science, to wrap up the course, and to revise and consolidate the content of the previous lesson. As a homework assignment, students had to write a 2,000-character-long essay on science as a social institution (HW 6).

7 Evaluation

7.1 First Approximations

Does this unit work? Naturally, it seems quite unreasonable to propose novel curricula, teaching techniques, or modules to replace already existing ones, unless their efficacy can be seen and shown. I have already tried to argue in the earlier sections that the proposed module works in the sense that it gives a less distorted view about science than some alternatives, the social dimension can be included in the NOS without weakening the epistemic element, etc. So if my argument that current approaches to NOS (discussed in Sect. 2) are in need of improvement is accepted, then the module described here "works" in the sense that it provides students with a view of NOS that is more in accord with the current understanding of science in history and philosophy of science (HPS) and science studies communities than the investigated other approaches—it transmits knowledge from the relevant scientific community towards students.

The module also works in the sense that it successfully utilizes resources and assets that students already have, and manages to bring students closer to critically understanding their surroundings as well as to connect the school curricula to their lifeworlds. To cite just one example: students were assigned to read a one-page text with the title "Economics meets science". Even though in this text induction and deduction were displayed as simply different strategies to obtain grants, apart from one single student in the two year groups,

[28] Importantly, none of these writers considered underdetermination as an insurmountable problem of science, and Duhem's *bon sens* (Duhem 1954), Neurath's antifoundationalism (Neurath 1913), and Quine's pragmatism (Quine 1951) all show how choice is not arbitrary, even though not logically determined.

[29] As students progress in their studies their position is constantly changing, and this change needs to be addressed and explicated, especially in courses that focus on the gradual development of reflective thinking and responsible citizenship.

all students clearly realised that the position taken in the text is not meant to be true (this was tested via an end-of-module questionnaire in the first year, and the 2,000-character-long HW 5: “Compare induction, deduction and falsification. …” in the second). This shows that students have (at least in certain cases) the ability to differentiate between reliable and non-reliable sources, even if a non-reliable source is offered by a teacher. By discussing their reaction to the text, students could reflect on their own attitudes, on how they could openly criticise a source given to them by an authority, why this was difficult, and how similar situations can be handled effectively. Students often made use of the numerous class discussions to openly share their experience and questions. Most notable were the discussions on demarcation and pseudoscience (several of the students came from “scientistic” backgrounds, but some had parents actively pursuing Reiki, Silva’s Ultra-Mind System, following astrology-columns, etc.), and the final discussion on science from the “inside” or “outside”.[30]

7.2 The Lack of Benchmarks

Of course the above observations are by far not enough to justify the introduction of a novel approach to teaching NOS. How do students receive the ideas communicated? Do they understand the conceptually novel elements in the module? Do they learn them? Is this knowledge retained? Can it be retrieved and actively used in everyday situations? Does this help them to critically evaluate knowledge-claims, to have a deeper understanding of the workings of science in our society, to become more responsible citizens? Will this module (and course) help them to be better at lifelong-learning, and more flexible in adapting to new environments? Will they make better choices in science and technology-related issues?

To properly evaluate this module on NOS, these—and possibly a number of other—questions should be answered. And in order to argue that this module should be used *instead* of the currently dominant approach that focuses on the epistemic aspects of NOS without embedding it in the social, one would need comparative data. But here one runs into serious difficulty. Even though programmatic manifestos as to what NOS teaching should achieve are not hard to find, there is very little literature on the evaluation of any module or curriculum. Succinctly put: no benchmark exists for NOS. Therefore it is difficult to properly compare the module proposed in this article to any other module, as—to the best of my knowledge—no reliable study exists on just how successful the already existing modules are. How is this possible, if NOS issues are included in more and more curricula, if teaching them is considered to be important by most educators, if NOS issues seem to be important for responsible citizenship, for reasonable decision-making in many areas, etc?

[30] These discussions allowed students to bring up and debate issues in a classroom or group setting where improving critical thinking skills was admittedly one of the main aims of the course. One very positive finding was that identifying the weaknesses and strengths of positions (as opposed to a “black or white” view of issues) also strengthened students’ willingness to practice these skills in a number of other areas. This is not a trivially achievable aim, as the famous Delphi report on critical thinking states: “RECOMMENDATION 4: Modeling that critical spirit, awakening and nurturing those attitudes in students, exciting those inclinations and attempting to determine objectively if they have become genuinely integrated with the high quality execution of CT skills are, for the majority of panelists, important instructional goals and legitimate targets for educational assessment. However, the experts harbor no illusions about the ease of designing appropriate instructional programs or assessment tools” (Facione 1990).

A few possible reasons should be listed before the next subsection attempts to evaluate the module despite the lack of clear benchmarks. One is that teaching NOS, while seen as important for many educators, is not a well-developed area. While there are long traditions of teaching specific subjects (like chemistry, maths, or history), NOS-issues have only been incorporated into curricula in the last decades, and comparatively little educational research is carried out in this field. Most research is either descriptive (very often about the NOS views that teachers hold) or investigates the effect of specific NOS views on science education (Bell et al. 2001; McComas 2000). Other subject-areas are also more canonized, and while novel approaches can challenge these canons and traditions, they at least recognizably exist. In NOS this is not the case. Not only do views on NOS differ among experts, but also agreeing on the 'nature of science' is a controversial task, ridden with difficulties (as was seen in the KD case). The present paper tried to point to certain general trends that a number of textbooks exhibit, but these are far from explicit, well-defined, or well-defended traditions. While more and more educators and curriculum-developers have expertise in NOS, the field is still not concentrated, as many of the articles in peer-reviewed journals still come from "outsiders", and the group of experts working in the area have very heterogeneous backgrounds: philosophers, psychologists, sociologists, historians of science, educators, critical-thinking teachers, etc. The experts who claim to know what science is like (but fail to agree on its exact nature) are not the same experts who design curricula, or test curricular efforts. It seems that at present small groups of experts locally decide on specific curricula, but generally there is little attempt to evaluate course material and teaching methods.[31]

Another reason for the lack of existing benchmarks in NOS is the complexity of the issues discussed and the problematic nature of their testing. There is no consensus here, either. While at times NOS issues surface in university entrance exams (or A-level type exams, like in General Studies in Great Britain), not all experts believe that there is much point in providing knowledge about science that can be evaluated in simple multiple-choice tests.[32] For some educators NOS should be taught in science classes (even though science teachers generally have no expertise in this area), and should be used to support the scientific courses, to offer students a comprehensive scientific world-view (Davson-Galle 2004). Some studies, however, show a hostility on the part of science (physics) teachers towards addressing HPS and NOS issues (Galili and Hazan 2001, p. 361), and some argue that education about science radically differs from education in science (Donnelly 2002). If NOS issues are not incorporated into science subjects, they can contribute to liberal education, bringing up responsible citizens who are able to make complex decisions in science-related issues—even if these decisions are not "pro-science". In toto, there is no agreement on who should teach what and for what aims.

[31] As I have argued in Zemplén (2007a), for the specific IBO course in Theory of Knowledge (still a course much ahead of many other attempts) curricular development is aimed more at refining the system of grading, operationalising assessment, and not on evaluating what the course actually does—the curriculum gets "black-boxed", and little effort is made to investigate what it is that students actually achieve by attending the course.

[32] In the area of critical thinking (in a number of respects connected to understanding and appreciating NOS issues and science education—see e.g. Bailin (2002)), where expert-discussions are more visible, these problems are well recognized: while critical-thinking exams obviously measure some skills, these skills are not obviously the ones that the test aims to measure (Fawkes et al. 2005). Also, although most of the reasoning skills taught can reach the strongest students, for a more varied student population their efficacy is questionable (Voss et al. 1991)—similar problems surface in NOS education.

A further difficulty is that the rationale behind teaching NOS (often expressed in course descriptions, like IBO) heavily relies on teaching reflective and critical thinking to students so that they can appreciate and evaluate multiple standpoints and balance them. This ideal, however, does not necessarily take into account the cognitive development of students. Some studies suggest that developing this level of reflective thinking may only be open to a small proportion of students, and is very much a function of their age (King and Kitchener 1994). In general, it is little known how good students *can* be at understanding and utilizing the complex NOS issues. It is reasonable to believe that not all the skills and sub-skills relevant for critically appreciating various standpoints in controversial issues (that often characterize NOS or Socio-Scientific Issues (SSI)) are fully developed.[33]

7.3 Measuring Success—A Limited Assessment

As no clear benchmark exists for evaluating NOS curricula or modules, in the following I focus on a limited number of issues that can point towards the development of some more systematic assessment. Clearly, a quantitative analysis would be preferable in many ways, but as the sample size was small (one class of 15 students in 2006 and another one with 22 in 2007), I only offer a meaningfully detailed analysis that relies on a number of qualitative and quantitative aspects without statistical analysis.

Does the sociologically based module lead to extreme relativism? I have earlier cited some critical views concerning the introduction of social constructivist views in the classroom. A major concern about stressing sociological aspects in the classroom is that while such accounts can avoid unwarranted scientism, they pave the way for unfruitful relativism. Even moderate authors, who support more contextual approaches, claim that "radical socio-constructivism derived from [sociology of science] has proved to be dangerous because of its sceptical and relativistic conception of knowledge" (Izquierdo-Aymerich and Adúriz-Bravo 2003, p. 28). So it seems crucial to see whether the module that I proposed actually leads to sceptical and relativistic views. It *is* thoroughly social-constructivist—not by introducing such models explicitly, but by treating all epistemic norms of science as constructed through a social process.

The general impression was that the students realised that historical contingency does not lead to extreme relativism, as the cultural background at any given time period will have more or less clear norms according to which decisions are made within a tradition, even though these norms themselves are subject to change. The fact that stressing the social did not lead to seeing accepted scientific knowledge as a matter of politics was—as discussions revealed—mostly due to the insights that students gained in the group-work that focused on designing an ideal social institution for the production of knowledge. I also suspected that not ending a module with the introduction of contingent social factors (as most textbooks do) will result in a less negative role being associated with the social. To check this informal insight, a written 2,000-character home assignment (HW 6) was given

[33] Experts in the Delphi report found good critical thinking to include "both a skill dimension and a dispositional dimension. The experts find CT to include cognitive skills in (1) interpretation, (2) analysis, (3) evaluation, (4) inference, (5) explanation and (6) self-regulation" (Facione 1990). Many of these skills develop well into adulthood, and even adults show weaknesses in certain areas, as specific patters of non-correct, "fallacious" reasoning are common, whether directed by "hot" or "cold" biases (Griffin et al. 2002; Holyoak and Morrison 2005; Kahneman et al. 1982; Kahneman and Tversky 2000).

with the title: “What does it mean that science is a social institution? Describe some of the implications of this view (ones that you consider to be important).”

The analysis of the essays showed markedly positive appreciation of science as a social institution. None expressed “dangerous” relativism, yet all portrayed science as “embedded” in society. Typical conclusions were “The various social institutions cannot exist and work without the knowledge and the help of others. Science is also a field of knowledge which is needed in many cases to let other institutions operate or function in a better way”, or “To sum it up, science is a system which was created by people for people to gain more information about the world around us”, “…a social institution … that serves the needs of the society, the needs of the people”. A third of the essays stressed that science is an institution that serves “us”, “humans”, more than two-thirds of the essays stressed the importance of science for other social institutions, and half of the latter group also stressed interaction with other social institutions (with one essay stressing *mutual* interaction of various social institutions and science). Science was seen as important in health care (5 essays), school science (3), economical-political-environmental issues (2), jurisdiction (1), architecture (1), and religion (1, science and religion were portrayed as conflicting social enterprises). This shows that when writing the assignments, students primarily utilized their knowledge about medicine (generally seen as the ‘paradigmatic’ example of science for lay people (Gregory and Miller 1998)) and science as taught in schools. The fact that the majority of the examples were not related to school-subjects like Physics or Chemistry, suggests that one of the main course aims was achieved: the course was centred around the student as knower, and not around specific subjects.

These—obviously early and local—results strongly contradict the claims that social constructivist views lead to extreme relativism. Even the most “relativist” of the essays (stressing the mutual interaction of institutions) concluded:

> In short, society can ensure funds, equipment and trained manpower to make a particular discovery possible, but at the same time it can prevent an advance by diverting sources and manpower elsewhere or establishing an intellectual atmosphere in which a particular question will not be asked. This way the most basic science that is done today is a product of our society, it is a social institution.

Although both the methods and the results of science were seen as contingent by the student, the essay cannot be considered “dangerous”, even if it might not be what many science educators want students to believe.

These essays also positively strengthened the view that the sociological approach is not too difficult. The conceptual apparatus was easily handled by the students, they could readily connect the theoretical insights with their own experiences and even though some essays showed conceptual weaknesses, this was rather rare and partly due to difficulties in handling English, a second language. (The worst paragraph read: “Consequently, as we can see, science cannot be separated from the social institutions because they are needed for the proofs, to make the people believe and get to know that what they are doing is right and it is in the way they do. Otherwise, if there was no science then social institutions would lose their reliability and trustiness.”)

Are not the epistemic issues compromised by spending a disproportionate amount of time on social ones? The module certainly offered more concerning the sociological aspects of the NOS than most current textbooks, that use a similar number of contact hours. It also attempted, however, to cover approximately the same material in traditional philosophy of science as textbooks like the ones discussed in this article. So a natural question is whether the epistemic aspects have been compromised in ways that this module offers *less* than other approaches. The corollary whether or not the social aspects have been understood to a sufficient depth has, to my belief, been answered in the positive. But if traditional elements of the NOS curriculum can be "condensed", the module discussed in the article can prove to be useful even if the original aim, to devote more attention to a sociological approach, is not endorsed.

To introduce the epistemic aspects of NOS, the module relied on some previous knowledge about argumentation theory and formal fallacies, and introduced concepts through a specific formalism. The students had some background knowledge about zero-order logic, truth tables, and simple formalizations, but the material relevant for the module can be restructured so as not to require these. As expected from the literature and from earlier experience, the crucial part of the material was to understand the conditional structure. For this the well known Wason-task was used, and at first the students did rather poorly on the task, even though they had already covered the material earlier in the year. Many of the students gave an incorrect answer to the first exercise (see Appendix, the responses for Q. 1. and 2. were 16, 11, 9, 11 and 17, 1, 0, 18, respectively for p, $\sim$p, q, $\sim$q for one group, for another 10, 3, 6, 4, and 9, 0, 3, 9), and question 3 yielded only slightly better results. However, as grasping the truth-function of a conditional was a crucial step in introducing the "scientific method", emphasis was laid on making sure that all students are at ease with the conceptual framework. Results improved significantly in question 4, when each student had to devise as contrived examples as they could, and was asked to test their partner, who had to be as quick as possible in supplying the correct answer. At first, though the theory had become clear for all, many of the students failed to solve correctly even their own examples. After approximately 15 min and lots of heated debates (and some extra examples by some of the pairs), all became confident and got used to using the logical structure in devising and answering the problem.[34]

The next lesson started with a revision (question 1 on page 2 of the Appendix). After spending ample time on the formalisation, the epistemic insights derived were more or less straightforward. The students generally had no difficulty filling out the second sheet on the "Scientific method". Question 3 (page 2, Appendix) was used to test what already existing background knowledge the students have as well as to see if the logical validity of forms and the Wason-task were in fact connected (identical answers in columns 2 and 3 were seen as a positive indicator, if column 4 contained correct and matching answers). About half of the groups correctly identified induction, deduction, and falsification; so even though introducing the scientific method via this specific formalism is not general in the literature, it seemed to have caused no major problems. Students were already familiar enough with the terms to be able to match formalisms and concepts. This reinforces the view that in NOS these issues need not be frontally introduced, as 17/18-year-old students have sufficient resources to tackle the problem in question 3. Only few individuals (4 out of 22) failed to correctly connect the logical validity of forms with the Wason-task, and the conceptual difficulty was again discussed in class. By this time several of the students felt competent enough at tackling the question to offer one-on-one tutorials to classmates. In general, it was found that once the conceptual difficulty of

[34] There was one student in the 2006 class but none in the 2007 class who at this point had difficulties, and who received extra homework. By the coming week the student was confident enough to share her examples with the whole class, and this was used as a warm-up repetition for the class.

properly appreciating the formal properties of conditionals was overcome, the rest of the insights were easily grasped. Even understanding and using complex NOS issues like underdetermination posed no problem (all students could easily and correctly identify and 'design' relevant situations), once the general formalism was understood. On this latter point, however, individual differences were—again, as expected—very significant. So cognitive development seems to be decisive on how successfully the epistemic aspects on the NOS can be condensed this way.

A homework assignment (HW 5) was designed to check whether this condensed approach to epistemic aspects of the NOS was sufficient to yield understanding comparable to that coming from standard textbooks (note that as no benchmarks exist, students' achievements were compared not to other students, but to the official curricula and textbooks). The general impression from the essays was very positive. Initially, one obvious worry was that the introduced formalisms would push students towards giving simplistic logical examples for the scientific method, and not "real life" ones. This worry proved to be unfounded, the number of real life examples superseded the simple logical ones (9 as opposed to 6 for 10 essays). While some non-scientific examples were given (4), most students gave scientific examples as well (8). Interestingly, and as opposed to HW 6, the examples here matched school subjects much more closely, with topics in Physics (4, 3 of these astronomical), Biology (3), and Maths (1). Medical issues received significantly less attention (2), and there was no conscious reflection on school-science, unlike HW 6. This difference is noteworthy, even though the sample size was very small.

The same homework was also used to check what the results of incorporating the epistemic into the social were. Again, none of the "hyper-critical" relativistic view that social approaches are feared to evoke appeared, though every essay stressed the relative applicability of induction, deduction, and falsification. Fallibility was addressed in most essays. About half of the essays were optimistic in tone, while the other half pessimistic. The optimistic ones argued for a mixed use of methods, sometimes claiming that all three properly combined can yield infallible knowledge. None of the essays with pessimistic conclusions attacked science: the ideal of certain knowledge was found wanting, but this was always worded as a critique of certain epistemic expectations, and never directed against science.

What is the general offshoot of the module? The final question of assessment addressed here is whether the module was suitable for the students and the specific course. An end-of-year questionnaire was used to obtain feedback from the students (questions including: What was good/bad in learning TOK? How much did it help you to prepare for presentation and essay writing? Suggestions for the coming year? Did TOK help you in other subjects? Do you have ideas to make TOK lessons more interesting/useful/profitable?).

One student explicitly criticised the module "because topic was sometimes ununderstandable", and continued in general about the whole TOK course "The topics also sometimes boring and difficult to pay attention [to] in 6–7th lessons." Apart from this, and the general demand to get more feedback for their written work (esp. HW 5 and 6, used for the evaluation of the module, but not graded and discussed in class), the responses connected to the module presented here commonly included appreciation of the importance of critical thinking skills, and of the fact that TOK helped students to improve in these skills. Many students thought that their presentation and/or writing skills improved, but would have preferred even more feedback. The emphasis on reflective and critical thinking was not always applauded, as one student wrote, "The only message that I discovered from our lessons was to look critically at everything. But this rather caused some kind of confusion in my mind instead of clearing the meaning of concepts." But even though this can be seen as a sign of frustration on the student's side, this again is not an endorsement of extreme relativism. While many students found TOK unconnected to their other courses, a minority pointed out that TOK-related knowledge could often be used (not just in the modules corresponding to the subjects) in other subjects.

8 Conclusions

As Taylor argued about a decade ago, "the creationist threat to the prevailing cultural understanding of science was made more significant by the expectations that typical science curricula produce regarding the nature of science" (Taylor 1996, p. 161). What I have shown is that in a recent ID court case the role of epistemic criteria decreased and those of the social norms increased compared to earlier rulings. Current NOS education, however, does not exploit the potential that lies in sociological approaches in general, and in the most recent developments of science studies and sociology of science in particular.

The general textbook-convention first introduces science as characterisable by a distinct and specific method, reliance on empirical data and logical reasoning (as *opposed to* other social institutions). This view is then gradually "softened", once it is granted that there is no distinct scientific method, and that there is no guarantee to cut nature at its joints. Textbooks still often use decontextualised epistemic criteria separately from social considerations, in ways that the latter are seen to be hindering the fulfilment of the former.

The approach outlined in the article runs counter to the above model. I argued that by putting sociology first, starting from „soft", social considerations, stressing *similarity* to other social institutions, one can better appreciate the never ceasing attempts of scientists to tackle sources of errors and acquire knowledge (that is as reliable as possible) about the natural world. I showed that simply by shifting the position of the social in NOS modules and embedding epistemic criteria in a social framework, a radically more constructive role can be given to sociological considerations without a major change in the contents of the course. By giving up unreasonable expectations about science, sociological insights can help students appreciate science as the main knowledge-producing organ in our society. As opposed to traditional curricula, this approach is closer to how historians, sociologists and philosophers of science think about science today—it is closer to a more realistic view of science, where the dynamically and historically changing notions of the normative can be studied and understood.

The broad sociological starting point can help students understand the presence of values in science, the biases that scientists at times are criticised for, and still appreciate science as a privileged form of knowledge-production. Although the approach starts with the consideration of the social, from this descriptive view the necessity of epistemic norms and normative statements follow.

In no way did the paper try to dichotomise the rational and the social; in fact, it attempted to find a way where both can be seen as indispensable for knowledge-production. If epistemic norms are to work, they need to be endorsed by a community, and specific practices need to be developed to guarantee their successful implementation. On the other hand, science is not just politics; a social institution will not produce knowledge by itself, unless norms are developed that have epistemic significance. The social level of interaction among experts (who generally accept and at times change the relevant norms of the community) ensures that empirical evidence and the beliefs of individual scientists *can become* knowledge shared by the community.[35]

This approach also supports the view that the public understanding of science should be an interactive process between technical experts like scientists or educators and lay people like students, rather than a unidirectional or narrowly didactic passing down of information (Wynne 1991). Taking social considerations into account and bringing NOS issues closer to the lifeworld of students help to sidestep the "cognitive deficit" model of scientific literacy that characterises much of science education (Gregory and Miller 2001; Ziman 1991). Social considerations also appear to be successful in separating science from non-science in the classroom. And, as stressing the social by no means equals neglecting the epistemic, it does not lead to the much feared extreme relativist positions, as I hope has become clear from the analysis of the pilot module.

Scientists often claim that in our disillusioned age scientific values are not considered highly enough. By recognising the difficulty of finding norms and maintaining them within a community, students can much more appreciate the impressive successes of the past few hundred years. At a time, when leading science journals see new threats to the scientific establishment and when there are calls for more involvement on the side of scientists and educators to fight the public-relations battle (Gewin 2005, p. 761), it seems wiser to carry banners of a modern and acceptable view on the NOS than to use the same epistemic criteria as the ones often endorsed by intelligent design advocates, too. Especially as the "creationist notion of science is at odds with contemporary scientific practice, not to mention most of the philosophy and sociology of science written in the last twenty years" (Taylor 1996, p. 146). It is, however, surprisingly close to the currently (still) dominant textbook-view on the NOS. If we teach an outdated view on the NOS to students that is very close to the view many ID supporters hold, it is no surprise that demarcation becomes a tough issue. If in today's courtrooms social criteria are more helpful than supporters of traditional epistemologies would have thought, then this approach might provide a viable way to tackle NOS issues in the classroom, too.

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[35] For a very similar position see Allchin (2003). It is important to note how a number of philosophers have made attempts to incorporate the social in accounting for knowledge-production. For examples see the works of Philip Kitcher, Helen Longino, John Stuart Mill, Miriam Solomon, etc.

Appendix

The scientific method – and the uses of arguments

I. Arguments

1. Solve the problem and measure the time it takes for you to come to a solution you believe is right!

You have a set of four cards each of which has a letter on one side and a number on the other side. The visible faces of the cards show E, K, 4, and 7. Which cards should you turn over in order to test the truth of the proposition that if a card shows a vowel, then its opposite face shows an even number?

Solution: Time needed:

2. Solve the problem and measure the time it takes for you to come to a solution you believe is right!

You are in a bar where four costumers are consuming beverage. You either know the type of drink they drink, or their age. In this case you know that the customer drinks beer, carrot juice, is 20 years old and 4 years old. Which customers should you ask for the other piece of information, in order to test the truth of the proposition that if someone drinks an alcoholic beverage in the bar, then she has to be over 16?

Solution: Time needed:

3. A crucial part of both exercises above is a conditional sentence with the if…then… structure.

   a. Did you notice this when solving the problems? YES NO

   b. Are your two solutions identical? YES NO

4. Make two problems that have an identical structure. Write them down here, **but do not write down your own solution yet**!

1st problem:

If……………………………………………………………………………………………………

, then…………………………………………………………………………………………………

The four options: Partners solution:
My solution:

2nd problem:

If……………………………………………………………………………………………………

, then…………………………………………………………………………………………………

The four options: Partners solution:
My solution:

5. Show a classmate your own problems. Write down your solutions and his solutions!

II. Scientific method

1. The above exercises had similar structures. The four options can be formalised as follows:
   ~ means "not" or "not true that" [so ~p = not p or p is false]; p and q stand for the first and second halves of the conditionals,
   ⊃ means that the relation between p and q is a conditional one [so p ⊃ q = if p then q]

	1.	2.	3.	4.
Form:	p ⊃ q	p ⊃ q	p ⊃ q	p ⊃ q
	p	~p	q	~q
	q	~q	p	~p
	modus ponens	negating antecedent	affirming consequent	modus tollens
1st ex.	E	K	4	7
2nd ex.	Beer	Carrot juice	20	4

Please also circle here which of the options you found necessary to check!

2. Now imagine a scientist who tries to use the previous game to see how one can draw inferences in science. p will be substituted be H hypothesis, q by O observation.

   So the sentence will be something like: if H hypothesis is true then we observe O. (H ⊃ O)
   How could you reconstruct the four options above?

   1. 2. 3. 4.

3. In science, one can use different methods to arrive at general statements (laws) concerning nature. Fill in the table working with a partner!

	Resembles option (choose from 1-4 above)	Did you choose this option as necessary for deciding truth of conditional?	Logically valid? (circle what is correct)	What can you know conclusively following this method about H or O?
Deduction		YES / NO	YES / NO	
Induction		YES / NO	YES / NO	
Falsification		YES / NO	YES / NO	

4. Formulate your findings and the connections you noticed between scientific method, argumentation and logical validity. Also write down any other observations!

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