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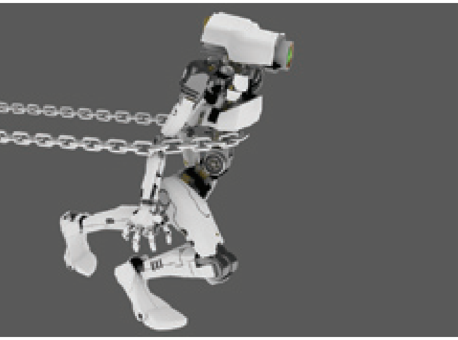
Report on the third joint Royal Society-Science Council of Japan workshop on new and emerging technologies

22 and 23 September 2008



partnership

POLICY WORKSHOPS

*International***Science***Activities*

Synopsis

The third Royal Society and Science Council of Japan (RS-SCJ) joint workshop was held at the Royal Society in London on 22-23 September 2008. The first two workshops focused on potential health, environmental and societal impacts of nanotechnologies. This third workshop briefly looked at latest developments in nanotechnology in the UK and Japan, noting progress toward assessing health and environment effects and understanding public views. The focus then shifted onto science and innovation strategies in the two countries and considered how new technologies drive social innovation and change. Four case studies were explored: synthetic biology, developments in computer networks, quality of life technologies and patient monitoring devices. Delegates discussed the governance of new and emerging technologies and strategies to develop the different forms of human resource required to support innovation.

This report has been produced to reflect the key themes that emerged during the meeting and is not necessarily an expression of the views of the Royal Society or the Science Council of Japan.

Summary

- Emerging evidence suggests that at least some engineered nanoparticles are likely to be hazardous for the human body and may have detrimental environmental effects. National and international initiatives are now underway to understand these risks.
- Activities have progressed in the UK and Japan to understand public views on nanotechnology. Participants underlined that these positive developments must now be transferred to other emerging technologies.
- Programmes such as Foresight and WIST (Wider Implications of Science and Technology) in the UK, and experiments with Technology Assessment in Japan, are useful innovations that examine the broad implications of new technologies and provide constructive analysis for policy makers. They may also be combined with public and stakeholder dialogue.
- New and emerging technologies present novel challenges for national and international governance. In particular, technologies that are intended to be transnational or which might be developed in one place yet impact on another, may develop faster than international safeguards can be put in place. New models of international cooperation may be required.
- New healthcare technologies tend to be favoured by patients when they maintain a level of personal control and choice and if they integrate with everyday life. Combining science, engineering, humanities, art and design may assist the production of appealing technologies that work with and for a person rather than reduce human involvement.
- Emergent and convergent technologies push for innovators that are to some degree conversant or even skilled in a broad range of disciplines and processes. Initiatives are emerging that break-down traditional discipline barriers, and which focus research and teaching on problem solving and innovation as well as to knowledge acquisition.

1 Nanotechnologies: recent developments

1.1 Nanotechnology in the UK and Japan

It was reported that nanotechnology research is increasingly linked to a goal and application led approach, driven by the need to address big societal challenges such as energy security, environmental change and ageing. For example, in the UK, the Engineering and Physical Sciences Research Council (EPSRC) leads the 'Nanoscience through engineering to application' programme designed to pull basic research through to application. In Japan, nanotechnology is a priority promotion area in the government's Third Science and Technology Basic Plan (see 2.1).

Against the background of rapid technical development, two issues discussed at the previous RS-SCJ workshops remain pertinent: health and environmental impacts, and societal issues and public dialogue.

1.2 Health and environment risk assessment

A key message from the first two RS-SCJ workshops was that while governments and businesses in many parts of the world, including in the UK and Japan, invest substantially in nanotechnologies, only a small amount of that investment is spent addressing concerns over potential negative health and environmental impacts. Research discussed at this third workshop suggests that emerging animal experiments, and analogies with studies on incidental nanoparticles (particles produced through high temperature combustion), imply that at least some engineered nanoparticles are likely to be hazardous for the human body.

There remains virtually no data on impacts of nanomaterials on the environment, although again there is reason to suspect that at least some particles, such as nanosilver, may have detrimental effects. Thus potential risk remains one of the most pertinent issues in nanotechnology today.

A range of national and international initiatives are underway to understand the toxicological and ecotoxiciological effects of nanomaterials. Examples noted at the workshop include:

- International Organization for Standardization working group on health, safety and environmental aspects of nanotechnologies.[1]
- OECD Working Party on Manufactured Nanomaterials, which is looking at international co-operation in health and environmental safety aspects of manufactured nanomaterials.[2]
- The Ministries of Environment, and Health, Labour and Welfare of the Japanese Government which are undertaking work on environmental and health aspects of nanomaterials.[3]
- The UK Natural Environment Research Council Environmental Nanoscience Initiative, which is funding projects on ecotoxicology of manufactured nanoparticles.[4]
- The UK Medical Research Council which is funding projects on nanotoxicology.[5]

1.3 Societal impacts and public dialogue

The first RS-SCJ workshop suggested that stakeholder and public engagement activities need to be undertaken and the results incorporated into policy-making processes. Activities to continue dialogue with the public, and to understand the societal impacts of nanotechnologies, have progressed in the UK and Japan.

In the UK, the Nanotechnology Engagement Group, convened by the Government, aimed to draw lessons from UK dialogue activities. The Group published its final report in June 2007 and noted excitement amongst the public about nanotechnology's potential in areas such as clean energy and healthcare, as well as its contribution to the UK economy, balanced with concern over safety and toxicity, and control and regulation.[6]

Further work was reported by the EPSRC that used public dialogue to inform funding prioritisation under the broad theme of nanotechnology for medicine and healthcare. Alongside established mechanisms including consultation with academics and research users, the EPSRC sought public views on where research funding should be focused.

Two reconvened workshops were held in each of four locations with 22 lay participants per workshop. Findings included strong support for medicine and healthcare as a broad priority for nanotechnology, and preference for technologies that empower people to take control of their own health and lives such as early diagnosis technologies that support people make informed and timely choices.

In Japan, the second International Dialogue on responsible Research and Development of Nanotechnology was held in Tokyo June 2006. The dialogue included sessions on ethical and legal issues, education and capacity building, and nanotechnology in developing countries. The Japanese Government also sponsors projects on societal issues and public dialogue, including a multi-disciplinary expert panel inquiry on societal implications of nanotechnology in 2006, and a Council for Science and Technology Policy programme on Developing Nanotechnologies and Engaging the Public.

1.4 Further issues in the governance of nanotechnologies

Some Science Council of Japan delegates noted that partnering the Royal Society in the previous two workshops helped stimulate discussion and research activities in Japan on the wider implications of nanotechnology. However, it was suggested that public engagement projects, as well as research on ethical and social issues, are currently less common in other areas of science and technology.

Experience in the UK suggests that where concerns about nanotechnology exist amongst the public, they generally focus on genuine issues such as participle toxicity. This suggests that public dialogue on emerging areas of science and technology can be approached without trepidation, and where goal oriented research is to be undertaken, it can be useful to explore whether expert goals are shared with lay publics (cf. the EPSRC work reported in 1.3).

Workshop participants discussed media reaction and potential negative impacts for industry from recently reported research on harmful health effects in mice from inhalation of carbon nanotubes.[7] Participants noted that media coverage of this research had been well balanced and had not sought to frighten the public. Commercial impacts are currently unknown. It was noted that in an unrelated development, US insurance company Continental Western Insurance Group will not cover liability related to nanotechnology and nanotubes. Participants knew of no similar moves by UK or Japanese insurers.

2 Science and technology policy and strategy in Japan and the UK

The science, technology and innovation strategies of the UK and Japanese governments were described.

2.1 Third Science and Technology Basic Plan of Japan

Launched for financial years 2006-2010, the basic stance of the Third Science and Technology Basic Plan is to deliver national innovation in the context of global sustainable innovation, and which is supported by the public[8]. Key features of the Plan are to: nurture creative science and technology human resources; reform science and technology systems to enhance innovation; and invest in basic research and R&D in strategic priority areas including life sciences, IT, environmental science, nanotechnology, energy and social infrastructure.

Two challenges face Japanese science and technology policy, as well as that of other nations: resolving the balance between international competition and cooperation, and nurturing human resources skilled in the current phase of discipline convergence. Discussion focused on the latter, in particular the different types of human resources to be nurtured. It was argued that at least four types are required: those trained in basic science and technologies ('type-B'); those working on foundational technologies and tools ('type-E'); those taking particular developments through to application ('type-D'); and a new proposed category, 'type-∑ (sigma) integrators of innovation' working both horizontally across a broad spectrum of science and technology and vertically through the types B, E & D. It was proposed that type-∑ is essential to realising the socio-economic value of converging technologies. Participants found the concept of type-∑ integrators particularly useful and it is further discussed below (see 5.4).

2.2 UK Science and Technology strategy: 'Innovation nation'

It was noted that many of the challenges facing UK and Japan science and technology are the same, but that policies are often different, reflecting the different strengths and weaknesses of the two nations. The current pattern of science and innovation investment in the UK reflects the Government's recognition of the importance of science and innovation for economic and social well being. Key UK policy commitments include sustained investment linking science and technology with innovation and wealth creation, and improved linkage of science and technology to business and other users. A series of strategy documents, and structural and investment reforms, have been implemented over the last decade. These include the 2008 *Innovation Nation* white paper, and the founding of the Technology Strategy Board (TSB).

Innovation Nation placed increased emphasis on demand-led innovation.[9] The current UK science and technology infrastructure supports strong technology 'push', but is relatively weak on 'demand/pull'. One aim of *Innovation Nation* was to increase demand for innovation from public sector and to align this with technology push. The paper employed a wide concept of innovation to include, for example, design, marketing and public services.

The TSB, set up in 2004 and turned into an 'arm's length' executive body in 2007 with a budget of £1bn over 3 years, links business with the science base in key technology or business areas. Key mechanisms include R&D competitions, knowledge transfer networks, and Micro/Nanotechnology Centres. TSB focuses on demand-led innovation, especially in areas that require multi-disciplinary action such as low-carbon vehicles, assisted living and intelligent transport.

3 The effects of innovation: foresight, implications and governance

Workshop participants turned their focus on to three generic issues important to innovation policy: projected future trends and scenarios, the societal impacts of innovation, and the governance of science and technology. Participants discussed three case studies for assessing likely social impacts and future scenarios, two in the UK (Foresight and WIST) and one in Japan (Technology Assessment).

3.1 UK Foresight Programme

The UK Government's Foresight Programme provides visions of the future to inform government policy and strategy, seek enduring solutions to societal challenges, and to improve how science and technology are used within government and by society[10]. It does this in three ways: Foresight Projects looking at big issues 50-100 years in the future (e.g. Mental Capital and Well Being, Land Use Futures); Horizon Scanning Projects looking at discrete issues 10-15 years in the future (e.g. Future of Families); and networks and toolkits to build futures thinking and share best practice across government. Each project is sponsored by a Government Minister and departmental Chief Scientific Advisor to increase Government buy-in. Foresight activities have successfully influenced government policy, spending decisions and research agendas.

A concern was raised that futures developed by Foresight may be improbable. Participants discussed methods to develop realistic depictions of the future. It was noted that Foresight does not aim to predict the future but uses scenario techniques to build different pictures of what the world may look like at some point in the future. It is then possible to, for example, test how robust current policies will be under the different scenarios. By grounding these scenarios in current experience, 'science fiction' elements are likely to be eliminated. The difficulty remains of predicting the future state of a non-linear stochastic process. To tackle this, Foresight findings are revisited and reviewed. However, it was noted that there is a difference between *foresight* and *forecast*: the latter demands review because it is a statement of what *will* happen, whilst the former implies no imperative to review, for it is a statement of what *may* happen.

Even if Foresight is relieved of strict evaluations of success, tracking the performance of top-level science and innovation policies remains an important and challenging process. Participants noted that it is relatively easy to evaluate the technical success of a research programme, but economic impact may be revealed only ten or more years in the future and not necessarily in the places and ways predicted. This difficulty encourages 'quick-win' policy-making, yet many policy challenges are long-term issues (e.g. climate change, obesity) requiring long-term strategy and investment. It is therefore important to demonstrate to government the need for a long-term view and sustained investment in science and technology. It also demands thinking beyond simple investment frameworks that back one or a few disciplines, solutions or applications. Developing interactions between different fields of science and technology and backing basic research are equally important. One third of the science research budget in Japan is dedicated to curiosity driven research.

3.2 Wider Implication of Science and Technology Programme (WIST)

Led by Foresight's Horizon Scanning Centre, the WIST programme aimed to deliver a coherent and coordinated programme of dialogue between the public, experts and stakeholders to explore the wider implications of new and emerging areas of science and technology.[11] Established partly in response to the Royal Society/Royal Academy of Engineering (2004) report on nanotechnologies, the WIST programme comprised expert and stakeholder appraisal integrated with a public-facing engagement process.[12]

WIST synthesised outputs from a range of different processes, beginning with analysis of horizon scanning activities to generate eight science and technology 'clusters' (e.g. energy technologies, sensors and tracking, mind and body sciences) which were then subjected to stakeholder and public analysis. Detailed descriptions were produced of views in 16 identified themes (e.g. 'ascent of the expert patient', 'powerlessness over areas of biological research', 'longevity surpasses predictions'). These themes were then mapped across Government to stimulate departmental strategic thinking. At the same time, topics were identified for future public engagement work to be delivered through Sciencewise-ERC, a resource funded by Government to help policy makers commission and use public dialogue to inform policy decisions in emerging areas of science and technology.[13]

Participants discussed the extent to which the results of processes like WIST are able to influence government strategy. It was suggested that the UK Government's decision to foster a coordinated response to nanotechnology from across its departments, based on multiple forms of evidence including public views, R&D and risk assessments, signals a new working method which may transfer to other emerging technologies. Again however, workshop participants discussed the difficulty of directing new technologies. For example, applications are frequently developed by private business and industry, and their success is dependant to some extent on market forces. It is not necessarily clear that governments can influence the commercial end of innovation. It was noted however that the TSB (see 2.2) shows that Government can have a part to play in the successful exploitation of technologies. It was also pointed out that one of Government's key roles was to provide infrastructure to allow innovation to flourish and the architecture of that infrastructure can shape technologies. Influence might be achieved for example through funding for the science base and ensuring that regulation balances permissive and restrictive effects.

Some participants noted that institutional structures such as Foresight and WIST could be adopted in other nation states, including Japan.

3.3 Experiments with technology assessment in Japan

Although sponsored by central UK Government, it is not certain that WIST will influence Government thinking. Work was reported on an ongoing government sponsored project in Japan seeking to understand why technology assessment (TA) had previously failed to influence Japanese government policy, and to suggest new TA methods and how they might be institutionalised. TA refers here to institutions and systematic practices that anticipate societal impacts of emerging technologies and support awareness raising, agenda-setting &/or decision-making.

As a governance tool, TA seeks to involve and manage stakeholder relationships in order to assess the implications of science and technology and steer their development and use. This is part of a move away from a vertically and centrally arranged *government* to more flexible and horizontal *governance* arrangements between different societal groups, including government. Tools like TA can assist in various ways, for example in assessing values and visions, stimulating innovation, and in risk management by clarifying risks and benefits and assessing risk trade-offs (where efforts to reduce one risk may increase another).

The particular project described at the workshop sought to understand why attempts to employ TA in Japan have been fragmentary whilst in other regions, such as parts of Europe, a more comprehensive and institutionalised form of TA has prospered. Many reasons have been identified including: that TA has not been clearly defined and has lacked clear methodologies; that a false belief was maintained amongst key policy-makers that TA-like activities were already being done in Japan; and that TA should not be an undertaking of government. To demonstrate the usefulness of TA, the next stage of the project was to develop a new method for TA that can deal with diversified value systems and stakeholders, identify likely societal impacts of technology, and cope with uncertainties in development paths. The approach developed – a form of 'Problem Structuring Method' – is currently being applied to nanotechnologies (in particular clinical testing, energy, and food packaging and additives). The project will report in 2011. However, although the project may demonstrate the utility of TA, it remains unclear which institutions in Japan will be the 'client' for TA, and from where funding for TA activities will come.

4 Case studies of new and emerging technologies

To further inform discussion of social innovation and governance issues, participants turned their attention to four areas of emerging technology: quality of life technology; patient monitoring devices; the future of computer networks; and synthetic biology

4.1 Digital Human Modelling and Quality of Life Technology (QoLT)

Research was reported that seeks to develop intelligent systems that augment body and mind functions to help older people and people with disabilities. The work brings together two different areas of research: digital human modelling and QoLT. The former models everyday human physical and cognitive functions and seeks to reproduce them with computer models. The latter seeks to enable independent life for those requiring physical or cognitive assistance. Together, the aim is the development of systems, perhaps a device the person carries, a mobile system that accompanies the person, or a technology-embedded environment in which the person lives, that works with a person in their everyday life. The intention is not to enhance but maintain a person's capability.

It was suggested that the social pull for QoLT systems is clear: estimated figures for the United States report that by 2030 one in two working adults will be serving as informal caregivers and 20% of the population will be 65 or older. With incidence and severity of disabilitating conditions increasing with age, required year on year increases in medical budgets will be unsustainable. It was argued that based on projections like these, new technologies to support everyday living are essential.

At the Quality of Life Technology Center, a US National Science Foundation Engineering Research Center based at Carnegie Mellon University, innovation is supported through continual partnership between engineers, users, social scientists, stakeholders and others. This multi-disciplinary and multi-stakeholder model is important not only to develop optimum technical solutions, but to simultaneously address social issues as they arise. For example, the project has had to consider privacy issues, such as who has the right or need to know a person's medical records and in what detail: the individual, their family, doctors, researchers, government?

4.2 Medical devices for monitoring patients in and out of hospital

Like QoLT, research on medical devices for patient monitoring responds to a changing healthcare landscape. The World Health Organisation predicts that by 2020 long-term conditions such as diabetes and asthma will be leading causes of disability. It was reported that even today, 80% of primary care consultations relate to long-term conditions and patients with these conditions use over 60% of hospital days. In response, the long-term goal of reported work on medical devices is to empower patients to take more responsibility for the management of their condition and reduce unplanned hospital admissions.

Research has centered on the use of mobile phone technology to support 'telehealth' monitoring and feedback systems. Mobile phones have distinct advantages over other options such as the internet for these systems. For example, they are moving towards ubiquity with 90% of the UK population owning a mobile phone. Worldwide ownership currently stands at 55%, but this is predicted to reach 75% by 2011. Mobile phones are then a technology many people are familiar with. There are further advantages: phones allow real-time feedback and two-way information flow; enable communication with a remote carer based on shared information; integrate into a person's lifestyle; and may be personalised.

Telehealth systems have been validated in 20 clinical trials across the EU, US, Middle and Far East with a range of different conditions and treatments (e.g. diabetes, chemotherapy, cystic fibrosis). Systems typically comprise a device that monitors a patient's current state, a custom mobile phone that can either be inputted manually or through direct transmission from the monitoring/sensor device, intelligent software that analyses incoming data, and a secure server that prioritises patients for nurses who then call the patient if appropriate. The systems have been shown to improve patient outcomes and reduce healthcare costs. Patients have been highly receptive and appreciated the regular support available from a remote healthcare worker. Patients felt less of a 'burden' because they were contacted by a nurse rather than presenting themselves for treatment, and were less likely to feel 'alone'.

4.3 Computer networks

Teleheath medical devices rely on digital networks and demonstrate how these networks may be used in novel ways. Further developments in information technology were described that lead to new capabilities that may benefit people and societies across the globe, and which prompt a new conception of the use and purpose of computer networks. Initially developed by computer professionals for their own purposes, the internet and other digital networks have become integrated into society's basic infrastructure and open to the general user. (It was shown for example that the time of peak broadband internet traffic is increasing close to peak TV use.) Early internet 'nodes' were general-purpose computers, but now a node can be almost any digital device: a phone, a camera, a vehicle, or a medical device for example. This means that the internet has extended to cover our living space and nodes can be mobile. The global digital network has also extended. Early cable networks by-passed large tracts of Asia, Africa and South America with most traffic passing between Europe and North America and between North America and Japan. Today, major connections link countries previously bypassed, opening up opportunities. For example, it was suggested that 'big science' requires international digital connections, and with the global network increasing, more nations have the opportunity to participate.

It was argued that describing the internet as a 'virtual' space is misguided. Digital networks operate in real space controlled by real people. However, quite who is in control and how control can be exercised is to some degree uncertain. For example, although the internet may be global and increasingly without national boundary, it is still subject to national forces, including whether search engines are subject to state censorship. Yet the extent of possible centralised control, national &/or international, is challenged by modern digital networks. For example, advertising revenue via the internet and digital signage (wired or wireless) is increasing whilst that of other sources such as TV is decreasing. This presents a challenge: TV advertising is strongly regulated in most countries, but no equivalent controls exist for the internet or other digital networks.

In Japan, the general trend toward ubiquitous digital networks presents difficulties for the current regulatory system. This trend is catalysed by the Japanese Government's drive to make Japan the world's leading ICT nation, where anyone and anything can easily connect to networks and use them anytime and anywhere. The challenge this presents has prompted a project that will report in 2010 on a new comprehensive legal system for communications and broadcasting.

4.4 Synthetic biology

Synthetic biology combines science and engineering in a manner quite unlike the other case studies, and does so in order to design and build novel biological functions and systems. It is a convergent field, taking elements of microbiology, genetics, nanotechnology, biology, chemistry and engineering to develop new capabilities.[14] Different approaches to synthetic biology were described, including the use of genetic elements to modify existing systems such as genomes and organisms, or to build new ones. This approach is perhaps exemplified by the aims of the 'BioBrick' registry of standard parts.[15] The 'parts' in the registry comprise DNA sequences of defined structure and function designed to be composed and incorporated into living cells in order to construct new biological systems.

It was suggested that key engineering principles such as abstraction and standardisation are currently compromised because biological parts do not conform to the standards of tolerability, reproducibility and performance found in 'traditional' engineering. Nonetheless, significant achievements in foundational technique have been made. For example, genome transplantation between two different *Mycroplasma* bacterium species has been demonstrated, as well as the synthesis and assembly of a complete bacterium genome.

A lesser know form of synthetic biology – 'semi-biotic systems' – is a pragmatic form of synthetic biology which integrates biologically derived (e.g. DNA constructs) and synthetic components (e.g. microfabricated systems) to produce hybrid devices. For example, work towards synthetic nuclei ('neonuclei') – self-assembling particles capable, like the nuclei of living cells, of sustaining gene transcription – offers an approach to the production of biomolecules of industrial or medical interest. 'Neochondria' (synthetic mitochondria) may power nanodevices.

Synthetic biology has a range of potential utilities. These were described as falling into three categories: performance (e.g. self-repair, evolvability), functionality (e.g. light harvesting, bioremediation, sensing) and applications (e.g. hydrogen generation, biological weapon sensors, environmental clean-up). It was noted that synthetic biology is in a fertile period with frequent demonstrations of technique and technical achievement. This current phase of 'playing in the lab' will have powerful consequences. These consequences may however not all be positive and beneficial. Risk factors and fears were described, including eco-contamination and eco-perturbations from release of novel organisms, or fear of bioterrorism from the construction of novel pathogens.

5 New and emerging technologies, social innovation and governance

Informed by the four case studies and previous sessions, in the final part of the workshop participants discussed the governance of new and emerging technologies and their role as drivers of social innovation. Four themes emerged.

5.1 Control

Participants discussed three aspects of control over emerging science and technology: individual control; state/societal control over the direction of innovation; and state/societal control over the space in which technologies are deployed.

Within national boundaries, control over technologies that do not normally transgress those boundaries is relatively attainable (through regulation for example) compared to technologies that are intended to be transnational (e.g. computer networks) or which may be developed in one place yet impact on another (e.g. released engineered organisms). Control of transnational technologies is possible – the Biological Weapons Convention is a good example – but because technological development is usually faster than international safeguards can be put in place, there is always the chance of an 'unregulated window'. Further, management is difficult in an area as diverse as nanotechnology with highly complex national and international webs of collaboration and trade. It may also be more difficult in converging areas. For example, it was suggested that regulatory control over the chemical end of synthetic biology is currently greater than the biological end.

In the early development of new technologies, control usually rests in the hands of small groups of researchers and companies. However, the chance of representative citizen and stakeholder participation is increasing. Some examples are noted above (1.3, 1.4, 3.2 and 3.3). In a further example, it was noted that patient representation in clinical trials of patient monitoring systems has been beneficial and not considered a barrier to innovation. For instance, representatives tend to force a justification for the technology and often become key advocates.

5.2 Everyday living and technology

Individual control is affected by the extent to which a technology works independent of the person being assisted. A striking feature of many of the technologies discussed at the workshop is that they are designed to work with people in their ordinary lives and maintain a level of personal control and choice.

For example, when public participants were asked to rank potential healthcare applications of nanotechnology, a form of theranostics combining diagnosis and therapy in one device was ranked least desirable for it was perceived to disempower patients and raise the threat of the automation of therapy. In a further example, research showed little uptake for the delivery of prescriptions through mobile phones because the system removed the social contact involved when collecting prescriptions in person.

Further developing the 'everyday living' theme, participants considered the potential contributions of the arts and humanities to producing technologies that appeal to people. It was suggested that artists and designers make products that appeal to the ways that people want to live, and collaboration with engineers and scientists may increase potential human-technology symbiosis. It was also suggested that although innovation strategies are frequently based on 'grand challenges', it is possible to learn from everyday living and that innovation can be driven on a more micro level, or in apparently mundane sectors. The computer gaming industry for example is not usually considered by policy-makers, but it is both a driver of innovation and appealing.

5.3 Regulation and speed of development

The acceptance and take-up of a technology depends on technical merit and on social and cultural forces. It was suggested for example that the market is a form of societal control on technology, with take-up of the same technology varying across cultures and sub-cultures. However, participants noted that the fate of new and emerging technologies cannot be left to market forces alone. Particularly if technologies might be hazardous or have ethical and social consequences, regulation and other forms of control may be required. TA and WIST had already been discussed as methods to assess the implications of technology, and during the discussion session participants considered the further effects of regulation.

Regulations, and processes such as TA, are sometimes perceived as potential barriers to innovation. One participant candidly noted that if a company board had been convinced of the potential of a particular technology, the last question asked was for the regulatory context. At the same time, it is the burden of those charged with governing innovation to consider if and in what form regulation and control may be required. Participants discussed the relative merits of quasi-legal 'soft law' instruments that are not binding and cannot be enforced, and more authoritative, state-led 'command and control' approaches.

One benefit of soft law instruments, such as action plans, self- and voluntary-regulations, and participatory and stakeholder dialogue forums, is that they are less troubled by the manner in which science and technology innovate faster than the policy and institutional structures designed to oversee them. One particular catch is that the outcomes of genuine innovation cannot be known, let alone robustly predicted. This catch is addressed by soft law structures such as principle-based codes of conduct which are flexible and adaptive. However, participants noted that soft law may not engender public trust to the same extent as state regulation. Moreover, it was pointed out that some soft law structures designed to govern nanotechnologies have either been set-up once significant numbers of applications have already reached the market place (e.g. European Commission code of conduct for responsible nanosciences and nanotechnologies research),[16] or have not been as successful as hoped (e.g. Defra Voluntary Reporting Scheme for engineered nanoscale materials in the UK).[17]

Hybrid forms of governance were discussed as a further option. One approach might manage risk through centralised regulation ('first order governance') whilst the uses to which technology is put are considered by public and stakeholder dialogue procedures ('second order governance'). This form of hybrid governance acknowledges that many technologies have multiple uses, some of which are not immediately apparent and some of which may be socially shaped.

It was noted that, in particular cases, current regulatory arrangements may prove adequate. For example, the emergence of nanomaterials may not necessitate the development of new risk management *systems*, but the properties of particles at the nano scale may require new assessment *methods*. The way forward may be to alter and strengthen existing procedures, not drive for new ones.

5.4 Type-∑ people/institutions and innovation

Participants noted the importance of 'unsung' areas of science such as metrology and toxicology, crucial to the successful development of innovations, but rarely in the limelight. Maintaining healthy numbers working in foundational and enabling technologies remains a challenge, but new and emerging technologies press for yet further human resources. In particular, workshop participants discussed the need for type-∑ people and institutions (see 2.1).

Drivers for type-∑ were discussed. For example, sometimes the intended purpose of an innovation is supplemented or even supplanted by other unexpected uses. Greater iterative dialogue with customers or user communities may anticipate this outcome, a process requiring people who can move between and communicate with both producers and users of innovation. Further, the convergent nature of many new and emerging technologies, as well as multi-dimensional and multi-discipline approaches to 'grand challenges', again pushes for innovators that are to some degree conversant or even skilled in a broad range of disciplines ('horizontal' skill set) and processes ('vertical' skill set, including basic science and technology, foundational and enabling tools, and the development of applications and products).

Methods for developing type-∑ resources were discussed. It was suggested that UK and Japanese higher education systems are strongly discipline based and not well suited to developing broadly skilled individuals. To do so successfully might mean re-thinking education right down to school level, but several successful approaches to breaking down disciplinary barriers at higher education level were described. It was noted for example that campus universities are usually designed to separate disciplines whilst college based systems mix disciplines together. It was suggested this can lead to fertile trans-disciplinary thinking.

Elsewhere, deliberate attempts have been made to create broad based institutions centred not on discipline areas, but on solving problems. In the US, the National Science Foundation Engineering Research Centers are required to create educational programmes and research projects that are interdisciplinary and involve industry and users.[18] Undergraduate scholarships are available for students to work on problem based research tasks and it was suggested that these students develop problem-solving skills that cannot be taught through traditional education approaches. With a similar outcome, the annual International Genetically Engineered Machine (iGEM) competition is a team synthetic biology competition for undergraduates who use parts from the Registry of Standard Biological Parts (see 4.3) to design and build biological systems.[19]

Other strategies that may broaden available skill sets were discussed. These included expanding peer review of funding proposals to include industry and user communities, and rewarding interdisciplinarity.

Participants

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Dr Yutaka Sata	Cambridge Research Laboratory, Toshiba Research Europe Ltd.
Dr Fumihiro Maruyama	Fujitsu Laboratories of Europe Limited
Koichi Matsumura	European Technology Planning Dept. Canon Europe Limited
Zaneta Ulozeviciute	Economic and Social Research Council
Dr Esther Wilkinson	Economic and Social Research Council
Dr Araxi Urrutia	University of Bath
Dr Ismael Rafols	University of Sussex

Agenda

SESSION 1: Overview of science and technology policy and strategy

Japan's science and technology strategy
Dr Ayao Tsuge, Shibaura Institute of Technology, Member of SCJ, Ex-Executive member of the Council for Science & Technology Policy, Cabinet Office of Japan

UK science and innovation strategy
David Evans, Director of Innovation, Department of Innovation, Universities and Skills (DIUS)

Japan's governance of science and technology – basic issues and experiments in technology assessment
Professor Hideaki Shiroyama, Graduate School of Law and Politics, University of Tokyo

UK horizon scanning: Foresight
Martin Glasspool, Foresight, Government Office for Science, DIUS

SESSION 2: Health, environmental and societal impacts of nanotechnologies – lessons from the first two SCJ-Royal Society workshops

Review of the 2005 and 2006 SCJ – Royal Society workshops
Dr Masahiro Takemura, General Manager, International Affairs Office, Planning Division, National Institute for Materials Science (NIMS), and Associate Member of SCJ

UK developments in nanotechnology
Professor Richard Jones FRS, Department of Physics and Astronomy, University of Sheffield; EPSRC Senior Strategic Advisor for Nanotechnology

Toxicology of nanomaterials
Professor Hideaki Karaki, member of Science Council of Japan

SESSION 3: Emerging technologies and social innovation: perspectives and case studies

Innovation and Institutionalization of Technology Assessment (TA) in Japan
Professor Tatsujiro Suzuki, Visiting Professor, Graduate School of Public Policy, University of Tokyo; Associate Vice President, Central Research Institute of the Electric Power Industry (CRIEPI); member of SCJ

Wider implications of science and technology: the WIST programme
Karen Folkes, Deputy Head Science & Society, DIUS

Digital Human Modelling and Quality of Life Technology
Professor Takeo Kanade, Director, Digital Human Research Center, National Institute of Advanced Industrial Science and Technology (AIST), Tokyo, Japan; Director, Quality of Life Technology Center Carnegie Mellon University Pittsburgh, Pennsylvania, USA

Synthetic biology
Professor George Attard, Director of University Cross-disciplinary Research Strategy, School of Chemistry, University of Southampton

Computer network
Professor Jun Murai, Vice-President, Professor, Faculty of Environment and Information Studies, Keio University

Medical devices for Monitoring Patients In and Out of Hospital
Professor Lionel Tarassenko FREng, Professor of Electrical Engineering, Director, Institute of Biomedical Engineering, University of Oxford

SESSION 4: Roundtable discussion on frameworks for the governance of emerging technologies

Contact

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Endnotes

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14 For more on synthetic biology see Royal Society (2008) *Synthetic Biology*. RS Policy Document 16/08, royalsociety.org/displaypagedoc.asp?id=31191

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- **Increase** access to the best science internationally
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