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RESEARCH ARTICLE

A Nanochemist and a Nanohumanist Take a Walk Through the German Museum: An Analysis of the Popularization of Nanoscience and Technology in Germany

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This paper is an analysis of the NST (Nanoscience and Technology) exhibit at the DM (Deutsches Museum) from the point of view of a German studies scholar and a nanoscientist. Established in 2005, the exhibit and its associated lectures, tours, and documentation purport to make the public more familiar with the new technology and its applications. Our task was to evaluate the science as it is presented and, equally importantly, the story the museum tells about NST, since science can never be isolated from its cultural narrative; it can never be culled from the culture in which it is embedded despite our penchant for a neat division between these two realms. By evaluating the science as it is presented in the museum and considering it within its German cultural context, we offer an analytical overview of NST in the public sphere. Secondly, we cast our eye toward discerning the 'why' of the exhibit. Is it designed to civilize and enlighten and thus empower the public in their understanding of NST as an emerging technology? Does the exhibit have a propagandistic aspect designed to sway the public in hope of avoiding the difficult struggles that have embroiled emergent technologies in the past? Or, is the nanoexhibit a hybrid of each approach intended to both enlighten and sway?

Keywords: nanotechnology; Germany; Deutsches Museum; Museum

Introduction

The official definition of nanotechnology used by the German federal government includes the following characteristics: 1) the application of scientific knowledge for the purpose of producing materials and systems that have at least one dimension of anywhere from 1 to 100 nanometers (one nanometer equals a billionth of a meter); 2) the use of the characteristic effects and phenomena that exist in the transitional area between the atomic and the mesoscopic; and 3) the explicit production or manipulation of nanostructures (Bundestag 2004).

Because of the extraordinary promise associated with nanoscience and technology (NST), it has become one of the most hyped scientific and technological terms of recent times, and the hype can blur the line between the science and its associated fictions. Popularization efforts like museum exhibits are often intended to allay such hype and give the public a realistic impression of this important, emerging science. Indeed, Wolfgang Heckl, director of the Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik (The German Museum of Masterworks of Science and Technology), more commonly known as the Deutsches Museum (German Museum), calls NST a twenty-first century 'key technology' (Breitsameter 2009: 6). This paper is an analysis of the NST exhibit at the Deutsches Museum (DM) from the point of view of a German studies scholar and a nanoscientist.

Established in 2005, the exhibit and its associated lectures, tours, and documentation purport to make the public more familiar with the new technology and its applications (Geiger 2005). Our two main goals are to evaluate the science as it is presented and the story the museum tells about NST, since science can never be isolated from its cultural narrative: it can never be culled from the culture in which it is embedded despite our penchant for a neat division between these two realms (Durant 1996: 154–55). By evaluating the science as it is presented in the museum and considering it within its German cultural context, we offer an analytical overview of NST in the public sphere.

Secondly, we cast our eye toward discerning the 'why' of the exhibit. In his ground-breaking work *Museums of the Mind* Peter McIsaac emphasizes that, historically speaking, the role of museums was to exert 'a civilizing and enlightening effect on public behavior' through so-called 'civilizing rituals', and in Germany such rituals are generally 'related to the important and evolving concept of *Bildung*' - often simply translated as education (2007: 14). McIsaac

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is closer to the mark when he defines *Bildung* as 'the contemplative aesthetic cultivation of the self' (2007: 3). With regard to the exhibit at hand then, is it designed to civilize and enlighten and thus empower the public in their understanding of NST as an emerging technology? Or, does the exhibit have a propagandistic aspect designed to sway the public in the hope of avoiding the difficult struggles that have embroiled emergent technologies in the past.[1] That is, does it adopt the 'deficit model' of popular scientific comprehension maintaining that public understanding of science is 'a homogeneous product delivered from a unified scientific community to an undifferentiated public' (Toumey 2006: 83)? The primary reason for bolstering the popular understanding of science in such a view is 'to secure public support for [further] funding of science' (Toumey 2006: 83). Therefore, a final possibility would be – is the nanoexhibit at the DM a hybrid of each approach intended to both enlighten and sway?

Our premise is that science and technology are fundamental components of culture, not merely existing side by side with art, politics, religion, etc., but woven throughout those other aspects of culture we like to think of as separate from science. They are not merely 'co-extensive with either culture or humanity', as the biologist Paul Grobstein (2005: 13) suggests, but rather deeply socially situated. As such, science and technology are not just demanding of a certain methodology, but also of an ability to tell a story like any other aspect of culture. Grobstein points out that science 'can and should be the ongoing creation, revision, and recreation of stories about humanity and its place in the universe' (2005: 13). Such stories are not crafted solely in the scientific laboratories of the world, but also in the public imagination. The places where scientific observations and conclusions are collected and told as stories are always both a reflection and an assertion of the extraordinary power of science. The nanoexhibit at the DM is a key example of such a repository of power and significance. Before delving more deeply into this exhibit, it will be helpful to provide some background on science and technology museums and their role in German culture.

Science Museums

The question as to whether science and technology museum exhibits are designed to enlighten and empower the public vis-à-vis technologies like NST has a long history in Germany. In his influential essay 'The Plan for the Development of a Mechanical Trade Class' (first published 1749), Johann Julius Hecker bemoaned, 'Among other things, one finds in natural history collections models of buildings, water works, instruments, etc., that are of little use because they only serve as objects of curiosity for strangers and through-travelers' (1966: 7).[2] In addition to the collections that served as proto-science museums, science actually took place in such cabinets and was not fully replaced by the laboratory until the nineteenth century. Indeed, as McIsaac points out, in the eighteenth century, the very idea of museum 'tended to be understood as a cognitive field of ideas, words, and artifacts – potentially a place, but very often a text' – a much more abstract understanding than our modern one (2007: 10). Hecker believed that the cure for science-as-curiosity, and for such abstraction, is the creation of a place – a mix of school and artifact collection/lab – where young people could be shown such things and therefore taught 'the important aspects of mechanical arts, crafts, and occupations in an easily understandable and historical way' (1966: 7). In addition, to comply with the old hierarchy of knowledge, such collections of scientific artifacts were suitable for display at a new type of school called a 'Realschule' and presumably not at 'Gymnasien', where the 'more important work' of culture was being carried out. One sees in Hecker's thoughts the close connection between museums and education. In fact, Barbara Mundt (1974: 18) maintains that this connection served as the impetus for the growth of science and technology museums throughout Europe. The efforts to found the Trade Museum in nineteenth century Berlin that was eventually opened in 1868, for example, were based on a combination of educational institution and artifact collection.[3]

The movement to marry museum and education is relevant to this analysis because, as Karlheinz Fingerle maintains, Oskar von Miller, the founder of the DM, was inspired by the strengths and weaknesses of museums in France and England. In seeking to establish a decidedly German museum of science and technology, Miller noted that a lack of emphasis on *Bildung* was a weakness in the French museums. In this way he was following a long line of German critics of the French museum impulse that included Wilhelm Humboldt, Heinrich von Kleist, and Karl Friedrich Schinkel, among others (McIsaac 2007: 59). Indeed, Miller's analysis of the Conservatoire des Arts et Métiers and Britain's London-based South Kensington Museum lead Fingerle (2005:12) to conclude that Miller demonstrated both a democratic inclination and pedagogic intentionality, following in the tradition of Humboldt and Schinkel who 'expended considerable effort to promote *Bildung*... through museums' (McIsaac 2007: 59). In the DM, therefore, Miller conceived a place where science was practiced; was inseparably linked to its wider, practical application; and then was taught, according to a limited understanding of teaching, to a broader public. This focus can also be seen in the by-laws of the museum discussed below. Moreover, Miller was writing in a post-Goethean era in which *Bildung* included science.

Despite such an emphasis on *Bildung*, scholars in the latter half of the twentieth century called into question the effectiveness of the pedagogical intent of museums. Reuter-Rautenberg and Simons characterize the first century of museum development as an 'early euphoria' that has since been interrupted by a more sobering look at the role museums actually play as opposed to the role they purport to play (Reuter-Rautenberg 1983: 23). Fingerle (2005: 31) points out that museums like the DM are also tourist destinations and places to spend the considerable free time average citizens have enjoyed since the industrial revolution. Durant goes further and correctly identifies science and technology museums as a part of the 'visitor attraction industry' (1996: 148). Beyond this recreational

role, they also occupy space in the public imagination as 'temples of genius': Fingerle writes, 'although the DM was conceived from its beginning as an "educational establishment in the grand style," it also has characteristics associated with a temple dedicated to genius' (2005: 37). As proof of this claim, he cites a 1984 article published in the magazine *GEO* by Alexander Rost (1984: 37) under the headline 'Treasure Chamber of Genius'. Such a characterization, clearly alluded to in the full name of the DM, implies that museums are places where genius is displayed in a manner to inspire the public to something higher.

The pedagogical nature of museums is further cast into doubt by an empirical study conducted by the German sociologist Heiner Treinen (1981: 18) who concludes that museums are decidedly not places of learning, but rather media of mass communications. It is not that one cannot learn in such a setting, it is simply that the museum setting does not foster learning *per se*. He characterizes a typical museum visit as cultural window-shopping in which the visitor displays a respectful but aimless curiosity. As such, the visitor cannot hope to have learned anything that would go beyond his or her short-term memory (Treinen 1981: 25–30). The most one can hope for is that the experience carries on informally into conversations with others and becomes retroactively effective.

Treinen's description of science and technology museums as sites of media of mass communication is an interesting analogy. A museum can be seen as a medium in that it communicates science, but does not necessarily teach it. The aimless curiosity that Treinen points to is akin to the way many users experience the Internet as a medium, for example. Seeing a great deal in a fleeting manner and hoping something stays with the viewer is another way of putting it. In order to avoid such criticism, a museum needs to go beyond the browsing-in-the-temple-of-genius approach – it must tell a broader story by showing a full context. Maria Osietzki (1984: 6) goes so far as to claim that museums, in the past, have simply ignored the social, economic, and cultural contexts of scientific and technological developments in their zest to popularize. They concentrated on so-called masterworks such as the first German automobile, the first diesel motor, and the first program driven computer – all in the DM. Such collections offered, in the words of Durant, 'a largely celebratory account of humankind's progressive mastery of the natural world' (1996: 156). It is difficult to proclaim and honor genius, for example, when there are distinct disadvantages and even dangers associated with many of these ingenious developments. It is however critical that a museum designs its exhibits in such a way that the broader sociocultural context is shown. This includes, but is not limited to, discussions of the politics, economics, and ethics of the scientific and technological developments, as well as an analysis of the consequences of such developments. The complete narrative surrounding the exhibit tells of the 'formation of a collection' and 'the stories people tell about [the collection itself]', but also reflect, as McIsaac points out, 'the values placed on the collection's objects' (2007: 13).

Based on the history of the development of science and technology museums and their purported mission, the questions we address are as follows: 1) Does the nanoexhibit at the DM educate the German public in terms of both the science it represents and the socio-cultural context within which it exists, including an analysis of the pros and cons of NST? 2) Does the exhibit have an air of a 'temple of genius', and does that air detract from the proper contextualization of NST? 3) Is there a corporate or political bias in the exhibit that would suggest an effort toward propaganda?

The DM in its Own Words

The best place to begin such an analysis is with the 'Satzung' or articles of incorporation of the DM. The self-proclaimed 'world's largest technology museum' was founded in 1903 and, given the events of twentieth century German history, has undergone many changes since its early establishment. Its latest articles of incorporation were updated in May 2011, but before looking at it, a brief word on the official name of the museum is in order. 'The German Museum of Masterworks of Science and Technology' stems from the turn of the twentieth century, and it bespeaks some of the concerns mentioned above. The use of the word 'Masterwork' is of course problematic. It implies a not-sufficiently-critical 'temple of genius' approach and an emphasis on the presentation of a series of products rather than science as a social process (Porter 1993: 25). If the museum is to house only masterworks, it is difficult to assume there will be much assessment as to the consequences of such works or even an analysis of their broader cultural context. And context is necessary because, as Butler aptly points out, 'objects can never unambiguously speak for themselves – they need to be read' (1992: 125), and it is the task of the museum to assist in writing the story for the public to read – precisely the narrative nature of museums McIsaac so expertly describes. There is also no hint of pedagogy in the name, but such an approach would have been assumed at the time of the founding of the DM. Moreover, the fact that it is specifically the 'German' museum and not simply the 'Museum of Masterworks of Science and Technology', signals Miller's intent to display decidedly German 'masterworks' and also emphasizes his interest in carving out a specifically German approach to displaying these works – an approach founded on the concept of *Bildung* that, by the time Miller was writing, comfortably included science in its understanding of self-cultivation.

Beyond a consideration of the name of the museum, one need only leaf through the articles of incorporation for an explicit discussion of the mission. Under the title *Aim and Mission*, one reads:

> 'The aim of the [DM] is to explore the historical development of natural science, technology, and industry; to show their reciprocal effects and cultural meaning; and to illustrate and document their most important stages through educational and stimulating exhibits especially as they relate to

> eminent and prototypical masterworks' (Deutsches Museum Satzung 2011: 3).

The museum therefore purports to highlight the most important stages in the history of science and technology. It also aims to contextualize the results by emphasizing the reciprocal effects of the scientific and technological developments, and by emphasizing their cultural meaning. The word 'educational' provides the obligatory nod, so to speak, to the pedagogical intent of the museum. It seems museum leaders hope that the 'stimulating' and 'eminent' nature of the masterworks, and the way they are displayed, will spark a learning process.

After emphasizing the non-profit nature of the museum in the second aim, the third aim is the most explicitly pedagogical, coupled as it is with research: 'One aim of the Deutsches Museum is the advancement of education and scientific research' (Deutsches Museum Satzung 2011: 3). Underneath this third goal, one sees that the display of collections of scientific instruments and apparatuses, as well as originals and models of eminent works of technology is a sub-goal central to the mission of the DM. The next two sub-goals relate to the public nature of its research and educational functions. The first sub-goal highlights the fact that 'scientific works, publications, and speeches, in particular in the Institute for the History of Technology and Science' (Deutsches Museum Satzung 2011: 4), are required. Such a requirement is an attempt to address the concern that museums have evolved from the era when they stood at the forefront of knowledge production to places where science is merely communicated, but not actively practiced. In the final sub-goal there is a discussion of 'educational training' characterized by public talks, guided tours, courses, symposia, and the production of educational materials.

From these articles, it is clear that the DM attempts to follow the centuries old tradition in German Museums of shaping a *gebildetes* (aesthetically cultivated) public. While there may be a hint of the 'temple of genius' in the 'Mission and Aims', a hint is not necessarily enough to undermine the museum's approach to its mission. There are then two further questions for the observers: 1) Does the whiff of the 'temple of genius', so to speak, prevent the museum from providing a critical analysis of emerging technologies like NST? And 2) Is the NST exhibit constructed in such a way that it supports the museum's educational mission?

The Exhibit

The organizers of an NST exhibit face certain challenges that those developing other types of science and technology exhibits do not. In the nineteenth century, for example, geology and natural science museums were wildly successful because the science in which they partook and the artifacts they exhibited, were tangible and comprehensible, and were therefore romanticized and popularized (Knell 1996: 31). In contrast with more abstract sciences, geology and natural science were relatively simple to display and therefore less challenging for the public to grasp.

NST's problem lies in its often abstract nature. It is simply not possible for a human being to imagine a nanometer. The field is therefore rife with metaphors designed to help with this problem. For example, a nanometer is to a meter as the distance between Boston and New York is to the distance between the planet Earth and the Sun. The website of the US National Nanotechnology Initiative points out that a single sheet of paper is approximately 100,000 nanometers thick. However, apart from indicating that a nanometer is very, very small, such metaphors are not helpful because one simply cannot conceive of anything that tiny. How then does one effectively exhibit the inconceivable? This is an important question given that museums function to exchange, collect, and assign value to *objects* in a given society during a particular era (McIsaac 2007: 90).

The answer lies partially in the shifting role of some museums from their traditional concrete and practical focus to that of a science center with a more abstract, affective domain (Simmons 1996: 81) and partially in the negotiated boundary between science and technology. Durant writes of the dominance of technology in many science museums simply because it is concrete and visually impressive. Science is just the opposite – it is unobtrusive and not always obviously useful in a practical sense, for 'where technology aims to master the forces of nature, science seeks merely to delineate them' (Durant 1996: 153). In NST, however, one does not experience the science and technology divide in quite the same way. NST is not necessarily visually impressive and it requires great explanatory leaps to get to its practically useful side. Given the subtle nature of nanotechnology there is not the usual tension 'between the nature of science as a process of discovery and the nature of the museum as a repository of material culture' (Durant 1996: 154). As you will see below, the NST exhibit at the DM is especially effective at balancing a presentation of the scientific process with the repository nature of a museum.

To reach the NST exhibit in the DM, one negotiates what McIsaac (2007: 93) terms a semiotically encoded route. It is intended for one to begin by going through the Hall of the German Future Prize – a prestigious award presented annually by the President of Germany for outstanding technical, engineering, or scientific innovations that can be turned into marketable products. The emphasis in this exhibit therefore seems to be on practical use, not only process. The room is a dark, futuristic and somewhat uninviting space dedicated to prize-winning scientists like Nobel Laureate Peter Grünberg. There are few places in the museum that are better examples of a 'temple of genius'. The visitor has the feeling of being in a place of respectful, pensive worship that most certainly has the effect of separating these leading German scientists from the rest of German society. In this instance, however, such a separation is positive because in a society where hero worship consists primarily of popular culture media figures, it is appropriate that this room be dedicated to people who have demonstrated courage and risk taking ability in the name of science and technology. This space is an effective and useful entrance to an exhibit dedicated to an emerging

technology. Moreover, the 'temple feeling' is abandoned by the time one reaches the NST exhibit. Even though there is a 'Founders Gallery' within the nanoexhibit, it does not dwell on these personalities. It emphasizes the science rather than the heroes of the science which is fitting given the interdisciplinary nature of NST, and the fact that when there are breakthroughs in NST they are generally made by scientific teams and not individuals.

After leaving the room dedicated to the Future Prize, one enters the large, open, naturally lit space that houses the NST exhibit. The first thing one's eye is drawn to is the open DNA laboratory shaped like a science fiction spaceship that is in fact referred to as the UFO. Given its elevation within the exhibit, it is quite literally the 'high point' McIsaac refers to in his discussion of the encoded route:

> 'The high point is usually demarcated by semiotic encoding [for emphasis]. Highly valued objects might be set off from other objects spatially or with special lighting, placed in the largest room, or put at the end of a path. Likewise, interpretive markers and texts reinforce the semiotic encoding, thus further heightening the sense of having reached a culmination' (2007: 93).

McIsaac's description perfectly captures the nano-UFO hovering above the NST exhibit. The encoding is not particularly complex. The lab space is intended to announce 'the future is here', so to speak, and, in many ways, NST represents the future of science given its emerging and interdisciplinary nature. The lab supports the mission of the museum by offering the public a hands-on opportunity to conduct simple experiments, thereby making the science feel more accessible. Beyond public engagement with science, it also makes the point that this exhibit is not solely about the technology, but also the scientific process, which can be equally impressive in its presentation. After the UFO, one's eye is necessarily lowered to the labyrinthine exhibit itself that seems to be beckoning the visitor to an adventure. To enter the labyrinth, one descends the dramatic stairs that border either side of the open lecture seating that gives the entire space a theatrical feel. Thus from the very entrance one has the sense of beginning a dramatic adventure into the new nanosized world.

While overall the exhibit itself is effective – the science is accurate and the story is not simply a 'celebratory account of humankind's progressive mastery of the natural world' (Durant 1996: 156), but as complete a contextualization as one might expect – there are however a few issues that can be addressed. The exhibit for example begins in a somewhat confusing manner with the display of two butterflies. What is probably meant to be an aesthetically pleasing enticement designed to attract the viewer comes across as unclear. A scientist's first thought turns to the so-called 'butterfly effect' and its role in complexity science and not NST. On turning the corner however one gleans that the butterflies are there to illustrate the nanostructural surface of the wing and to emphasize that nano is everywhere in nature. The exhibit then emphasizes the idea that manufactured, nanosized products have been around for centuries. For example, the process for producing leaf gold is over 4000 years old and dates back to classical Greece. The opening seems to be designed to allay any concerns the public may have that this emerging science is completely new or even somehow 'unnatural'. The problem with the way the introduction is designed, however, is that the viewer still does not really know what NST is, so the discussion of how it is all around us and always has been present can be lost on the visitor.

After the opening, the visitor simply follows the labyrinth and is introduced to many of the key concepts of NST, as well many of the social issues surrounding it. One particularly compelling aspect of the exhibit, designed to engage the public in different controversies surrounding NST, are the media stations that contain recorded opinions by scientists on such matters and the way they relate to NST or biotechnology. The visitor sits down at the media station, is introduced to an issue, given three strongly worded opinions on it, and is then asked to vote to agree or disagree with the stated opinion – very different from the deficit model of scientific understanding outlined in the introduction. Far from showing NST as yet another step by humankind in its eventual overcoming and domination of nature, the recordings discuss some of the conceivable dangers surrounding NST like the possible toxic effects of nanoparticles, the controversies surrounding genetic manipulation, and even gene testing. One particularly unfortunate recording however deals with the topic of 'out of control nanobots' (nanoscale machines that are self-propelled, able to reproduce, and autonomous). We assume that the term nanobot was included because if it were not, people would wonder where the nanobots were, given that the term is so present in the US popular understanding of NST. The problem is that nanobots as conceived by Eric Drexler in his nanovisionistic work *Engines of Creation* (1986) are not feasible, particularly in the way they are popularly conceived as independent, self-reproducing entities. They are a peculiarly US imagining that holds very little truck in the German NST community or the mainstream NST community for that matter. The consensus is that nanobots are not something German society needs to fear in the foreseeable future. The inclusion of such a discussion therefore detracts from the otherwise effective story of NST the museum offers the public.

The discussion of nanobots leads to one of the most interesting but problematic displays in the exhibit, that of biomolecular machinery – the complex structures designed to illustrate important biological functions such as muscle contraction movement driven by the use of the body's energy saver, the ATP molecule. The models are mechanical in nature and look very much like ordinary machines, complete with a conveyor belt. They are built in such way that the visitor controls the start of the process and observes this 'machine' in action. It is truly one of the exhibition's highlights from the standpoint of a scientist familiar with the concepts and processes and for its visual impact. The model falls short in engaging the scientifically uninitiated. A more informative explanation of actual effects and the fuel for these machines in our bodies would enhance the exhibit greatly. Another welcome

touch would be to show ribosomes –responsible for the transfer of genetic information into tangible, biologically relevant molecules and some of the most complex biological mechanisms in the body. Ribosomes are also highly biotechnologically relevant as gene translators and protein constructors, and therefore would have been an effective addition.

Even though the ATP exhibit is very impressive in the way an exhibit should be in a repository like the DM, the whole mechanical nature of the display is problematic. It sends the message that our bodies and the components that comprise them are machines. The machine metaphor is reinforced throughout the exhibit as well as in the accompanying booklet, *Nano- und Biotechnology in the Center for New Technologies* (2009) – another manifestation of McIsaac's encoded routing. Here, Walter Hauser writes, 'Biologists have learned not to consider a cell as merely a biochemical reactor, rather as a complex factory made of molecular machines all networked together' (Breitsameter *et al.* 2009: 17). While the machine-factory-network metaphor is colorful, it will certainly be troubling to those who prefer a bright line be drawn between human and machine. And while we understand that many think of these systems as nature's machines, such a mechanical presentation underplays the importance of chemistry, among many other things. The standard criticism of Drexler's idea of self-replicating machines, for example, is that he does not take basic principles of chemistry into account.[4] Such a mechanical representation calls to mind the famous quotation from Neil Postman, 'to a man with a pencil, everything looks like a list. To a man with a camera, everything looks like an image. To a man with a computer, everything looks like data' (Postman 1993: 14). In other words, to a group of people, like scientists, beholden to the machine in its various forms, does everything eventually look like a machine?

Another potentially confusing message is sent by the spatial conflation of biotechnology and nanotechnology. Hauser clarifies the intellectual justification for this in the exhibit booklet. He explains that as the concept of 'synthetic biology' becomes well known thanks to recent developments in molecular cell biology along with the development of novel, artificial life forms, the close relationship between nano and bio becomes clear (Breitsameter *et al.* 2009: 17). While the proximity between the two scientific endeavors may be close, the exhibit does not effectively convey that. It should either be separated physically more prominently or the relationship between the two should be made more explicit to the visitor. As it is presented now, the transition is either unclear (for a non-scientist) or too abrupt (for a scientist).

Beyond these concerns, a particularly strong point of the exhibit is the products section. As the accompanying booklet declares, 'In the End, It's the Benefits That Count: Nano is More Than a Vision' (Breitsameter *et al.* 2009: 102), and the products section delivers on this promise. It provides an overview of industrial materials, household products, and medical advances with an emphasis on specifically German commercial markets. While the exhibit as a whole may not be the clearest explanation of NST, it does give an indication of the future of the field, and thanks to the products section that concludes the exhibit, the visitor most certainly leaves with an idea of where NST has led us in terms of commercial uses. This section also ties the scientific process featured so prominently in the exhibit with the more visually impressive technologies derived from the science.

One place from which the exhibit could have gained some much needed clarification is by making the accompanying book publication, *Nano- und Biotechnologie im Zentrum neue Technologien* (2009), available to the visitor ahead of the visit to be able to reference while touring the exhibit. The book is generally available in the Museum Shop, but if one does not know this ahead of time there is no way to anticipate its necessity. Written by a team of authors including Florian Breitsameter, Brite Hauser, Walter Hauser, and Lorenz Kampschulte, the book is both well-conceived and informative. It effectively fleshes out the exhibit, and is so detailed that it could, if necessary, stand by itself without the exhibition. Walking through the exhibit with this guide in hand would make for an entirely different experience for the visitor. The science, as well as the narrative the exhibit is trying to tell, is enhanced by the well-written, well-researched series of articles that precisely follow the route of the exhibition. Moreover, the volume comes with a CD that replicates the social, political, and ethical controversies discussed in the several so-called media stations in the exhibit.

The bottom line is that the exhibit is still very effective in what it is trying to do. Overall, the science is precise and very detailed, perhaps too much so in some places. The science also needs to be updated on a regular basis considering the fast pace of change in NST. Craig Venter, for example, is mentioned in the Founders Gallery as looking to design an artificial microorganism – a feat he and his team have already succeeded in completing. In terms of the story, it is very well done. It is not a monument to human progress in our pursuit of domination over the natural world, as Durant fears for so many science and technology museums. Rather it is an honest account of an emerging development that does not merely hail NST as the savior of humankind in an increasingly endangered world. It recognizes NST, along with biotechnology, as twenty-first century 'key technologies', but does not ignore the need to place this technology within the broader socio-cultural context. Wolfgang Heckl, Director of the DM, emphasizes the many socio-political questions associated with NST when he writes in the foreword to *Nano- und Biotechnologie*, 'a thorough sounding of opportunities and risks of new technologies can only succeed in a democratic society through the active participation of all citizens. It is in the best tradition of the DM that we offer all societal groups a platform to help acquire exhaustive, knowledge-based information on [the theme of nano and bio]' (Breitsameter *et al.* 2009: 6). This is not only a German museum tradition, it is part of their mission according to their by-laws, and it is perhaps the most effective aspect of the exhibit.

Conclusion

Our primary goal was to evaluate the science as it is presented and the story the DM tells about NST. In doing so, we also hoped to provide an analysis of NST in the German public sphere. What we encountered was sound science and a sufficiently complex story in terms of advantages and disadvantages of NST that struck a balance between the process of science and the natural tendency of the museum to be a repository of visually impressive technologies. Our other intent was to evaluate whether the exhibit is designed to enlighten and therefore empower the German public in their understanding of NST as an emerging technology, taking into account the idea that scientific knowledge 'is always integrated with supplementary assumptions that render it culture bound' (Toumey 2006: 84). We indeed found a strong intent and an explicit effort to engage the public in the name of public understanding of science. This is also the stated intent of the DM and Director Heckl, as pointed out above. Walter Hauser says it most effectively when he insists that the exhibit spells out 'the contrast between the great hopes and fears' associated with emerging technologies (Breitsameter *et al*. 2009: 18). He then explains the underlying approach to this exhibit when he writes, 'Humans can and must determine themselves which research they want to press ahead with – and which they do not. Technology is not "fate", but rather is individually and societally shaped, be it through the political decision making process or through personal career choice' (Breitsameter *et al*. 2009: 19).

In that it attempts to show the pros and cons of NST and has only one corporate sponsor (AMGEN), it is by no means a pure propaganda effort. Nor does it adopt the 'deficit model' of popular scientific comprehension. It presents NST in all of its interdisciplinary diversity and offers members of the public not only an opportunity to learn about the science, but also to carefully weigh the issues surrounding NST. The final display of nanoproducts is of course designed to sway the public for further support, but by the time the visitor gets to that point, he or she has been faced with many of the most controversial issues surrounding NST and biotechnology. Moreover, commerce is not the high point of this exhibit; the UFO is the high, as pointed out above. In this way, the nanoexhibit at the DM is intended to both enlighten and sway.

Finally, the DM is a self-proclaimed 'temple of genius', but this proclamation does not detract from the effectiveness of the science or of the pedagogical mission of the NST exhibit. The real temple, the room featuring the Future Prize, is sufficiently separated from the NST exhibit, and the exhibit itself, as pointed out earlier, contains an understated Founder's Gallery highlighting the important names in NST in the last half-century. The most problematic aspect of the exhibit remains the success of the pedagogical mission. While it would require an empirical study to accurately determine its effectiveness, there are some aspects worth pointing out. First, while quite unique, the exhibit is similar to many other museum exhibits in that it has the feel of a mass medium. That is, one walks through in the manner of a window shopper, and if the visitor skips for example some of the early exhibits, the rest would indeed be very difficult to understand. Second, the best the exhibit can hope for is to spark some interest in the topic so that visitors are motivated to look further into NST when they go home. Sparking interest is an important aspect of pedagogy, and in this way, the NST exhibit at the DM is successful. In the end, we observed an overall effective exhibit that was not without its flaws, but does a competent job explaining the science, its outcomes and its associated costs and benefits of nanoscience and technology.

Notes

[1] The most frequently cited example of an emergent technology that struggled, and continues to struggle, with public acceptance was genetically modified foods. Resistance was and remains especially acute in the European Union, but resistance to such foods is not entirely absent in the United States.

[2] As is often the case with translations from previous centuries, this title – 'Der Plan zur Gründung einer mechanischen Realklasse' – presents substantive difficulties. Hecker had in mind the establishment of the first German 'Realschule' where trades would be studied, as opposed to the German 'Gymnasium' where a classical education for university bound students could be had. Therefore a 'Realklasse' would be an artisanal trade class and 'mechanisch' or 'mechanical' refers to the technological orientation of this class.

[3] Germany followed France's Conservatoire des Arts et Métiers, whose roots date back to the eighteenth century, and Britain's South Kensington Museum in the focus on pedagogy and museum.

[4] See Smalley-Drexler debate in the December 1, 2003 issue of *Chemical and Engineering News* (Baum 2003: 37–42).

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