Technology in Society 32 (2010) 173–182

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Envisioning nanotechnology: New media and future-oriented stakeholder dialogue

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Keywords:
Emerging technologies
Human enhancement
NanoFutures
Nanotechnology
Web 2.0

A B S T R A C T

Nanotechnology promises to transform everyday life, yet there has been little reflection about the dilemmas, trade-offs and complex choices involved. Our project constructed a virtual public engagement platform in order to elucidate perspectives on multiple, plausible visions of human enhancement. Our new media platform operationalized open-source scenario planning to enable diverse communities to assess, critique and debate prospective nanotechnology-enabled products. Extending participation and deliberation through open-source mechanisms was an experiment involving not only an innovation of public engagement but also of traditional scenario planning. By revealing the NanoFutures project design and analysis, this paper explores to what extent this public engagement led to genuine dialogue and illustrates the risks and benefits of using multi-media tools in social science research.

1. Innovations in public engagement

Public engagement has long been used in technology assessment to promote more democratic means of designing and prioritizing technological systems [1,2]. Involving a wide range of stakeholders in technology assessment builds upon lessons learned from science, technology, and society studies (STS), especially the public understanding of science [3]. While many technology developers imagine that their relation to the public should be that of an information disseminator, the works of Wynne [4] and Irwin and Michael [5] have shown that laypeople construct their own meanings that have less to do with expert explanations and more to do with experience with technology, media frames, religion, culture, and political awareness. Such findings also have been validated in surveys that explore public perceptions of nanotechnology [6,7]. Such research shows that people immediately outside of technological development make sense of technology in surprising ways that may not be known by analysts conducting technology assessments *a priori*. It is this understanding that lies at the core of the rationale for an open-source rendering of "naïve" technical futures. Our project developed what we describe as "open-source scenario planning" as a platform to enable diverse stakeholders to assess, critique and debate prospective nanotechnology-enabled products. Setting the stage with nanotechnology scenarios, we invited individuals to explore and critique their appropriateness, thus enabling a level of reflection often absent in public consultations. This project set out to serve as an antidote to limited, or one-way, engagement. This deeper investigation into public perception positions this engagement akin to consensus conferences [1] and citizens' juries [8], and stands apart from the deficit model [9] of public engagement that is still prominent [10].

1.1. New media as a tool of outreach, education, and research

The Center for Nanotechnology in Society at Arizona State University, a National Science Foundation sponsored research program, designed an experiment with public

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doi:10.1016/j.techsoc.2010.07.008

engagement using Web 2.0 tools, which provide not only the potential for interactivity but also for the transparency of knowledge production available through collaborative platforms like blogs, wikis, and social networking sites. We were inspired to confront the resource, geographic, and temporal limitations of traditional public engagement forms. By employing new media technologies, we encountered novel educational opportunities, challenges around data collection and analysis, and unexpected successes with reaching new audiences.

Blogs, wikis, virtual worlds, multi-player games and interactive websites are all part of Web 2.0—a transformation from the one-way communication that was characteristic of the first-generation Web. Web 2.0 tools are designed around an "architecture of participation" [11] and are enlivened and defined by user-generated content. Through Web 2.0 tools, users add content and make connections, in real time, across space. By encouraging knowledge sharing, debate, play and reflection, Web 2.0 venues stimulate personal connections and rewards that often accumulate large and loyal participation. In an era of time famine, social fragmentation, and disintermediation across many everyday practices, these tools allow participants to customize their level of engagement, which can encourage greater involvement. New media offers a potentially valuable tool for social scientists to conduct research, outreach, and educational activities though forays into harnessing massive collaboration for research is limited.

We ventured into the world of Web 2.0 via a project called NanoFutures, which uses a variety of new media applications to scale up public engagement on the societal implications of nanotechnology. The core aim of the NanoFutures project is to cultivate society's ability to govern the implications of its own ingenuity by creating spaces dedicated to deliberation and reflection on the role of technology in society. This article describes the NanoFutures project design, explains to what extent its public engagement led to genuine dialogue, and illustrates the risks and benefits of using multi-media tools in social science research.

1.2. NanoFutures: an experiment in open-source scenaric thinking

While the methodological dilemmas arising from employing new media form a central intrigue in this paper, the overarching aim of the broader NanoFutures project was to evoke discerning, future-oriented conversations about the social implications of nanotechnology. This objective was born from the notion that technologies need to be thought about in advance of their adoption and implementation. Upstream deliberation takes advantage of the relative openness of early technological design, thereby leveraging a window where public values and a broader range of options can be considered. Implicit in this agenda is the notion that technologies are guided and shaped by social values, and that such values become embedded in the technology. However, specific choices about emerging technologies are tricky due to the Collingridge dilemma [12]: outcomes cannot be predicted until a technology is adopted, yet once path dependencies materialize and technologies get "locked in," control or modulation becomes difficult. The relative openness of early-stage technologies close down as rigidities form in markets, cultural values, institutions, and policies. The governance of emerging technologies is mired by the limits of knowledge in the first instance and an obduracy of technological design in the second.

We build on the lesson discovered from many engagements about technology and society, such as the theory that "more heterogeneous participation and debate have the potential to improve the scrutiny and accountability of science within representative democracies" [13]. Efforts to cultivate society's ability to better govern emerging technologies must convene disparate groups, with often contrary agendas, in order to increase the range of options considered and the sources of wisdom bearing on them.

Governing emerging technologies then faces at least two main challenges: (1) insufficiently diverse and reflexive decision making, and (2) the speed of technological change when uncoupled from the capacity for sociopolitical understanding or response. Our ability to confront these dilemmas and to responsibly govern the outcomes of our technological endeavors is deficient. We need to learn how to create space for discerning dialogue, generating options, and setting priorities upstream [14].

2. Creating space for reflexive futures

While there are no completely reliable and grounded ways to talk about the implications of a technology that is in its embryonic stage, future-oriented tools and dialogues, such as scenarios, have the potential to create spaces for reflexivity. In addition to the possibilities conceptually available from framing nanotechnology in the future, an orientation toward the future is a necessity given the inchoate form of nanotechnology.

One way to achieve this reflexive space is to utilize foresight. Foresight refers to a set of methodologies and practices that are forward-looking and aim to generate intelligence about possible futures in a way that highlights both desirable and undesirable pathways. Convening conversations about the role of values in technological design, about priority setting in science, and about the social implications of technologies can be provoked through developing and presenting scenarios. Scenarios are "stories describing different but equally plausible futures systematically representing perceptions about certainties and uncertainties" [15]. As prominent scenario planners Aries de Geus [16] and Kees van der Heijden [17] make clear, scenarios are meant to evoke conversation and add contextual awareness to problematic situations rather than to predict the future.

Scenarios are accessible narratives that can articulate prospective technologies. Through describing future worlds, scenarios allow a grounded but imaginative display of complex socio-technical products and systems and draw out the social choices they present. The use of scenario development is one element in anticipatory governance, a new direction for technology assessment. Anticipatory governance refers to the skills and capacities to

Table 1
NanoFutures scenes.

Engineered Tissues
Using tissue printing technology, this system builds tissues with a vascular structure that enables the building of new organs.
Living with a Brain Chip
A cranial chip that features a data feed, which puts information into the brain while the user is resting.
Automated Sewer Surveillance
Ultra-fast sequencing technology is used to analyze the DNA in harvested waste water, thus screening large populations.
Disease Detector
A device that tracks an individual's protein levels to monitor changes that may imply early-stage illness or disease even before symptoms emerge.
Barless Prison
A caged drug that is injected into prisoners, then becomes activated by radio control if prisoners cross designated boundaries.
Bionic Eyes
An optical implant that looks and functions like a normal eye yet has enhancements enabling magnification, visualizing infra-red, and night vision.

"collectively imagine, critique, and thereby shape the issues presented by emerging technologies" [18].

Using foresight to enable the anticipatory governance of emerging technologies encounters several looming dilemmas. How to study and encourage deliberation about the implications of something that has yet to occur? How are credible data about the future constructed? How can actors, distributed across space and time, convene in a dialogue about the outcomes and embedding of new technologies? How can the co-production of technology and society be made visible and thus subjected to conscious choice and steering in a mediated environment?

One envisioned solution, pursued here, is NanoFutures. As a research project, NanoFutures utilizes a host of methodological innovations oriented toward capturing how different professional communities characterize plausibility and imagine the social implications of nanotechnology. The NanoFutures website is one tool of data collection and outreach. It hosts a wiki platform and discussion forum that present future technological products for critique by a broad range of stakeholders.

The NanoFutures research project began by crafting visions of nanotechnology-enabled future products based on themes of human identity, enhancement, and biology (see Table 1). These visions were culled from peer-reviewed scientific articles, popular science journals like *Science* and *Nature*, and one from a science fiction work entitled *The Diamond Age* [19].[1] We call the visions "scenes," and they are technical descriptions of emerging products that are meant to be "naïve," that is, they call attention to but do not explicitly describe the moral, ethical, or political issues. These product "scenes" were vetted for plausibility through focus groups with scientists who possessed the relevant expertise. The vetting continued with a bibliometric analysis of key terms produced in the focus groups [21].

[1] Such visions are important not just for their provocation but also as part of the innovation process and culture of science that should be scrutinized [20].

Plausibility is important due to the proliferation of extreme and incredible visions about nanotechnology in circulation. Like Nordmann, we believe it prudent not to "squander" ethical concern "on incredible futures" [22], but to focus on plausible technological products. By plausible we refer primarily to the technical sense as in, "Is this product technically feasible to invent and build?" While plausibility could be established through a number of different methods, NanoFutures used workshops, laboratory meetings, and bibliometric analysis to validate the scenes.

However, as will be described, the vetting was not complete with a look to the technology as material properties, engineering designs and historical precedents. The social, political, economic, and ethical plausibility of a technology—just as crucial as the physical aspects—were determined by a broad range of stakeholders on the NanoFutures website. NanoFutures strove to bring the future into the present by enabling the stakeholders to consider plausible futures, values, politics, and ethics in advance of the solidification of nanotechnologies' markets, products, policies, and practices. The future products were therefore first co-created with nanoscale scientists and engineers through vetting engagements and then opened up to broader scrutiny and collaborative authoring on the website in an open-source styled scenario exercise.

3. Open-source scenaric thinking

With the overarching idea of elucidating the preferences, values, and politics of diverse communities, consideration was given to the design of the NanoFutures website to entice and provoke users to respond and interact with the scenes in a meaningful way.

Extending participation and deliberation through open-source mechanisms was an experiment involving an innovation of public engagement but also of traditional scenario planning. The naïve product scenes are qualitatively different from scenarios generated using standard scenario planning methods. Whereas scenarios are normally created with attention to plot, storyline, and colourful actors that weave together a complex interplay of politics, economics, culture, and values, naïve product descriptions are meant to be scenes that set the stage. The scenes are stripped of elaborate social description and function as a starting point for broader debates, visioning, and communal figuring of implications. Through open-source scenaric thinking, the broader implications of the plausible technologies are determined jointly by the various stakeholders.

The concept behind open-source scenaric thinking is that as researchers we cannot presume to know what different communities make of implications, so instead we solicit their perspectives. By employing naïve product scenes, we set the stage for "extended peer review" [23], which is heralded as a solution condition raised by post-normal science, or the state of scientific knowledge as uncertain, with high stakes, and critically important to decision makers. Extended peer review takes seriously the limits of expert bodies of knowledge and advocates for more diverse knowledge to assess science and technology.

Fig. 1. Screen shot of NanoFutures website.

4. Designing for future-oriented dialogue

The deliberative component of NanoFutures asks and records how different stakeholder groups assess and assign values to the technical scenes that were generated. The website contains three main areas where users can READ[2] the scenes, REVISE them as they see fit, and RANT about the issues raised. Fig. 1 shows a screenshot of the website.

We make it clear that these scenes are used to spark debate and generate insight and therefore not depictions of inevitable technologies. The READ section serves as a static representation of the vetted technical descriptions. The REVISE section directs users to a wiki platform where they are prompted to "start with an existing scene and change it, or create a completely new one." Wikis produce knowledge in an iterative, collaborative fashion, executing the kind of open-source scenaric thinking in which users can begin with the base scene and elaborate how the technology could be used and with what kinds of societal impacts. The RANT section invites users to "critique and explore the scenes." Blogs are easier to use than threaded discussion forums in that they enable users to easily link to other sites and post images. The open-source styling of the wiki and the transparency of the blog enable diverse intelligences to come bear on a topic in real time, and establish communal understanding.

In order to recruit individuals to read, revise, and rant on the NanoFutures website, we sent unsolicited email invitations to approximately 2000 people. We hoped for a cross-section of individuals representing different views of the technology based on individuals' professional affiliations or social group.[3]

In determining which groups to include, we worked to establish a range of perspectives, a range that Collins and Evans [24] usefully specified as housed in categories of *no expertise* (no knowledge of nanotechnology), *interactional expertise* (familiar with nanotechnology) and *contributory expertise* (involved in shaping nanotechnology). However,

[2] The READ section explains: "The following fictional scenes are extrapolations from current nanoscale research; they have been vetted for their technical plausibility by scientists currently working in nanoscale research. We hope these scenes will stimulate you to reflect upon the meanings, potentials, and problems surrounding nanotechnology. The goal is to cultivate our collective ability to govern the implications of our technological ingenuity."

[3] Social scientists: 4 S members. Lay citizens/Publics: Arizona State University alumni, National Citizens Technology Forum participants. Nano-interested people: Foresight Institute members, the Center for Responsible Nanotechnology community, the Center for Nanotechnology in Society network. Public policy folk: Consortium for Science, Policy and Outcomes community. NGOs engaged with nanotechnology: identified through Internet research. Nanotechnology experts: scientists and engineers awarded grants through the National Nanotechnology Initiative.

it is worth noting that the categories of actors—social scientists, publics, scientists and engineers—are meant to bring in a range of expertise, disciplines, and professional perspectives, but do not strictly signify particular identities. We do not see any group as a discrete, cohesive entity, and we expect disagreement, misalignment, and diverse values to flourish within each set of categories. Following Evans and Plows [13], we have adopted the term "experts" rather than "scientists" and "lay citizens" instead of "publics" to clearly demark the inclusion of non-experts "who can authentically represent the lay perspective implied in calls for the democratization of science" [13: 829]. Indeed we are asking scientists to perform more as citizens, i.e., speculating on the social implications of the technological products, rather than as scientists critiquing the underlying principles. Scientists are also not privileged in the deliberative component of the project but are rather one community among many who are given a voice.

4.1. Discerning or distorting dialogue?

As a means of stimulating debate about emerging technologies, the scenes provided a way of grounding and specifying a locus of discussion. Since nanotechnology is a broad category, isolating an example of a future technology provided an orienting point of reference. This effect has been observed in university classroom discussions, public lectures, and forums focused on emerging technologies. We have used the scenes to explain nanotechnology to students and lay people from a broad range of backgrounds in live settings and discussions were vivid, grounded and discerning. The scenes were featured in the materials provided to participants in the National Citizen's Technology Forum and gave shape to many of our Science Cafés, held at the local science museum. Once the scenes were posted online to the NanoFutures site we received numerous accounts of the scenes being used in other educational settings, such as graduate courses on Science and Society for natural scientists. Given such feedback and experiences, we determined the scenes were useful tools for inciting and structuring discussions about the potential risk and opportunities of emerging technologies. However, the question remained: Can these experiences be replicated online, scaling up deliberative engagement?

We launched the website in May 2008 and retrieved 78 comments in the RANT blog portion of the website by July 2008. At the time, we could identify no standard practices for analyzing blog discussions qualitatively by theme. There are formulas for identifying prominent bloggers [25,26], studies on Weblog conversations and their styles of argumentation [27], and on the connectivity of blogs [24]. Traditional social science methods for analyzing text are appropriate in this instance, but we wanted to additionally experiment with visualization techniques to better understand the patterns and connections the blog postings made. We employed a number of different methods for analyzing and visualizing the blog data using (1) a coding software, (2) tag clouds, and (3) a qualitative coding scheme. These methods enabled different reads of the blog postings to emerge and contributed towards our assessment of the strengths and weaknesses of the online discussions.

To achieve a simplified view of the richness of the discussions, we began with two visualization techniques. Crawdad textual analysis software, which employs "centering resonance analysis", offered a means of quantitatively grasping the relationship between recurring concepts in a large body of text; it also had the capacity to compare, classify, sequence, and browse text [28]. Its visualizer feature yielded useful results by identifying the most "influential words" in the text and constructing a concept map (See Fig. 2 for indicative layout).[4] However, the coherence measure was not "smart" enough to give any greater meaning to the text. What we lacked was a sense of the frequency of the influential words.

These shortcomings led us to experiment with tag clouds. This technique represents the most frequent terms by size, enabling the viewer to quickly get a grasp of the text. The website Tag Crowd was utilized to create the tag clouds. These clouds were very effective at capturing dominant themes and their relative importance (displayed larger and bolder in Fig. 3) and quickly showed the types of discussions that occurred around each scene.[5] For instance, "people" can be considered a main actor in Barless Prison, whereas "DNA" and "Government" are the main actors in the Automated Sewer Surveillance scene where the word "disgusting" was frequent. We also quickly found that the Brain Chip scene had frequent use of the term "negative," whereas the Tissue Engineering scene raised a host of ethical, legal, and medical issues for individuals and animals. We also noted which scenes brought forth words related to the ambiguous reality status of the scene. We did not clean the text for "really", "question", "probably", and "early"—words that might normally be considered common and eliminated, because such terms highlight uncertainty and indicated the degree to which plausibility is a concern. Fig. 3 shows tag clouds for all the scenarios. The tag clouds offered a quick sketch, a scanning, of issues that were raised by the users, but the clouds lacked detail.

To more closely scrutinize the blog discussions, we conducted a traditional coding analysis. An initial coding scoured the blog posts to identify themes brought up in each post. A second round of coding was performed to unify the identified themes across the scenes. For instance, two themes identified in the first round were 'Biological Identity' and 'Medical Community'. During the second round of coding, in every post where one of these themes appeared the content was analyzed again, and it was decided that the broader theme of 'Medical' was more fitting. The general categories were Medical, Equity, Ethics,

[4] See: <http://www.crawdadtech.com/>. Accessed June 2008. The Crawdad Text Analysis map showed the connection between words and placed the influential words in boxes to denote their importance. The program described influential words and this feature with the following explanation: "Word influence measures the extent to which a word creates coherence in a text. Influential words connect concepts that would otherwise be disconnected." (www.crawdadtech.com).

[5] See: <http://www..tagcrowd.com>. Tag Crowd enables the quick cleaning of text; a sort list is generated that weeds out uninteresting scenes or common words (the, we, and). The images in Fig. 2 represent tag clouds cleaned minimally because we found some common words interesting.

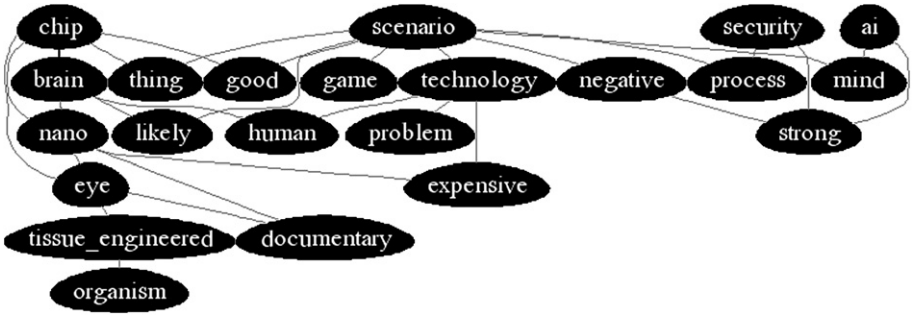

Fig. 2. Crawdad visualization of Living with a Brain Chip blog discussion.

Surveillance/Privacy, Economics, Social, Human Enhancement, Technological Components, and Laws/Regulation.

With the themes appropriately merged, all the themes across all the scenes were compared to see which ones appeared most frequently, as shown in Table 2.

Figs. 4 and 5 depict radar graphs[6] that show the frequency of themes in the Bionic Eyes and Living with a Brain Chip scenes. The Bionic Eyes graph (Fig. 4) shows that human enhancement and equity were major issues raised in the comments. The Living with a Brain Chip graph (Fig. 5) shows that the conversations covered all of the issues except laws/regulation. The differences in these graphs are valuable when comparing scenes.

The Disease Detector scene describes a technology that tracks a patient's protein levels to monitor variations that could imply illness or disease before symptoms actually appear. Conversations for this scene were oriented toward issues of equity. One user said: "Presumably this will be very expensive, at least at first, so most people won't have access to it, certainly poor people won't. Won't this mean a rapid exacerbation of health inequities?" Another user, commenting on the same technology, wondered: "Won't a lot of people be treated unnecessarily, since diseases detected at such an early-stage might or might not actually develop into illnesses. The body manages to stave off lots of diseases without outside help. So what's the potential here for a huge upsurge in iatrogenic illness, i.e., illness caused by the treatments themselves?"

These issues highlight potential unintended consequences of this type of convergence between science and technology, putting the technology in a broader social context. But NanoFutures produced not only a list of ethical, legal, and social issues related to new technologies, but also a space in which to critically reflect on the role of technology in society. With this in mind, we noticed many entries that brought up complex interplays between values, politics, and metaphysics and how technology shapes and is shaped by society. Users were concerned with issues well beyond the mundane, focusing more philosophically on fundamental changes to the human condition. For instance, one commented: "This technology begins to break the plane between what is human and what is mechanical. Should we be gradually building ourselves into cyborgs? My inclination is that most people would object to the full integration of human machinery and technological machinery; however, it remains unclear at precisely what point altering human functions becomes morally unacceptable." This ambiguity remains, with no consensus or final judgment rendered by other users.

Another user noted the complexity of not just the interdependence of technology and society, but also those interdependencies that form between technological systems: "Convergent technologies to enhance human performance will combine into a system, either well or poorly. So a future generation might have the option of combining bionic eyes, enhanced tissue-engineered organisms, neural implants, novel pharmaceuticals, clothing with embedded smart sensors, genetic enhancements, etc. How will we monitor the interaction among these technologies as they develop?"

"Dual use" was a common theme, where the technologies in the scenes were considered to have the potential to be used in dramatically different contexts. For instance, tissue engineering for organ replacement could be transformed to engineering edible meat; monitoring DNA in sewers could be used to track biological contaminants, criminals, or illegal immigrants. One user wrote: "There's nothing wrong with the technology itself, in my opinion. However, it does open the door to interesting abuse—extrapolate toward the movie *GATTACA*, perhaps, where only 'genetically healthy' people can receive extended training due to the risks in training others."

Science fiction was not widely used in the forum as a means to relate to the future, but analogy was. For example: "Given the demonstrations of hacking pacemakers, what security protects the Brain Chip from malicious use?" Another user, commenting on the presymptomatic disease detector, noted: "The current furor over genetic testing for disease proclivities being potentially made available or required for medical insurance is just the starting point of this. The capability discussed here is just an extension." So while the scenes are framed in the future tense, most users showed how their thinking is conditioned by already existing technologies and contemporary social effects and responses.

[6] Using the nine themes, a matrix was created with the themes placed in the far left column and the scenario titles placed in the top row. The number of times a theme was coded in each scenario was placed in the matrix where each theme aligned with the scenario title. This was done for each scenario and then totalled to obtain an overall feel for the topics addressed. From this matrix, radar graphs were made for each scenario as well as for the total.

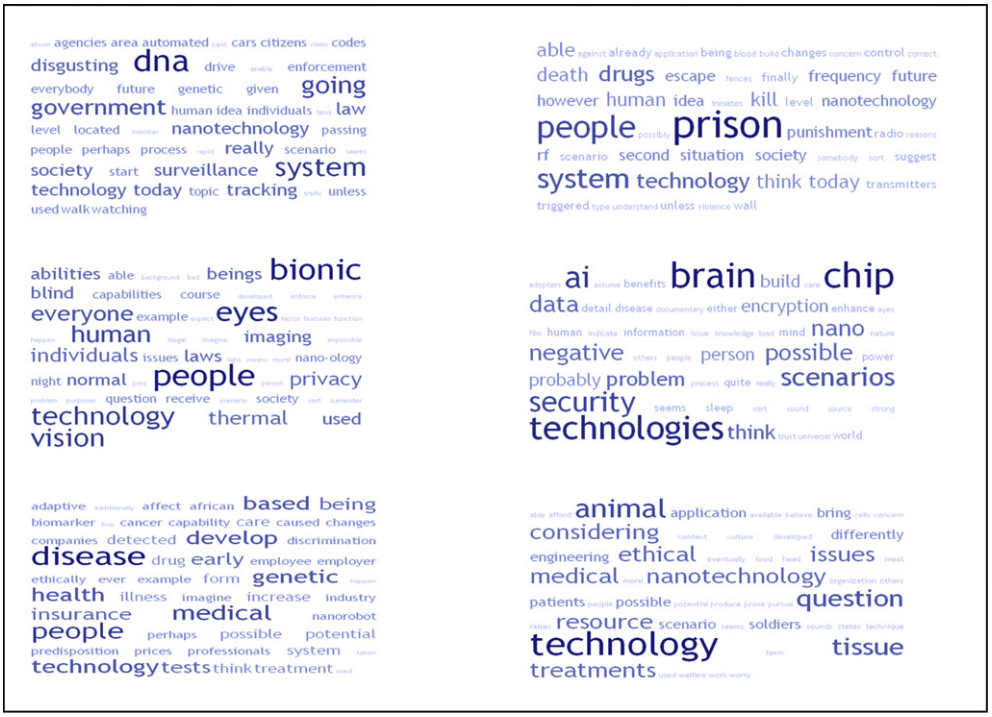

Fig. 3. Tag clouds, scenarios (left to right): Automated Sewer Surveillance, Barless Prison, Bionic Eyes, Living with a Brain Chip, Disease Detector, Engineered Tissues.

The future technologies presented in the scenes were also regularly understood as becoming embedded into current social structures ("Our prison system is already so corrupt I only see this going very wrong.") rather than in utopic or dystopic future social structures. Some users argued that our current social ills require consideration of new technologies: "Considering our negligence in addressing environmental challenges and increased resource scarcity … pressure to amend our physiology and that of other species may be a course of action we have little choice to pursue without considering longer-term socio-economic, medical, and environmental consequences. Now is the time to prepare our society accordingly."

There was debate about the timing of the intervention: when is the right time in the innovation cycle to debate social and ethical issues? Some users were bold: "Just do it… make it happen! Prove the capability, and then we can argue the ethics and other issues." Others in the same vein offered a more conditional view: "I feel we should first develop this technology to save lives and enhance lives rather than worry about insurance/price increases etc." In a sort of cost/benefit analysis, the user implicitly stated that security, equity, and privacy issues are secondary to the benefit of saving lives. Clear disagreement came from another user who covered many different issues in his comment, including equity, economics, affordability, and regulation. He responded to the above comment by saying: "The key, actually, will be to address these questions early on—NOT, as the first comment says, after the capability has been proved…"

It is crucial to note that these posts were not attempts to get the future right. Instead the scenes were presented to build the capacity among NanoFutures users to confront technological change through anticipation. The exercise caused users to reflect on values, the role of technology in society, and some of the stubborn problems—and solutions—proposed by new technologies.

Table 2
Frequency of scenes by theme.

Scenes/Themes	Engineered Tissues	Living with a Brain Chip	Automated Sewer Surveillance	Disease Detector	Barless Prison	Bionic Eyes
Medical		X	X	X	X	
Equity	X	X		X	X	X
Ethics	X	X			X	X
Surveillance/Privacy		X		X		X
Economics		X		X	X	
Social	X	X		X	X	
Human Enhancement	X	X				X
Technological Components		X		X		
Laws/Regulation			X	X		X

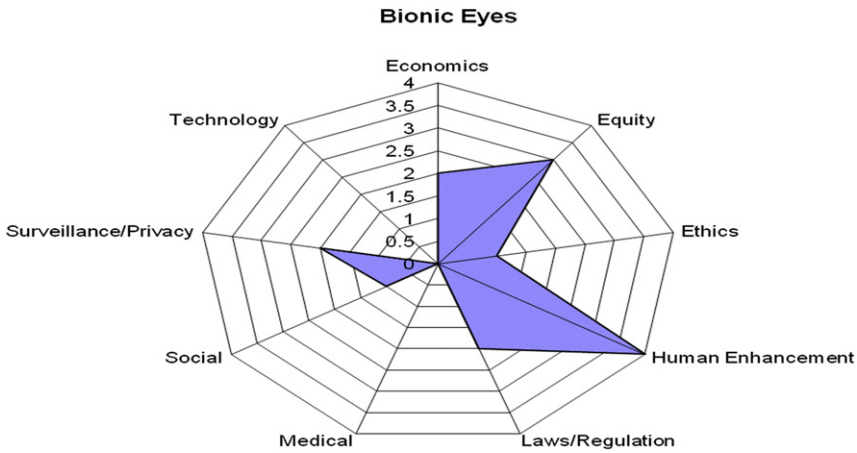

Fig. 4. Bionic Eyes radar graph.

We have evidence that the scenes support educational objectives as well and are valuable tools for outreach activities. Results from the blog discussions demonstrated that smart, inclusive, and reflective discussion can be mediated virtually. The aim of supporting dialogue by using scenes and encouraging online discussion about social implications was met.

5. Benefits and risks of new media for social science

We found that the online comments were comparable to those that occur in live conversations but they lacked a situatedness, interactivity, and stickiness that occur when people engage face-to-face. That is, while we might venture that learning occurred, satisfied by the astute comments made, there is no way to ensure that users "listened" to each other, weighed alternative perspectives, or left the engagement having learned something useful. We can see interactivity as users responded to each other, but we have not gauged the impact. We could have conducted pre and post-tests of respondents to assess these variables, but such added features were discounted for fear of creating hurdles that could hinder participation. We did not have a "captive" audience like other forms of public engagement, such as citizen forums. These conclusions point to design obstacles unique to mediated interventions, yet also raise questions as to the depth of learning and impact possible through large-scale, virtually distributed public engagement exercises.

A key point is that while the discussions were intelligent and probing, the barriers to participation were daunting. Our response rate was dismal, although greater participation than in most face-to-face deliberative exercises. This shortcoming could have been addressed with added resources and capacities in the form of a well-organized marketing campaign. We were also rather naïve as to the users' motivations to engage and limited in our programming capabilities. NanoFutures did not go viral and take on a life of its own

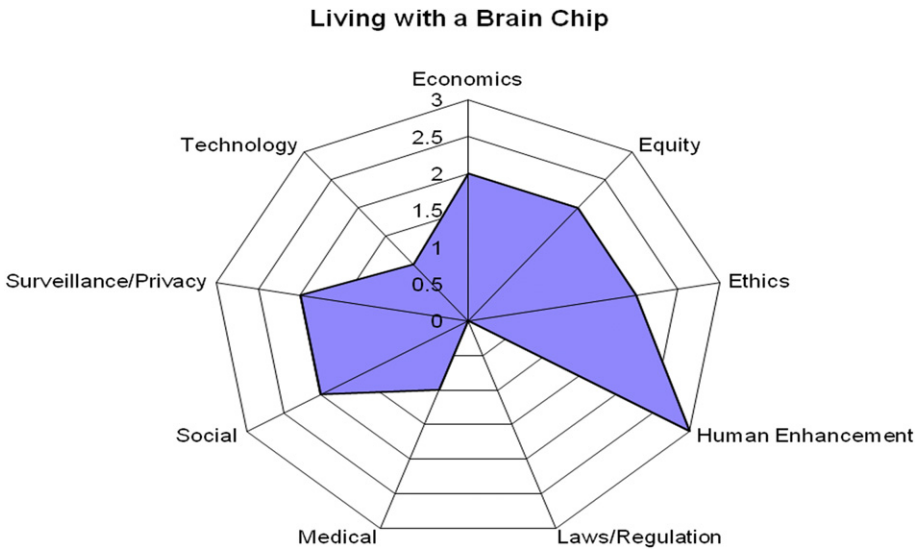

Fig. 5. Living with a Brain Chip radar graph.

as we had hoped. Invitations were sent via email, thus vying for attention within the barrage of email facing most users. Another strategy to encourage participation could have been to build NanoFutures into existing collaborative communities concerned about nanotechnology, thus keying into mature platforms. We anticipated some difficulty getting people to participate, so we modified the site so as not to require registration.[7] The downside of this decision to lessen the barriers to entry meant that we could not track who said what beyond tying posts to the social categories that users self selected (and that we could not validate).

Coupled with these design constraints are broader general problems with Web 2.0 itself. Critics of wikis and the blogosphere suggest that the knowledge produced is unreliable, amateurish, and sometimes even dangerous. Some lament the paucity of real understanding emerging from the broad accessibility of publishing. A noted advocate against the "wisdom of crowds" is Andrew Keen, who believes that Web 2.0 does not produce new knowledge but instead creates "more dubious content from anonymous sources [that ends up] hijacking our time and playing to our gullibility"[29]. Regardless of varying views on the utility of the content, the widespread application of Web 2.0 capabilities cannot be denied. The issues of the validity and the qualifications needed for making sense of data generated in Web 2.0 are interesting ones worthy of further research.

The results achieved with the automated coding software (Crawdad and Tag Crowd) were good starting points for a greater understanding of the texts, but did not produce a sufficiently compelling analysis. This appears to be an issue with the social research community, who are experimenting with Atlas Ti, Wordscores, HiMatt and the like in search for an automated solution to coding that replicates human judgment.

Looking at NanoFutures as an outreach project, these shortcomings may be minor, but as a research tool, our inability to trace and qualify the comments limits the usability of the data generated. One of our early aspirations for the project was to systematically assess different professional communities' determination of plausibility, but without the ability to accurately relate each comment to a professional category, the research would be based on illegitimate data.

The dilemmas surrounding participation were also probably aggravated by the distance of nanotechnology from everyday concerns, such as making the rent, meeting deadlines, and tending to families. Winning this battle for attention could have been aided by adding a competitive element to the site, like a contest, or as with many public deliberation exercises, a purposeful outcome such as informing legislation. For instance, the National Citizens Technology Forum [30] produced recommendations for policymakers, thus creating practical outcomes that organized attention and focused involvement. Building in enduring reasons to care and an end goal might encourage greater participation. This notion of understanding motivations and building in rewards to engagement platforms is well understood by designers of massively multi-player games [31].

In many ways, the successes and failures of NanoFutures speak beyond the role of new media in research to the obstacles that face public engagement in science and technology more generally. Given an opportunity to learn about and voice concerns about emerging technologies, experts and non-experts alike are generally thoughtful, enthusiastic, and opinionated. Yet without clear avenues to exercise political power over the direction of technologies, to influence legislation, to set priorities, to recommend precaution or innovation, the potency of such exercises remains debatable.

[7] This lack of personal identification also helped smooth permissions from the Internal Review Board.

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