FOCUSED DISCUSSION (invited paper)
Frankenstein in Lilliput: Science at the Nanoscale

Disciplining Nano

Ana Viseu*

Monsters, argues Haraway, are sites of confusion and hybridity, entities that defy easy categorization and, as a consequence, hold promise, pleasure, and peril (Haraway 1991; see also Law 1991). Haraway adds that monsters are also not accidental or innocent: their creation requires sustained work, their existence has effects. Thus, to understand how Frankenstein came to be in Lilliput, the theme of this special edition, it is crucial to examine how monsters are constructed and how they do things in the world.

In this article I propose to start, if modestly, that examination. To do so I draw upon ethnographic data generated at two conferences held in 2005 to investigate some of the processes through which the monster of "nano"—this elusive and emergent entity—was brought to life by social scientists and humanities scholars. My initial goal is to explore how nano was defined, framed, and analyzed at these meetings—on the ethics and history of nano, respectively—and how these different ways of constituting and enacting nano have shaped subsequent understandings of, and interactions with, nano. The article next examines the stances and stakes of those who, through their involvement, became nano practitioners, and the ways in which nano was disciplined through their practices.

A History of Entanglement

Current science policy emphasizes the need to engage with the public so as to increase scientific accountability, foster responsible innovation, and decrease the damaging public backlash (Irwin 2006; Kearnes and Wynne 2007; Royal Society 2004). This has translated into the funding of research on "social dimensions" by most Western governments sponsoring efforts in nano. The United States has uniquely formalized this research as a program component

* Ana Viseu is currently an Assistant Professor in the Department of Communication Studies at York University, where she is also affiliated with the Science and Technology Studies Program. The research presented here was part of her work as a Research Associate on the societal and ethical issues of nano, at the Cornell NanoScale Facility and the National Nanotechnology Infrastructure Network. In her research Ana examines the practices of development and use of emergent (and contested) technologies, from both theoretical and material perspectives. Focusing on the ethnographic examination of technologies that posit the body as the interface between biology and information, she anchors herself on 'cyborg anthropology' and seeks to understand how they are reifying and reformulating notions of identity, embodiment and agency.

area of its National Nanotechnology Initiative (NNI), which coordinates the country's efforts in nano.

The NNI is guided by the 21st Century Nanotechnology Research and Development Act, which Congress passed in 2003. The act lays out a center-based integration model for the NNI and mandates that "ethical, legal, environmental, and other appropriate societal concerns" be "considered *during* the development of nanotechnology" (Public Law 2003, 108-153; my emphasis). To this end, the act requires that any social sciences- and humanities-focused research program identify its areas of concern and be integrated whenever possible with the physical sciences in the process of research and development (R&D). It also requires participating centers to include activities that address these issues within their portfolio. This research program has so far been awarded about 2.5 percent of the NNI's total budget, that is, an average of $37 million per year (see table below).

Investment in NNI's Societal Dimensions Program by Federal Agency since 2006 (dollars in millions) †				
	2006 Actual	2007 Actual	2008 Estimate	2009 Planned
DOD	0	0	0	0
NSF	31.0	34.4	33.8	35.5
DOE	0.5	0.5	0.5	0.5
DHHS (NIH)	4.1	4.2	4.6	4.2
DOC (NIST)	0	0	0	0
NASA	0	0	0	0
EPA	0	0	0	0
USDA (CSREES)	0.1	0.1	0.1	0.1
DHHS (NIOSH)	0	0	0	0
USDA (FS)	0	0	0	0
DHS	0	0	0	0
DOJ	0	0	0	0
DOT	0	0	0	0
TOTAL	35.7	39.2	39	40.3
SD program as % of total NNI budget	2.6%	2.75%	2.6%	2.7%

†CSREESC—Cooperative State Research, Education, and Extension Service; DHS—Department of Homeland Security; DOC—Department of Commerce; DOD—Department of Defense; DOE—Department of Energy; DHHS— Department of Health and Human Services; DOJ—Department of Justice; DOT—Department of Transportation; EPA—Environmental Protection Agency; FS—Forest Service; NASA—National Aeronautics and Space Administration; NIH—National Institutes of Health; NIOSH—National Institute for Occupational Health and Safety; NIST—National Institute of Standards and Technology; NSF—National Science Foundation; USDA—U.S. Department of Agriculture

Elsewhere I have argued that there is a pressing need to review the actual workings of this integration and funding structure (Viseu in review), because power asymmetries are not effaced in "integration" and those stakeholders with the most power are able to control what is studied, by whom, and how. Here, however, I want to take a more historical perspective to examine the early incursions of social scientists and humanities scholars into the field of nano.

Alfred Nordmann has argued that the work of maintaining nanotechnology's "reality" is being conducted not by scientists but "by advocates and activists, visionary policy makers, scientists when they speak to the public or argue for future funding—and by philosophers, ethicists, and social scientists" (2007, 223). He goes on to say that it is the latter who "have … been recruited to do some of the work that is required to convince a larger audience that 'nanotechnology'… [is a] meaningful concept" (2007, 223). "The principle at work here," says Nordmann, is that "if it has social impact, it must be real" (2007, 223). One can disagree with Nordmann on the grounds that this construction would have taken place independently of the work of social scientists and humanities scholars, but there are at least two reasons why Nordmann's argument is important. First, the engagement of the "soft" sciences with nano is palpable. At the latest of the annual meetings of the Society for Social Studies of Science and the European Association for the Study of Science and Technology, at least twenty-nine papers had the word "nanotechnology" in their title and many more focused on it. A new journal, *NanoEthics*, was created in 2007, and a Society for the Study of Nanoscience and Emerging Technologies was established this year. Secondly, as the example of genetically modified food so well demonstrates, science is made not only in the lab but also in the media, in politics, and in legislation. If such a process is not innocent, then the research of social scientists and humanities scholars is not either. Examining the engagement of these scientists and scholars contributes to our understanding of how nano was created and what it is today.

The Ethnographic Settings

The two nano conferences that I examine here were held within two weeks of each other and some of the participants and presenters were the same in both. The first, on Nano Ethics, was held at the University of South Carolina on March 2-5, 2005 and was organized by the nano Science and Technology Studies (nSTS), which in turn was one of the earliest recipients of funding by the National Science Foundation for the study of nanotechnology's social dimensions. This conference was attended by over sixty participants from around the world, most of them with a background and interest in philosophy and or ethics. It comprised eighteen sessions, some running in parallel, and featured high-profile speakers, such as Mike Roco, one of main the architects of the NNI, Kevin Ausman of the Center for Biological and Environmental Nanotechnology, and Jean-Pierre Dupuy, a French philosopher from the École Polytechnique and Stanford University. The second conference was held on March 18-19 at the Chemical Heritage Foundation in Philadelphia, and it explored the theme of "Nano before

There Was Nano: Historical Perspectives on the Constituent Communities of Nanotechnology." As the title indicates, this conference took a historical slant—I will henceforth call it "Nano History"—and the majority of those in attendance had a background or interest in the discipline of history, but it also featured a panel with practitioners from the hard sciences. Organized by Cyrus Mody,[1] it was a small, intimate conference with about twenty-five participants, most of whom were also presenters in the meeting's four panels.

I attended both conferences as part of my new position as research associate with the Cornell NanoScale Facility, where I coordinated efforts on the societal and ethical dimensions of nanotechnology. I took detailed notes of the talks which I later analyzed to understand emerging topics in nano. It is not my goal here to provide an exhaustive description of these events.[2] Instead, I will focus on a topic that was recurrent at both, that of attempts to define, label, and categorize "nano." Determining the subject matter of a field is important, because it puts in place different entities, thus organizing the world and experience in different ways. It also steers research in particular directions, making some contributions and interactions possible while excluding others. Understanding what different definitions of nano entail, how they are positioned within distinct frameworks, and how they "do" things is what I turn to next.

What is Nano?

Efforts to characterize and demarcate any discipline are instrumental to the creation of boundaries, shared spaces, and identities of belonging, ultimately affecting funding and academic and disciplinary status (Bowker and Leigh Star 1999). Accordingly, it is no surprise that such efforts were staples in all sorts of nanotechnology symposia, talks, presentations, and publications. *Nature Nanotechnology*'s first editorial, for instance, was titled "Small Is Different" (2006). Making nano "different" makes its research and funding worthwhile, but it also has implications for how it should be studied and by whom. This was certainly true of the Nano Ethics and Nano History conferences; at both, size or fabrication methods (bottom-up and top-down) were often cited as the defining characters of nano. But three other issues were recurrent topics of discussion at these conferences: hype, science versus technology, and old versus new.

Examinations of the role played by hype in the shaping of the field of nanotechnology featured prominently at both conferences, with presentations on nanotechnology's revolutionary rhetoric and examinations of media and fictional accounts of looming disasters such as Drexler's (1986) and Crichton's

[1] Currently an assistant professor of history at Rice University.

[2] For this reason I will focus not on the individuals who spoke at these meetings but on the ideas they expressed.

(2002) infamous "grey goo".[3] Rather than being viewed as external and parasitical, the consensus was that hype is a constitutive part of nano. From this standpoint, one cannot study nano without looking at the hype. (Less visible was the opposite position, that one cannot study the nano hype without examining the nano science.) It was also argued that nano hype fulfils an important role: it reinterprets the small, incremental character of scientific practices, awarding nano a revolutionary character that can then be successfully used as a catalyst to obtain funding and media attention (see, for instance, Hessenbruch 2004).

Practitioners present at the Nano History meeting legitimized this proposition by expounding on the notion of hype. Yet they conveyed a distinct approach to it. Hype was described as "nano-baggage" and practitioners argued that nano had plenty of it. This nano baggage was considered both a distraction—which forces researchers to spend time engaging with non-scientific audiences to explain what they do—and a springboard to funding. Nano practitioners were careful to distance themselves from the hype, emphasizing that their scientific practices (mostly in the well-established disciplines of chemistry and physics) have not changed but instead have just been relabelled as nano. We may want to critically examine such assertions, since what seems to be emerging is a will to take advantage of the (funding) opportunities afforded by nano's revolutionary discourse while foregoing its revolutionary promises.

The discussion of the character of nano also revolved around traditional dichotomies, namely, is it a science or a technology? Is it old or new? On the first issue, science and technology are too often presented as unquestioned and unquestionable opposites: science is abstract, technology is applied; science is pure, technology is utilitarian; science is unaccountable, technology suggests responsibility. Rather than critically examining the assumptions and rationales that underlie these representations, participants at both conferences used them as starting points for analysis or as foundations onto which to build their own proposals for, say, the ethics of nanotechnology or codes of ethics for nano engineers.

Scholars from the field of science and technology studies (STS) have long called attention to the problems of dichotomies. Within STS, dichotomies appear as instruments of power (Haraway 1991; Latour 1993), constructs that are used to organize reality and experience. In a well-known rebuttal of the compartmentalization of the world, Latour argues that we should "direct our attention simultaneously to the work of purification and the work of hybridization" (Latour 1993, 11), that is, we should study the processes through which difference and hybridity are constructed, so as to understand their rationales and politics. The example offered by James Murday at the Nano History meeting is telling. Murday is a scientist at the Office of Naval Research and Naval Research Laboratory who was actively involved in the creation of the National Nanotechnology Initiative. He explained that using the word

[3] In *Prey*, Michael Crichton (2002) posits a scenario where all matter becomes grey goo, a mass of runaway and out of control nanorobots.

"nanotechnology" rather than "nanoscience" in the naming of the NNI was a strategic move that reflected the recognition that Congress provides funding for technology—deemed to create jobs and revenues—but not for science, deemed to apply to knowledge production. Murday later added that "we called it nanotechnology and spent the next five years apologizing for it. It was politically well-named but not scientifically." The recognition that each of these terms carries a particular political strength is an important acknowledgment not only of the situated and social character of science and technology but also of the connections between these two terms. Unfortunately, these connections were, for the most part, absent from the discourse of conference participants, especially at the Nano Ethics conference.

The second set of dichotomies—is nano new or is it old?—is just as problematic. Leaving aside the issue of whether an argument should consist of a set of binary choices, I believe that questioning the age of nano is a misguided effort for it not only reveals little about the practices of those who constitute the field but also ignores the fact that nano could be both old and new. That said, however, the question of nano's age does illuminate the stances of those raising it, and so is worth examining.

If nano is a new field or discipline, then it must have an equally new praxis, values, methods, and so on. If it is old, then it has a story that can be uncovered through careful archaeological work. Not surprisingly, historians have tended to defend the "old" position. History is, after all, the study of incremental change; it relies on continuity. The philosophers and ethicists, however, emphasized the notion of the emergence of a new discipline, hence justifying the need for the creation of a new subdiscipline of "nano ethics" and the allotment of both intellectual and material resources for its study. One example that was frequently mentioned was that of bioethics, a field that grew out of initiatives in bioengineering and genetics and that has since been recognized in policy and scientific circles as legitimate (McCain 2002; Wolfe 2000).

One of the outcomes of the debate at the Nano Ethics conference was a call for introspection from within the ranks of nano ethicists. This exercise in self-reflection pointed to a number of questions, technical and non-technical, that should be adopted by other disciplines currently involved in the study of nano. These questions concerned a variety of issues, from the ethics of establishing a field of study that piggybacks on a science of "unrealistic visions" to the problems inherent in being funded by the same entities that one is attempting to study—in such circumstances, how critical and independent can researchers be? Can they bite the hand that feeds them? Finally, the debate on nano's age touched upon the problem of compartmentalizing reality: Should each technology have its own set of ethics? What is lost when reality is split into small slices?

The Nano History conference was not immune to self-reflection, and one point raised there that warrants further discussion is how to incorporate a field that is emergent and oriented towards the future (nano) with one that is traditionally oriented towards the past (history). In many realms, especially those pertaining to emergent technologies, the "future" has become a legitimizing space where the present is played out, simultaneously validating the feasibility and desirability of the techno-scientific initiatives. Questioning this category is crucial, and one of the ways in which it is being successfully done is through historical studies of past "emergent" technologies.

The emphasis on disciplinary self-reflection fell short of my expectations in one important respect: there was a noticeable lack of calls for, or even encouragement of, empirical engagement with the actual world of nano fabrication, for instance, the research laboratory. While a view from above is necessary, in order to understand what nano is and how it operates in our world, it must be complemented with empirical examinations of the actual practices of nano research and development. Empirical studies of practices sheds light on the many factors—classifications, values, morals, methods, contingencies, personnel, and instrumentation, among others—that constitute nano-technoscience. These studies are all the more important given the intimate and complex depictions that scientists at these conferences gave of their work, speaking for instance, of the ways in which they "get to know molecules as individuals," of being "politically an anti-nano," or of rebranding their work as nano so as to take advantage of funding opportunities.

Conclusion

This short analysis has not done justice to the richness of these two conferences, but it has singled out an important issue, namely, the sorts of entities that we—social scientists and humanities scholars—are creating and disciplining. Nano, as described in these two conferences, is composed of dimensions other than reason, science, and technology, a point illustrated by the discussions on hype and rhetoric. However, and somewhat surprisingly, nano here relies too often on the juxtaposition of dichotomies of science versus technology and new versus old. Viewing the world in terms of dichotomies, ontological categories, and causes and effects is not productive for at least two important reasons: it reifies problematic categories, rather than calling them into question; and it disregards the constructed and distributed character of the world, that is, its multiple shades of grey, multiple voices, and movements of support and resistance. It is important that social scientists and humanities scholars work together to examine how boundaries are erected, how categories emerge, and what roles they play.

Nano also emerges as a disciplined site of study, not only in terms of its age or novelty, but also in regard to the methods that should be used to study it. In discussing what "counts" as a social issue in nanotechnology, Lewenstein argues that "the exercise of power has been hidden in the definition of what is

legitimate to study" (2005, 211). What is being defined here is the very identity of nano and the ways in which it is being disciplined by different constituencies to the detriment of others. This brief analysis points to the need to continue establishing a dialogue between the sciences, the social sciences, and the humanities so as to find a common ground and vocabulary. The Nano History meeting offers a good example: on the one hand, practitioners recognized that the multiplicity of applications for nano requires them to be able to communicate to disciplines other than their own; on the other, some described the need to engage with the general public as a "distraction."

Since, as stated above, definitions are not innocent or neutral but instead "do" things in the world (Martin 1994; 1999), it is necessary to go a step further to examine the relationships between these standpoints and current engagements with nano. A 2007 literature review by Kolberg and Wickinson (2007) found that issues of governance, perception, and philosophy dominate the literature on the societal and ethical dimensions of nano at a rate of about 90 percent.[4] The prevalence of these themes has implications for the kinds of contributions that can be made in the field of nano. Issues of public acceptance and governance are important and necessary, but it is equally important not to fall into the trap of what one participant described as the "dark side of deliberation," which transforms society's engagement with science into the subject of a research seminar.

Kolberg and Wickinson (2007) also found that science—that is, work that focuses on the practices of scientists and engineers—accounts for less than 10 percent of the published literature on nano's social and ethical issues. There may be numerous reasons for this, access to field sites being perhaps the most obvious, but this is an important issue that deserves further examination. If our goal is to engage with nano so as to understand, open up, and perhaps shape its research and development trajectory, then the research portfolio must be diversified so as to include neglected areas. I have suggested here that one way in which this can be done is by engaging in fieldwork and experiencing (and reporting) the richness and multitextured reality of laboratory work.

I started this article by discussing the issue of monsters: monsters as hybrid entities that defy categorizations and thus open up the realms of possibility; monsters as sites of promise and peril (Haraway 1991; Law 1991). Nano is a good example of such a monster. Lying at the intersection of nature, science, and society, it is an emerging field and so is open to different ways of being. But monsters are also sites of responsibility and accountability—their creation is not an innocent or neutral act. The early engagement of social scientists and humanities in the development of nano makes them more accountable for the resulting entities. The solution is not to engage in what Latour calls "exercises in purification" (Latour 1993; see also Suchman 2007) that are compliant with

[4] The distribution is as follows: 40% governance, about 33% public perception, 15% philosophy.

existing categorizations and drive a further wedge between techno-science and the social. Neither is it to disengage or disentangle from nano (Nordmann 2007). Instead, it is important to engage but to engage in ways that problematize and analyze nano as it is articulated within cultural imaginaries and the practices of scientists, engineers, lawyers, and policy makers. The goal is to help foster the most hopeful monsters.

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ANA VISEU
Assistant Professor
Department of Communications
York University
Toronto, Ontario
Canada
+1-416-736-2100 x.20329
aviseu@yorku.ca
http://www.yorku.ca/aviseu

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