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Mutable Matter: Using Sensory Methods in Public Engagement with Nanotechnology

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ABSTRACT

Mutable Matter is an experimental public engagement pilot program that seeks to enable non-scientists to explore and co-imagine the future of nanotechnology. Located at the intersection of geography, science communication and art practice, Mutable Matter is intended as a starting point for examining playful sensory engagement methods bridging tangible public and intangible scientific spaces. The project both challenges the role of non-scientists as mere commentators on pre-decided innovation trajectories and draws attention to the way scientific information is creatively encountered in the public realm.

Mutable Matter is an experiment in engaging non-scientists with the future of nanotechnology. A response to the public engagement projects that have been undertaken in many countries, the project specifically explores whether sensory methods can enable more creative public participation. Public engagement here refers to the process of convening a public—in this case non-scientists—for the debate of a controversial issue or something that is expected to develop into such an issue (in many cases, the resulting debates are aimed at feeding into future legislation). Nanotechnology, for instance, is considered to have no significant public (and thus no opposition) because of its early stage of development. Nanotechnology stakeholders such as governments and industry seek to take advantage of this situation by inviting debate before an opposition has already formed.

Nanotechnology is thus often portrayed as an opportunity to develop new methods for public involvement in debating new technologies [1]. This characterization is, in part, a government response to negative public reactions occurring during the genetic engineering debates, which were slow in bringing public comment into the discussion. Consequently, new methods were designed by public engagement practitioners, who often included social scientists, to involve citizens at a formative stage of nanotechnology development [2]. This early or "upstream" public engagement is intended to prevent recurring controversies about new technologies by making institutional processes more transparent and by facilitating dialogue among stakeholders such as government, industry, scientists and nonexperts. This new trend in participation has produced mixed reactions. While some have called this move toward upstream engagement an attempt at engineering mass complicity in unchecked economic development, others have embraced the opportunity to create new forms of participation in scientific governance [3]. In the U.K., the negotiation of the lack of trust in the neutral position of the government has led to a mixture of government-funded and independent public engagement projects [4].

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Article Frontispiece. Image from the Mutable Matter pilot project. (Photo: Angela Last) Participants explored visions of nanotechnology through images, nanotechnology publications and materials symbolizing features of the nanoscale.

Currently, in most nanotechnology engagements, the nanoscale, which is defined as the scale of atoms and molecules, is portrayed as an "immaterial" space, accessible to scientists but off limits for everyone else, because highly specialized tools and knowledge are required.

This characterization of the nanoscale as an exclusively scientific domain has consequences related to the role and status of non-scientists in decision-making about nanotechnological trajectories. As the sociologist Ulrich Beck points out, public visions of immaterial interactions prompted by many new technologies, such as, previously, links between nuclear power stations and leukemia, are seen by governments as irrational concerns to be "managed" [5]. The method I developed during the Mutable Matter project is an attempt to challenge this perception by drawing attention to the value and complexity of public visions of nanotechnology or relations between "scales" in general.

As an independent pilot project based in geography, Mutable Matter is shaped by a set of concerns similar to those of geography in general, such as human-environment relationships and their reflection in the public imagination [6]. However, it differs from other geographically informed engagement projects through its theoretical [7] and methodological approach. As a geographer with a background in science and art and design, I was interested in the way sensory methods might promote a different engagement with nanotechnologies. Drawing on my experience with other "tactile engagements" (e.g. *Mutation, Animal Lab* [8]), I created a prototype of how such an engagement could take form.

Using sensory methods to engage non-scientists with a "scientific subject" is not a new idea. Science communicators, museum professionals and artists regard hands-on experimentation as an essential part of communication. Although nanotechnology operates at a scale too far removed for humans to experience it without the enhanced senses of scientific apparatus, many have hailed the technology for bringing about a new age of tactility and interconnection. Art-science projects at the forefront in exploring the sensory possibilities that arrived with the disclosure of the nanoscale include Vesna and Gimzewski's *NANO* [9] and Sommerer and Mignonneau's *Nanoscape* [10] (Fig. 1).

Experimenting with human-scale multimedia versions of nanoscale phenomena, these projects have pointed to sensory and, particularly, tactile engagement as a means of opening up this remote space of material interaction to the public. The installations represented interfaces between the nanoscale and the sensible world that supported users in forming their own vision of the materiality of the nanoscale. It is exactly this interface that the Mutable Matter project was designed to introduce to "upstream" engagement, where policy-makers and public engagement practitioners tend to consider public imaginations of material interrelationships irrelevant or inaccurate by default.

Sensory Methods and Policy Engagement

One of the key considerations during the project design was the embedding of sensory methods in a setting intended to influence nanotechnology policy-making. While tactile experience is provided in most spaces of science engagement (e.g. science museums), such methods require substantial justification and an unpacking of assumptions about art practice, play and sensation when transferred to a policy-making setting. The most significant obstacles to the adoption of tactile methods in the policy context include the apparent uselessness of verbal and physical outcomes (participants do not supply scientific data) [11] and the fear that "touchy-feely" engagement will be seen by other members of the public or engagement evaluators as a means of persuasion [12]. The role sensory engagement normally tends to fulfill in the policy context is that of documentation and advertisement. Documentation occurred during some of the U.K. nanotechnology engagements in the form of collage-making (e.g. as part of the Nanodialogues project) and artist drawings (e.g. during the Governing at the Nanoscale project) [13]. The latter also highlights the common practice of designating artists rather than participants to produce artwork [14].

Perhaps an even more difficult problem for advocates of sensory methods is public engagement practitioners' uncomfortable relationship with science communication. A tactile exploration of the materiality of nanotechnology would immediately be associated with science communication. The tendency to avoid engaging non-scientists with the "science" of nanotechnology is likely a result of the practitioners' desire not to fall back on modes of communication that placed scientists and public into unequal opposition, creating the impression of scientists educating an uninformed "public." Instead, conversations in public engagements have tended to center on "how science is practiced" [15]. This problem haunts nanotechnology engagement, which continues to suffer from a lack of strategies to relate what many to date have written off as a "boring," "difficult" or "esoteric" science [16]. Another justification for the omission of "science engagement" from nanotechnology engagement is the claim that non-scientists' comments are bound to have little impact on legislation, as "hard" scientific data is needed for the risk assessments in question [17].

The current lack of recognition for nonscientific imaginations of matter confines nonscientist explorations of the nanoscale to the "safe" domain of art-science collaborations that invite such experimentation, but in ways that remain unconnected with decision-making processes. The intention of the Mutable Matter project is to work across this division of engagement and to bring the two modes—policy-oriented discussions and museum/art-based experimentation—into dialogue.

Fig. 1. Christa Sommerer and Laurent Mignonneau, *Nanoscape*, interactive computer installation, 2002. This work facilitates interaction with an invisible magnetic sculpture modeled on atomic behavior. (© Christa Sommerer and Laurent Mignonneau. Photo © Herling & Gwose.)

The Workshops

Mutable Matter resulted in a series of workshops offering a playful, sensory exploration of nanoscale phenomena through dialogue and materials representing certain nanoscale phenomena. Workshop design was guided by the question of how to exemplify certain nanoscale phenomena at our own scale without inhibiting the participants' ability to express their own vision of the interconnections between the nanoscale and "their" scale. The choice of materials was decided by the materials' connotations, although budget limitations also played a part (Mutable Matter was run as part of my Ph.D. project). After two pilot runs testing different kinds of materials, setups and facilitation strategies, Mutable Matter settled on plasticine, polystyrene balls, magnets and play "slime" as materials. These materials were chosen primarily for their capacity to represent certain forces at the nanoscale; see Table 1.

The plasticine acted mainly as a catalyst for participants' ideas, allowing them to represent objects, forces or concepts across scales. (This could also be done with the other materials, but not as extensively.)

Participants for the main project workshops were recruited from Open University [18] undergraduates and alumni, and through snowballing (participants recruiting friends, colleagues and family). Of the more than 20 participants who volunteered at the beginning, 16 attended the workshops. These took place in five locations in the U.K. (Leeds, London, Milton Keynes, Nottingham and Southampton). For the main project run, each workshop was divided into four phases. Small groups of participants

Table 1. Materials used for Mutable Matter workshops.

Materials were chosen primarily for their capacity to represent certain forces at the nanoscale.

—Magnets to evoke the "stickiness" brought about by electromagnetism.

—Polystyrene balls (shaken about in a transparent tub) to emulate Brownian Motion, the "jiggling" motion of particles suspended in a fluid, an important phenomenon at the nanoscale [34].

—Play slime symbolizing viscosity, as "the properties of any fluid . . . become increasingly dominated by viscosity as the size of the object becomes smaller" [35].

(ideally 3–4) were guided through these phases in the space of about 2 hours. Modeling and dialogue were recorded with the help of a Dictaphone, a camera and, on occasion, a video camera. In the section below I describe what happened in these phases and present the project's main findings.

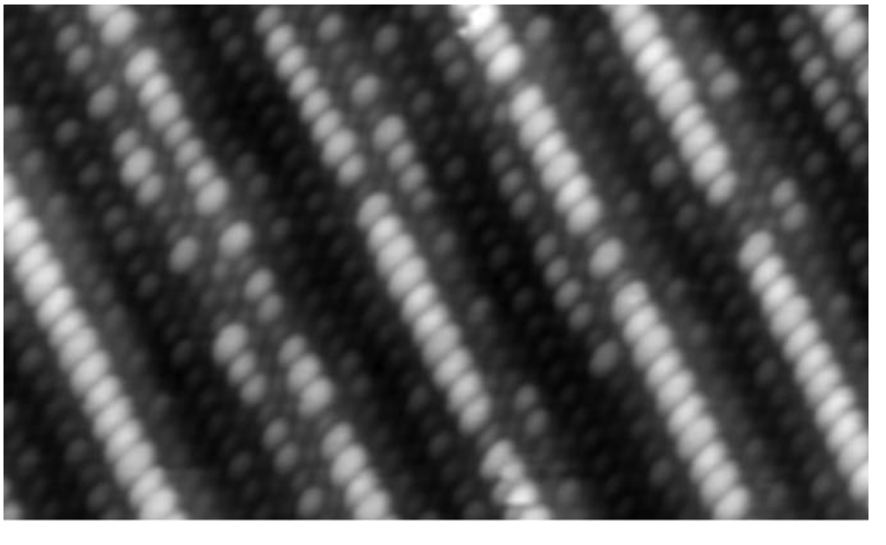
Phase 1: Building Blocks

At the beginning of the first phase, participants received a set of images produced with the help of a scanning tunneling microscope (STM) and were told how these images were created (Fig. 2). Previous articles in this ongoing *Leonardo* special section (such as Paul Thomas's article on the *Midas* project [19]) explain that running a super-fine needle—ideally ending in one atom—so closely over a conducting surface that the tunneling current can be measured produces these renderings of the atomic scale. The resulting data gives an indication of the distribution of atoms on this surface. STM and atomic force microscope (AFM) images play a central role in the scientific imagination and design of nanotechnology because they allow scientists to visualize the nanoscale. I chose the images shown in the first phase (mainly taken from the web site of the Vienna University of Technology [20]) for the way they embodied a particular aesthetic: They resembled the round, solid atoms of some of the nanotechnology designs found in scientific articles and industry magazines. The "atoms" in these images further appeared to be arranged in discernible patterns.

I intended the explanation of the images to stimulate the first phase of discussion, which tended to revolve around what was shown in the images and how these images were produced. Participants asked to what extent these images were the result of scientists' expectations or, given that many were taught that we could not image atoms, were "simplified to the point of being wrong" [21]. Some participants inquired whether scientists could change these patterns. After these discussions, I gave the participants the task of making something, taking the atoms as they appeared in the STM images as a reference. I encouraged the participants to use the materials to realize their ideas.

How participants responded to the task differed from workshop to workshop (see Fig. 3 for an example): Participants built anything from nanoscale switches to entire ecosystems. What unites the activities in the first phase is the combination of playful, humorous experimentation and critical reflection. Participant-suggested "improvements" included building something atom by atom, while simultaneously pointing out the dangers of making everything "too perfect." Another example of this interplay was concern about "copyrighting" one's creations, as in the case of a participant's "designer element." This interplay of playful exploration and criticism continued through the other phases.

Fig. 2. An STM image from a Vienna University of Technology study, 10 × 5 nanometers, 1994. (© Michael Schmid) The image was used in the first phase of the workshop.



Phase 2: Liquid Landscapes

The second phase again used STM images (Fig. 4; see also Article Frontispiece) as a basis for modeling and discussion. This time, the images, while representing a similar kind of data, appeared as "liquid" formations featuring waves and peaks. Participants were set the same task: to create something from the "atoms" they were presented with in the workshop (see Color Plate B No. 2 for an example). In most cases, the "liquid" images posed a considerable obstacle to completing the task. This barrier was not always overcome. The most frequently cited reason for the inability to "make something" was the lack of stability these "atoms" suggested. While posing a challenge, this alternative representation of atoms added another dimension to the discussion on representation: What are we seeing and what will we ever be able to know about the nanoscale, due to our "human" limitations? ("Here I am in this little three-dimensional world!" [22])

Participants also commented on the "temporary structure" of matter and the impact different kinds of imaging may have on the way we design or think about nanotechnology. On several occasions, this included references to debates about quantum physics. During the discussions, many participants started playing with materials (the "slime" was very popular here) to see if they could come up with a suitable "design." A few participants felt unable to make anything at all because of the "unruly" nature of these atom formations; others did not see any problem, stating that the new images were based on the same kind of data as the first ones.

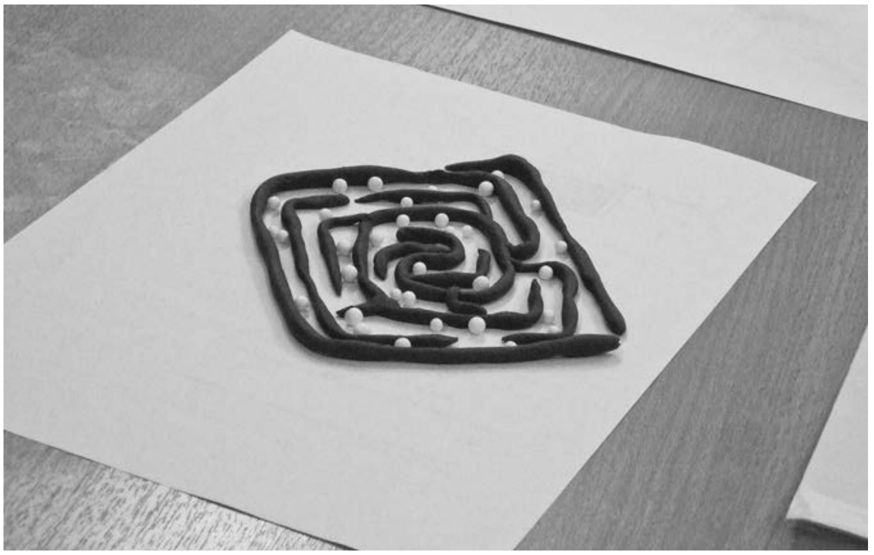


Fig. 3. A transformable "copyrighted designer element" from the London Workshop. (Photo: Angela Last) Other "inventions" in Phase 1 included wound dressings, carbon detectors, cancer detection, electronic paper and living aids for blind people.

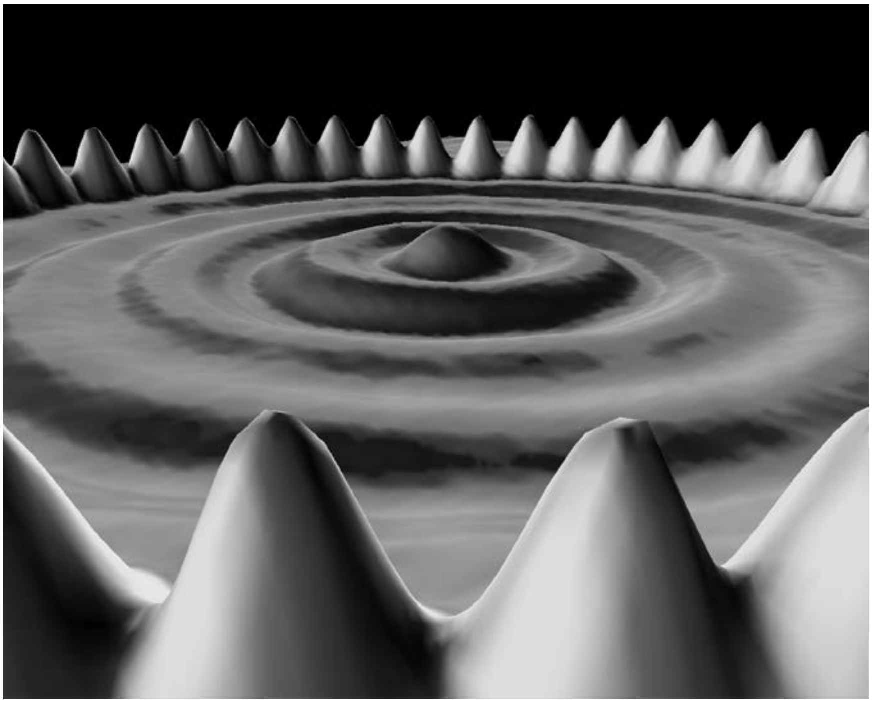
PHASE 3: FORCES

The third phase pointed to further obstacles to the potential limitlessness of nanoscience applications, as well as to creative solutions these obstacles might inspire. This time I handed out a short extract from scientist Richard Jones's book *Soft Machines* to the participants [23]. The extract describes what the 1966 film *Fantastic Voyage* would have looked like if the forces at the nanoscale had been observed correctly. The film *Fantastic Voyage* revolves around a technology that allows humans to shrink atoms, so that the targeted matter becomes miniaturized. When the technology's developer is about to die from an assassination attempt (because he can potentially shrink soldiers), his body is entered by a miniaturized team of rescuers in a "submarine" who try to remove the blood clot in his brain that is endangering his life. Jones's comic vision of the misadventures of the shrunken submarine draws its humor from the contrast between our desire to apply macroscale intuition to the nanoscale and the nanoscale's "reaction" to such an approach. Once the Mutable Matter participants had followed the "actual" voyage of the submarine, and after additional clarifications about nanoscale forces, they were asked to consider these conditions in their designs (these could be new designs or modifications of previous "inventions," depending on the participants' preferences).

In this part of the project, the perspective moved from shapes to forces: What does the nanoscale "feel" like? (Fig. 5) What do these phenomena mean for nanotechnology—and for us? Jones suggests that we have an "intuitive notion of physics" when it comes to phenomena at our scale; for the nanoscale, this intuition is lacking [24]. The third phase played with this notion of "intuitive physics" and asked whether it is possible to gain a sense of some of the phenomena scientists are struggling with in their laboratories. Most participants appeared to welcome the shift toward the inclusion of nanoscale forces, as they found that the previous images did not point to the fact "that there is [something] in the way" [25]. In this phase, the materials did not constitute the only source of information on the nanoscale. In each workshop I provided commentary on nanoscale phenomena that could not be symbolized through proxy materials, and, in Phase 4, other source materials were provided as well. In this sense, the project can be quite demanding on facilitators.

The subsequent modeling saw an increased use of the "dual" function of the offered materials: as representations of nanoscale phenomena and as carriers of metaphor. Many participants made "nanotechnology" that accounted for motion and even demonstrated the features of their models by subjecting them to "environments" of "wobbly" play slime, hidden magnets (that attracted visible magnets) and polystyrene balls being shaken or combined with play slime. Particularly in this phase, participant innovations reflected avenues of thinking also pursued by scientists, such as working with the phenomena of the nanoscale rather than engineering around them [26]. Several participants asked whether the "stickiness" at the nanoscale could become part of designs, and one

Fig. 4. Donald Eigler and colleagues, *Quantum Corral*, 1993. (© American Association for the Advancement of Science <www.sciencemag.org>. From M.F. Crommie, C.P. Lutz and D.M. Eigler, "Confinement of Electrons to Quantum Corrals on a Metal Surface," *Science* 262, 218–220 [1993]. Reprinted by permission. Image originally created by IBM Corporation.) This image was used in the second phase of the project [36].



participant in the London Workshop proposed using Brownian motion as a "free energy source" for nanotechnology [27]. Such proposals often had an element of parody. Participants were very aware that the "experimentation" they were undertaking was only symbolic. It was frequently understood that certain ideas were unrealistic but permissible within the environment of the workshop. However, many participants also discussed whether they could actually make their designs.

Fig. 5. Two-dimensional nano "plant" (foreground) and "supermolecule" (background) being modified in Phase 3 (Leeds Workshop). (Photo: Angela Last) Other models in Phase 3 included: "nationalized" nano, confectionery, glue, Brownian motion turbine, encapsulating in carbon nanotubes, transit tube.

Phase 4: Context and Applications

The fourth phase took participants back to the macroscale and gave them a chance to compare their nanotechnological visions with those of scientists and industry. Nanotechnology industry magazines (e.g. *Nano: The Magazine for Small Science*) and extracts from science publications (e.g. *Nature*, *Science*) served as sources for the discussion of "real life" applications. Many participants remarked on the similarity between their "inventions" and those presented in the magazines and articles. This positively affected their confidence to question scientific visions through playful but critical counter-suggestions. Some participants felt prompted to make new designs or alter earlier ones (Fig. 6).

The discussions in this phase tended toward a mixture of critical engagement with nanotechnology and further exploration of material interrelationships. In addition to voicing very similar concerns as had participants of "official" nanotechnology engagements—for instance, about market-oriented research, patenting and product testing—these workshop participants were keen to discuss nanotechnology in the context of information they had come across on phenomena that still puzzle scientists. Examples were Fritjof Capra's book *The Tao of Physics,* science-related radio programs (e.g. the workshops happened to coincide with the reporting on the Large Hadron Collider at CERN), images or fictional stories. A theme that featured strongly in these discussions was "interconnectedness" (Fig. 7). For many participants, nanotechnology entailed a renegotiation of the boundaries of life in an even more drastic sense than genetic engineering. Looking at the nanoscale brought up questions about the distinction between the organic and the inorganic. One question was "Why are we alive as opposed to rocks?" [28] There were also questions about boundaries between seemingly distinct objects. As one participant put it:

> I'm more inclined to think that things are like this web . . . things moving in and out of each other affecting each other; there is nothing isolated anywhere that stands alone, because everything . . . is basically . . . much of nothingness connected with forces [29].

Such discussions about the nature of matter contributed to a perception of nanotechnology less as the result of someone working on "matter" "down there" at the nanoscale than as an experiment negotiating the interrelationships between scales. At the end of the workshop, participants were encouraged to pursue their engagement with nanotechnology beyond the frame of the workshop, for instance, by looking up nanotechnology news and events on science web sites or by visiting the project's blog [30].

Main Findings

The method used in the Mutable Matter project allowed participants to engage with the "social" as well as the "scientific" aspects of nanotechnology. All of the materials ended up having multiple functions throughout the project, representing nanoscale, macroscale and even social phenomena. The project's method of playful "experimentation" was also reflected in the dialogue. Verbal experimentation included improvisational, as well as cautious, use of scientific terminology and speculations about the "scientific accuracy" of the produced models. Parody was a popular way of verbally engaging with nanotechnology. These parodies represented important sources of critique and addressed issues ranging from scientific research ethics to the obligation to buy into nanotechnology. The retracing of scientific practices through playful experimentation further invited the consideration of nanotechnology development as a result of economically and curiosity-driven research.

Participant interactions with the materials indicated that the different components both assisted participants in exploring aspects of the materiality of nanotechnology and played an active role in shaping ideas. On several occasions, starting points for ideas emerged from "material accidents," such as slime "escaping" off a table, or simple plasticine-shaping mishaps. These "accidents" were not only integrated into designs and ideas but also prompted comments about the potential liveliness of "nano" and inevitable jokes about laboratory escapes and "grey goo." At times, struggling with materials motivated participants to assist one another, which, for example, resulted in a collective effort to develop a nanotechnology-assisted ecosystem.

These manifold interactions with materials are an example of how the Mutable Matter workshops supported

Fig. 6. Envisioning nano-motors at the Leeds Workshop. (Photo: Angela Last) Other models from Phase 4 included viruses, water filters, plastic-eating microbes and a global nonprofit organization monitoring the use of nanotechnology.

a different kind of public engagement with nanotechnology. Official attempts to demonstrate the value of public contributions to nanotechnology-oriented decision-making frequently result in a sober, task-focused and often pre-framed debate [31]. This is due to their emphasis on what "the public" thinks about current scientific visions of nanotechnology and how these opinions can best be integrated into existing frameworks. Through playful "experimentation," the Mutable Matter project provided a much more "messy" engagement; it was messy not as in "disordered" (or even physically messy) but as in moving across and beyond established frameworks and supporting a variety of "exploration styles." The project supported participants in building their own themes and visions and encouraged placing these on a more equal footing with works of scientific imagination.

Conclusion

The Mutable Matter project draws attention to possible methods for involving non-scientists in the co-shaping of nanotechnology. Its playful mode of discussion is an attempt to move away from public engagement as the management of public fear, mistrust and skepticism—a strategy that appears to widen the gulf between "science" and "public."

Contrary to claims that the science of nanotechnology is too complex or uninteresting for non-scientists to engage fully, the outcomes of the Mutable Matter workshops demonstrate that it is possible not only to discuss nanoscale phenomena with people who have limited or no science background but to involve these people in making creative contributions to "scientific" issues. The project's use of playful "experimentation" supported participants in inventing their own "nanotechnology" and debating its consequences. The resulting models and discussions showed that while participants generally enjoyed experimenting with "nanotechnology," they did not cease to be critical of the technology's development and uses.

The Mutable Matter project also emphasizes the value of nonscientist imaginations of the materiality of nanotechnology. Participant articulations of a sense of "interconnectedness" between scales and the general complexity of their visions of nanotechnology call into question the negative stereotyping of non-expert interactions with controversial technologies. In particular the ongoing framing of public concerns about new technologies as fears of invisible "bodily invasion" [32] has been highlighted as an obstacle to participation. In this context, the project raises the question of whether there is a place in official public engagements for the imagination of complex and generative materialities—or whether such visions will continue to be seen as a troubling reaction in need of containment.

Lastly, the Mutable Matter project addresses questions that center on sustaining and widening public engagement with nanotechnology. As pointed out by the final report of the UK's Nanotechnology Engagement Group, many official projects struggled with the problem that nanotechnology was not yet controversial enough to draw public interest. At the same time, this kind of attention is what these engagements seek to prevent [33]. By inviting an exploration of the peculiar materiality of nanotechnology, rather than exclusively focusing on debates about its unknown risks, the project attempts to stimulate interest in the subject and offer alternative ways of engagement. Creative and meaningful forms of engagement with nanotechnology may provide a key to continuing the public debate. Mutable Matter was a small project with limited resources. Better resourced projects could build upon its approach (and those of similar projects), developing ways to work toward engagements with new technologies through strategies that involve all stakeholders in shaping technological futures. This process could involve anything from online virtual laboratories to projects addressing the temporalities of nanoscale phenomena.

More about the project, and opportunities to contribute to the discussions, can be found on the blog at <http://mutablematter.wordpress.com>.

Fig. 7. Two examples of interconnected "communicating matter" (plasticine on the left containing magnets) from Leeds Workshop 1. (Photo: Angela Last)

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21. Participant, Leeds Workshop 2.

22. Participant, Leeds Workshop 1.

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24. Jones [23] p. 55.

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