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The Expert's Role in Nanoscience and Technology

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Abstract. Richard Sclove writes in *Democracy and Technology*, "if citizens ought to be empowered to participate in determining their society's basic structure, and technologies are an important species of social structure, it follows that technological design and practice should be democratized" (p. 27). This paper will begin exploring what this view of democracy implies for the development of nanotechnology. In particular, I will look at the role of "the expert" in both communicating and guiding the development of nanotechnology. This will lead us to an exploration of both the relationship between the expert and the nanovisionary and the expert and the citizen in the context of public decision-making about the prospects of nanotechnology. The foundation of my argument will be the claim that the appropriate role of an expert in a democratic society, at least when acting in the realm of public science policy, should be to make possible informed decisions on issues of science and technology by fellow citizens.

If citizens ought to be empowered to participate in determining their society's basic structure, and technologies are an important species of social structure, it follows that technological design and practice should be democratized.
(Richard Sclove, *Democracy and Technology*, p. 27)

Introduction

I want to argue for a fairly straightforward proposition. *In a democratic society the appropriate role for a scientist or engineer when participating in the process of public decision-making as an expert in his or her field, is to facilitate informed decisions on issues of science and technology by fellow citizens*. The claim here is normative. When an individual dons the role of a scientific expert participating in the public policy process his or her primary obligation is to help produce the conditions necessary for legitimate and significant public participation in that process. An underlying assumption to my argument is that in democracy, legitimate political decisions have to be, in some reasonable sense, 'by the people'.

That this proposition be correct is critical as I am going to go on to argue that this idea of the expert as facilitator must be foundational to any public debate about nanoscience and technology. Without experts effectively playing this role nanoscience and technology risks becoming and being understood as an inherently authoritarian technology. What I mean by this is a technology that because of the structural elements it imposes places in the hands of a relative few power and decision-making ability, or what is properly called authority over vital elements of individual's lives.

1. Expertise and Technoscience

There is a significant authoritarian tendency in technoscience[1], that is, in the social networks that lead to the application of scientific ideas to social life, whether it be in the creation of material technological artifacts, or in the application of scientific ideas to social structures.[2] This tendency stems from the very specific epistemic demands that usually accompany decisions about the application of science and technology. The decision process for the application of any technoscientific item is complex. But from a normative point of view, a necessary condition is some understanding of the item in question. The decision makers need to have a basic understanding of the item, its use, its function, and its risks. If this is not the case, the decision probably cannot qualify as a good (where good is taken to be synonymous with some sense of rational) decision. Roughly speaking, you cannot make a good decision about technoscience without understanding the science.

Understanding the science, however, reduces to some fairly specialized disciplines. The development of specific scientific expertise arises from the difficulty of grasping anything more than a very small subsection of what we think of as science. Experts are around precisely because of the division of labor that contemporary science and technology seem to require.

John Hardwig calls the epistemic situation I'm describing 'rational deference' and argues that it is built into the structure of expertise. The basic structure of expertise demands that the individual or group ('A' below) who comes to depend on the expert must place him or herself in a subservient position within an authoritarian relationship.

> Rational Deference
> 1. A knows that B says p.
> 2. A has good reason to believe that B (unlike A) is in a position to know what would be good reasons to believe p and to have the needed reasons.
> 3. A believes (and has good reason to believe?) that B is speaking truthfully, that B is saying what she believes.
> 4. A believes (and has good reason to believe?) that B actually has good reasons for believing P when she thinks she does.
> (Hardwig 1994, p. 88)

The individual or group that comes to depend on an expert has to depend on the authority of the expert. The value of expertise is precisely that it allows one to have a reason to accept certain judgments in situations where one does not have access to the information necessary to make the judgment. It is the authority of the expert that serves as the foundation for accepting the judgment in question. Deference implies a necessary trust between expert and layperson. A non-expert judges the reliability and character of the expert rather than the information provided. The trust in the expert is legitimated by the community to which the expert belongs and the status of that community in the larger society.

The obvious upshot of all of this is that scientific decisions either are or should be made by experts. To the degree that a basic understanding of the science involved is necessary for a rational decision only those who have that understanding can or should participate in the decision. 'Expert' becomes not just an epistemic category, but also a political category. Experts not only know, they decide. This leads to some obvious conflicts with at least certain conceptions of democracy.

At the heart of these conflicts is the idea that in our contemporary society technology is a crucial social structure that shapes the real possibilities of individual's lives. Technology is (or perhaps more accurately, technologies are) not just a set of gadgets at the periphery of our lives, but rather a central element in the material reality of our existence. The types of technologies and our access to them make a crucial difference to what we can be as individuals, and the type of and access to technologies that individuals' have stem from decisions made in the political and social realm.

If the claims in the previous paragraph are correct, and this paper assumes that they are, then deference produces significant problems for democracy when democracy is understood as depending on autonomous decisions on the part of the citizens. Autonomy implies that individuals participate in some significant way in decisions that affect the possibilities of their own flourishing. Here, however, it is the experts who are making decisions about things that profoundly affect individuals' lives. Citizens are simply depending on the authority of the experts.

There is a quick response available to this problem. One can deny the problem and claim that autonomy is unaffected because while the experts are making the decisions, the citizens can in some sense choose and remove the experts. The idea here is that as long as the authority, both epistemic and political, of the experts is legitimate, then there is no real conflict with autonomy. We can have a kind of representative theory of expertise.[3] I think this response fails and this failure is perhaps nowhere more apparent than in the case of nanoscience and technology.

2. Nanoscitech

I want to discuss nanoscience and technology[4] both to illustrate what I am arguing and more fundamentally because the issues raised so far are not best understood as abstract issues, but as issues connected to the actual decision making of science policy. Science policy is itself an abstraction. Policy is not usually made about science, but rather policy is made about a technoscientific process, item, or approach. There is no official physics or biology policy in the United States or the European Community, but rather policies about genetically modified foods, building particle accelerators, funding alternative fuel research, etc. Policy is made at an intermediate level of abstraction and nanoscience and technology is at the moment at that level. Of course one of the questions to ask is whether nanoscitech should be at this level, but that is for another paper. The reality of the moment is that both the US and Europe are in the process of developing a national and international nanoscience and technology policy. This reality allows us to ask just how this policy ought to be made. It is in the context of this more specific normative question that the concerns about expertise become concrete.

What are these concrete concerns and what is it about nanoscitech that produces them? There are two features that offer entry into the normative issues raised by nanoscitech. Nanoscitech is both interdisciplinary and transformative. It is interdisciplinary in a fairly strong sense in that what nanoscitech shares in common is concern about a specific size of objects.[5] What it does not share in common is any shared approach or specific theoretical context that guides it. As it stands, individuals from almost every discipline in science and engineering participate in nanoscitech. This leads to a wide variety of assessments of the goals, methods, and prospects of nanoscience and technology. These assessments are sometimes at odds with each other and lead to some very significant disagreements about what is possible and not possible for nanoscitech. But perhaps more interestingly, these assessments lead to disagreements about what is to count as 'real' nanoscitech and what is simply some pseudoscience.[6] Interdisciplinarity, often considered a strength by the practitioners of nanoscitech, is paradoxically also a source of controversy and contention.

Simultaneously, nanoscitech is one of a suite of relatively new NBIC[7] technosciences that seem to have the capacity to radically transform our world and ourselves. This is perhaps the most notable and certainly the most publicized feature of this technoscience. Wherever you look you will find some very large claims being made about nanoscitech.

Bill Joy has very public concerns about the dystopian future that might await us if we proceed with nanoscitech (Joy 2000). A series of organizations such as the ETC Group (ETC 2003) and Greenpeace (Arnall 2003) have called for public scrutiny and control over the development of this technology. Michael Crichton has given us a fictional vision of just how badly this technology can go wrong (Crichton 2002). At the same time, Eric Drexler and the Foresight Institute see the emancipatory possibilities of nano (Drexler 1986, Foresight). The United States pursues the National Nanotechnology Initiative and commits substantial funding to this research (NNIb).[8] Forbes, among others, develops a newsletter, with a significant subscription fee on the investment possibilities of nanoscitech (Forbes). Utopian claims about the coming nanoscitech revolution are ubiquitous in science literature (Crandall 1996). And Hewett-Packard is now running adds touting the coming benefits of nanotechnology on U.S. television.

While the organizations and individuals mentioned above offer a wide variety of assessments of nanoscitech, they all agree, at least in their rhetoric, that nanoscitech will in the immediate future transform the world we live in. This transformation might be benevolent, malevolent, or simply profitable, but it is inevitable. Like all the NBIC technosciences, nanoscitech seems to provide tools for the transformation of the human self and environment so that lines between the artificial and natural are obliterated. In the case of nanoscitech these tools are the ability to manipulate, assemble, and disassemble molecules. The idea itself is very simple. Change the atomic structure of a molecule and you get a different molecule. If we can remove and attach atoms and small molecules from and to each other or other molecules, we can assemble and disassemble almost any substance. Molecules, in theory, can be used like Legos™[9] and we can, from fairly common, easily available materials, assemble materials with the specific properties required for whatever task we are trying to perform.

Of course, the description I have just provided is itself highly contentious. While everyone agrees that nanoscitech allows one to manipulate molecules, to what extent and degree this manipulation is possible, indeed what manipulation in this context means produces considerable disagreement. Just how far the Lego™ metaphor works is not at all clear and like many metaphors the Lego™ metaphor is as misleading as it is enlightening. In fact the Lego™ description is a version of the preferred description of nanoscitech of those who agree with Eric Drexler and the Foresight institute, though this agreement (Bill Joy comes to mind here) might only be about the nature of the science and not its benefits. This description also appears to be the most common description of nanotechnology in non-technical discussions.[10]

This last claim is based on an admittedly non-systematic survey. For example if we google (a new and useful verb favored by my students) nanotechnology, the first web site listed (making it the site with the most cumulative hits) is Ralph Merkle's web site about nanotechnology. Ralph Merkle recently moved to Georgia Tech where he is the director of Georgia Tech's Information Security Center in the College of Computing. He is a well-known expert on encryption and is also the vice-president for technology assessment at the Foresight Institute. Until recently he was also working with Zyvex and I assume some sort of connection is still maintained because as of this writing the Zyvex logo is prominently displayed at the top of the web site. Merkle is closely connected to Drexler and the Foresight Institute. This site describes nanotechnology as follows, "Manufactured products are made from atoms. The properties of those products depend on how those atoms are arranged. If we rearrange the atoms in coal we can make diamond. If we rearrange the atoms in sand (and add a few other trace elements) we can make computer chips. If we rearrange the atoms in dirt, water and air we can make potatoes" (Merkle). Here nanotechnology looks like modern alchemy. We can finally get gold from lead.

There are much tamer descriptions of nanoscitech. If we turn to the U.S. National Nanotechnology Initiative (number seven on the google hit parade) we get the following description. "[Nanotechnology is] research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1-100 nanometer range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size" (NNI). Clearly the NNI description promises less, but there is still a strong sense of the transformative power of nanoscitech. This sense is clearer in the following text from the executive summary of *Societal Implications of Nanoscience and Nanotechnology: NSET Workshop Report.*

> Advances in nanoscience and nanotechnology promise to have major implications for health, wealth, and peace, in the upcoming decades. Knowledge in this field is growing worldwide, leading to fundamental scientific advances. In turn, this will lead to dramatic changes in the ways that materials, devices, and systems are understood and created. The National Nanotechnology Initiative (NNI) seeks to accelerate that progress and to facilitate its incorporation into beneficial technologies. Among the expected breakthroughs are orders-of-magnitude increases in computer efficiency, human organ restoration using engineered tissue, "designer" materials created from directed assembly of atoms and molecules, and the emergence of entirely new phenomena in chemistry and physics. (NSF 2001, p. iii)

The transformative nature of nanoscitech is still apparent here, and it is only in comparison with Merkle's claims that the NSF/NNI vision appears less radical. What is different is both the scale and the type of transformation foreseen. Many different groups agree that nanoscitech is the next big thing, but just what that thing is, is not at all clear.

3. Expertise, Nanoscitech, and Democracy

This potential for transforming our social life is a good starting point from which to consider the types of problems nanoscitech might pose for a democratic society.[11] Agreement that nanoscitech will be transformative and disagreement about *how* it will be transformative, together produce potential problems. Because nanoscitech promises to transform society in important and even fundamental ways, there is a significant question about who gets a say in how and whether this transformation happens. But having a say in this transformation is difficult when there is no real agreement about just what is the nature of the transformation. Here I am pointing to more than the standard problem about the unintended consequences of a new form of technology, but rather to some basic disagreement about the direction of and the intentions behind the science and technology.

The problems around expertise become particularly telling here, as the most obvious response to the issues being raised is to simply go ask the nanoscitech experts and use their answers as at least a starting point. *But there are no experts in nanoscience and technology!* Admittedly the last claim is there to catch your attention. Of course there are experts, but the notion of an expert is used equivocally, and there is an important sense in which the claim that there are no experts in nanoscitech is true.

To see why this is the case we need to distinguish the loose everyday sense of 'an expert' – which can mean no more than an individual who knows a lot about a topic – from a more specific sense of the term, which is used when we are discussing the social role that experts should play. There are four features of expertise important to this social role that should be made explicit: 1) The expert has specialized training and knowledge not easily available to a layperson; 2) this knowledge is usually technical (what this means is at least that the knowledge is of specific methods for knowing or doing things); 3) the expert is recognized as such by his/her own professional community; 4) the professional community is recognized as legitimate within the larger society. While the first and second feature apply unproblematically to nanoscitech, the third and fourth are more complicated.

In order to examine the third feature we need to return to the interdisciplinarity in nanoscitech. As I suggested earlier, interdisciplinarity is so strong in nanoscitech precisely because there is neither a paradigm nor a tradition guiding the work. Nanoscitech is so novel that it is not clear that it should yet be called a field. The frequent appeal by nanoscitech that size matters is here – as in its lewder version – open for debate. But with neither a tradition nor a paradigm to draw from, it becomes difficult to be recognized as an expert by one's professional community since the professional community itself is in the process of being constructed.

What in fact we see in nanoscitech is a real debate about where the limits of legitimate expertise lie. Bill Joy, Eric Drexler, Ralph Merkle, Richard Smalley, George Whitesides among others all appear to have legitimate scientific credentials and yet they have all been accused, often by each other, of not really understanding nanoscitech. Part of the problem is that there are few ways, formal or informal, of legitimizing claims for expertise internal to nanoscitech. Nanoscitech finds itself in an odd situation. It is not so much the case that there are no experts as it is that there is disagreement about who is to count as these experts. Again interdisciplinarity is part of the problem. Expertise in nanoscitech depends on the perspective from which one looks at the discipline, as there are significant differences in what is thought possible in nanoscitech.[12] This is not particularly unusual in a young discipline, but when the promise of the discipline is that it can have a profound and relatively immediate effect on the lives of citizens, the inability to legitimize expertise becomes a significant social issue.

The fourth feature of expertise comes into play precisely because of the issue of legitimacy. A science matures as a professional discipline when society recognizes the legitimacy of that community of knowledge. When the science matures then we have a situation where the social role of an expert is possible. A catalyst expert is not simply someone who knows a lot about catalysts, but someone who is recognized as having this knowledge by both her professional community (I would assume an appropriate subsection of inorganic chemistry or chemical engineering) and society at large. The way this recognition is conferred would require a very long digression about professionalism and the development of professions, but the central points are simple. Without some significant societal recognition of the community of knowledge from which an individual emerges, that individual cannot play the social role of an expert. The social recognition that allows for the creation of experts is a deeply political activity embodying values as much as facts.

All of this takes us back to the discussion of rational deference. When we look at the second and fourth elements of deference[13] we see that in fact it is not at all clear that the public has the "good reason(s) to believe" in the authority of the nanoscitech expert. Again it is not because the experts are not knowledgeable, or because the public is not able to judge whether they are knowledgeable or not, but rather because the institutions that allow the public to trust the experts are not in place. But this produces some very significant problems for anything that looks like the representative theory of expertise I describe at the end of the first section. What is in question in nanoscitech is the epistemic and political authority of experts. The representative theory assumes an already existing cadre of experts, but at least in the case of nanoscitech this is not yet in place. Instead we are only in the process of the production of legitimate nanoscitech expertise.

The concern that nanoscience will have a strong authoritarian tendency becomes more significant here, since what we are in the process of developing are the criteria of expertise for a technoscience with transformative potential. Those criteria must include a series of political and normative judgments. But it seems that there are no experts who can legitimately guide this process. So the possibility of this process being dominated by a small group produces significant worries about authoritarian technoscience.

4. Democratic Nanoscience and Technology

There appears to be a rather simple way around the problems I have been laying out. All we need do is move to a mode of decision-making that is more effective at including the public. If we can lay out an appropriately participatory model of decision-making then the concern about nanoscitech as authoritarian should be mitigated. Here the role of expert as facilitator becomes essential and we can return to the thesis that is at the core of this paper, namely that in a democratic society the appropriate role for a scientist or engineer when participating in the process of public decision-making as an expert in his or her field is to facilitate informed decisions on issues of science and technology by fellow citizens. The approach I am indicating here takes as a guiding model a common sense approach to how an expert should function in legal and quasi-legal proceedings. Here, objectivity is the guiding goal. The normative requirements of expertise demand that the experts efface any subjective bias and stick to as Joe Friday demands, 'just the facts, ma'am'. The expert's role is to present unbiased testimony that can serve as a foundation for judgment by citizens. The goal is to explain the information needed in order for citizens to make a rational decision. Martin and Schinzinger therefore refer to the expert as value neutral analyst. Here the expert is completely impartial and avoids any type of advocacy (Martin & Schinzinger 1996, p. 373). The crucial skills needed by an expert under this conception are the ability to communicate technical concepts effectively to a lay public and a commitment to objectivity. The expert supplies citizens with the information necessary for them to come to a reasonable decision.

While the goal of this paper is to defend a version of the expert as facilitator, the version as stated above is likely to appear both overly simple and naïve. And this naïveté becomes apparent when we apply it to nanoscitech. The version stated above is subject to several criticisms. It denies rational deference, because it requires the public to be able to judge the experts' knowledge, but this is precisely what deference thinks cannot be done. It overestimates the possibility of value neutrality and objectivity. And in the case of nanoscitech it is beside the point since the problem with nanoscitech is that the public is not able to identify legitimate experts in the first place. Of course, the notion of the expert as representative is subject to the second and third criticisms as well. The absence of objectivity and value neutrality is just as pernicious to the representative model of expertise, and the inability of the public to recognize experts is a problem for any conception of nanoscitech expertise.

It is important to note that all these criticisms target the possibility of the expert as facilitator; they do not question the desirability of this conception. They are all versions of the "ought implies can" problem: at the heart of each criticism is some version of the claim that it is not possible for the experts to facilitate democratic decision making in the way suggested above and that therefore it is not reasonable to demand that they do so.

The response to 'ought implies can' problems is straightforward. Show that the impossibility claims are not particularly strong and the problem is solved. This can be done in the case of nanoscitech, but to do so we need to consider just what the goals of a nanoscitech expert in this role as a facilitator for public decision making on science policy would be. This is not as difficult as it sounds, once we are clear that the autonomy of the citizens is the motivating value. People affected by a decision or a policy should, if possible, have a significant part in making that decision or policy. This claim seems to summarize a minimal demand of autonomy that is at the heart of democracy. The role of the expert becomes to disclose relevant information to the public in ways that can be understood. The questions around rational deference suggest that the public is simply incapable of understanding the information. The questions around objectivity and value neutrality suggest that the experts' cannot adequately make decision of relevance and will therefore not disclose the appropriate information. The questions around legitimacy suggest that we cannot discover who is most appropriate to play the role of the expert. Roughly speaking, people are ignorant, experts are biased, and we wouldn't recognize a real expert if one fell out of a tree and landed on us.

But the situation is simply not this bad. What we must keep in mind is that we are making political decisions in a democratic society. These are by their nature decisions under a certain degree of uncertainty. The primary virtue of a political decision is that it be legitimate, not correct. Ideally the decision will be both, but a series of illegitimate decisions call into question the justice of the system as a whole, while a series of wrong decisions, particularly in a democratic system with methods in place for changing the government, tends to simply get new people elected. This sounds counterintuitive in the context of science were one would really like to get things right, but democratic societies are structured with the assumption that we can get things wrong (within reason) as long as we protect autonomy.

What we have to avoid, then, is not mistakes, but rather, catastrophic mistakes. And here, nanotechnology becomes interesting. There is the underlying fear of the catastrophic mistake. This is why Bill Joy's article raises such a specter. But once the stakes are raised this high, the problems raised by rational deference, bias, and the absence of experts actually lessen.

If one wants to exclude public participation because of the problem of bias, one has to argue that experts or the public are so inherently biased that the tendency toward deception or self-deception guarantees not just that some mistakes will be made, but that catastrophic mistakes will be made. This bias needs to be constant and pathological. The other option is to argue that the accumulation of small biases somehow aggregate into the functional equivalent of this pathology. Moreover, any control mechanisms in place for managing bias has to be ineffective or nonexistent and the public must be incapable of detecting bias.

If one wants to exclude public participation because of the problem of rational deference, one has to argue that the knowledge gap between experts and lay people is simply unbridgeable. But this ignores the obvious point that lay people, in order to avoid making a catastrophic decision, do not need a full knowledge of a discipline like nanotechnology. Experts should be able to offer enough of an explanation so that individuals can make informed decisions. This does not require knowledge of the details of the formation of buckyballs for example, but rather access to an effective overview of the research.

Finally, when we look at the problem of identifying appropriate experts we once again find the problem to be quite tractable if the goal is to both preserve autonomy and prevent the catastrophic mistake. While the question of expertise in nanotechnology remains an unsettled question, it is not a field without limits. This is not astrology, though on occasion some fairly outlandish claims are made. Nanotechnology draws from already established disciplines and is embedded in the scientific institutions of the nation and world. These existing structures serve to grant enough legitimacy so that expertise can be established within reason.

If ought implies can, and the problems of bias, deference, and expertise are tractable, then the only conclusion to be drawn is that we ought to think that a legitimate and important role of experts in a democracy, at least when it comes to nanotechnology, is to facilitate democratic decision making. To reject the role of expert as facilitator is to reject the idea that individuals can make decisions about the sciences and technologies that most directly impact their lives. Clearly the level of scientific illiteracy is alarming and individuals, whether in or outside of science, are far from bias free. But any position that takes decision-making about technosciences away from citizens – particularly for their own best interest – is disturbingly authoritarian, paternalistic, and deeply undemocratic.

Notes

1 I borrow the term 'technoscience' from Bruno Latour, though I use it in a slightly different way (Latour 1987, pp 174-5).

2 Science also has a significant democratic tendency particularly in the publicity that is ideally required of science, though this tendency is often only internal to the scientific community. The scientific community itself is often citied as a model of rationality that is appropriate to democracy. These congruencies with democracy however tend to distract from the authoritarian tendencies that I discuss.

3 Joseph Schumpeter and, from my point of view, some social choice theorists favor such an approach. They see these experts as the most competent representatives of the people (or of appropriate interest groups) and give the democratic process only the negative task of eliminating from decision-making those positions that seem to egregiously fail in their representative function. Max Weber is much more negative about such a society, but seems resigned to its existence. The Frankfurt School, contemporary critical theorists, and perhaps most notably Jürgen Habermas, are all critical of this approach (though the late Adorno for example follows Weber in his resignation). This paper reflects this debate but does not directly engage much of it. Such engagement would require an exegetical task that would turn the paper away from its point. It is also worth noting that the basis of this debate is really as ancient as Plato's *Republic* with its argument that political legitimacy depends on knowledge of the good.

4 I am using the awkward phrase 'nanoscience and technology' both to be accurate and to keep before the reader the variety of activities that are subsumed under this heading. I avoid shortening this to simply nanotechnology, for example, because there is significant research here that is not particularly interested in application. Early work with buckyballs for example seems not to have been motivated in a strong sense by a concern with application. Nanotechnology, then, seems too narrow a name. The same of course goes for nanoscience. I have in the course of the paper reverted to using the unfortunate neologism 'nanoscitech' for brevity.

5 Nanoscience and technology is concerned with the study, manipulation, and construction of or from molecular sized objects in roughly the 1-100 nanometer scale.

6 A significant example of this is the public debate between Eric Drexler, Richard Smalley, and George Whitesides about the possibility of constructing nanoreplicators. (Smalley 2001, Whitesides 2001, Drexler et. al 2001a and 2001b). At the heart of this debate are a series of fundamental questions about what is possible with nanoscitech. But these assessments of possibility might partially depend on the different disciplines, methods, and traditions of the participants. It would be very interesting to try and understand the disagreement between Drexler. Smalley, and Whitesides along disciplinary grounds (Smalley and Whitesides are chemist while Drexler is a computer scientist and engineer) and see how much their different starting points affect their assessments of what is possible.

7 Nanotechnology, Biotechnology, Information Technology, and Cognitive Science (NanoBioInfoCogno). Independently each of these allow human beings to alter their environment and themselves in what appear to be fundamentally new and different ways, whether it is the creation of "intelligent" machines, the ability to manipulate the genome, or the ability to manipulate molecules. And more powerfully the convergence of these technologies amplifies the effect of any of them individually so that both the human self and the material world can appear to be much more available for manipulation and transformation (NSF 2002).

8 Including funding for the writing of this paper.

9 Arne Hessenbruch should get credit for this comparison between how some nano folk understand the recombination of molecules pursued in nanoscitech and Lego™. See his "Nanotechnology and the Negotiation of Novelty" (this volume).

10 This is at least partially due to how active both Drexler and the Foresight Institute have been in publicizing nanoscitech. It is also the case that this description offers the kind of sexiness that makes it very attractive to journalists. How nanotechnology is and ought to be represented is a significant issue and one that is being pursued by colleagues here at the University of South Carolina and at Cornell University. The University of South Carolina hosted a conference on "Imaging and Imagining Nanotechnology" in March of 2004.

11 Much of what I argue in this section might well apply to any of the NBIC technosciences, but there needs to be some caution in making such a claim. For example the question of legitimate expertise appears much less vague in biotechnology, while the human enhancement issue is more significant. This might well make a significant difference in the types of issues posed by biotechnology. Of course where the technosciences overlap, the problems do as well.

[12] There seems to be a real difference in the assessment of some of the more optimistic claims in nanoscitech, particularly about the possibility of self-replication, between researchers with a background in computer science and those who come from chemistry. Whether this is a real or apparent difference is worth exploring.

[13] See above: 2. A has good reason to believe that B (unlike A) is in a position to know what would be good reasons to believe p and to have the needed reasons. 4. A believes (and has good reason to believe?) that B actually has good reasons for believing P when she thinks she does.

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