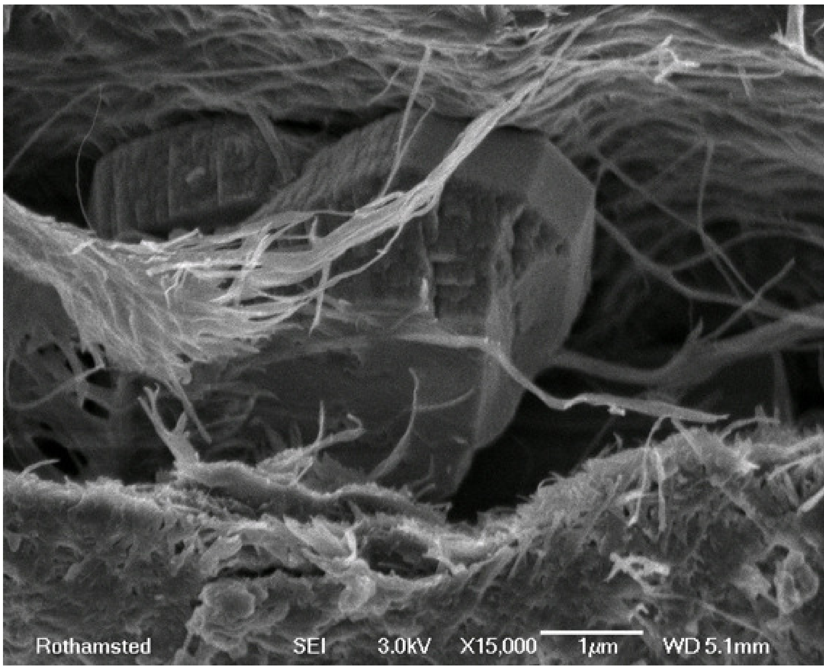
Playing Democs Games to explore Synthetic Biology



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1. Background

The widespread public concern which emerged from about 1998 over genetically modified food has had a profound impact on biotechnology innovation and policy. The shock of opposition to a technology well researched and confidently adopted by Government and industry led to a pragmatic need "to avoid another GM", and a belated recognition that the public have a right to more say on what is researched and developed in their name.[1] Rather than merely "educating" the public about emerging technologies, two-way processes of engagement were needed.

Nanotechnologies were the first new area of innovation to be so treated. The initial phase of engagements had mixed results.[2] The concept was highly technical but vague and unfamiliar. It applied over a huge range of sectors, but many of its developments were still in basic research or "proof of concept" stage. Its comparative lack of concrete examples contrasted with the considerably hyped future promise. In the use of manufactured nano-sized particles, it carried plausible risks that the Royal Society notably acknowledged to need urgent examination.[3]

Synthetic biology was the next case, brought to the wider attention of ethical and social science disciplines at a meeting organised by the UK research councils in Swindon in February 2007.[4] Like nanotechnologies, it expresses obscure and difficult scientific ideas for the lay person, has few applications to grasp, has a largely future promise, and considerable potential risks. The ESRC Genomics Policy and Forum at the University of Edinburgh was awarded funding under the Scottish Government's Science Engagement Grant Scheme to run a public engagement programme on synthetic biology. The Forum contracted Edinethics Ltd. to devise a Democs card game on Synthetic Biology which would be a resource to explore the issues widely with lay publics in Scotland. Amongst the many methods developed to address the need for public engagement, the Democs game concept has established itself as an unusual and effective place seen as highly appropriate to explore synthetic biology.

This is the report on the creation of the game and the first round of public use.

2. The Democs Concept

DEMOCS (DEliberative Meetings Of Citizens) is a novel form of lay participation on complex technical issues, devised by Perry Walker of the New Economics Foundation in 2002.[5] The original game was originally devised for stem cells, with sponsorship from the Wellcome Trust and with expert consultants (of which the author was one). Democs games have now been created on a wide range of issues from cloning to climate change. They have been used in Government consultations, such as the "GM Nation?" debate on GM crops in 2003, and on genetic testing kits for the Human Genetics Commission, and on nanobiotechnology, as part of the EC FP6 NanoBio-Raise project.[5] Simplified versions of four games were successfully made available in various European languages as part of the EC FP6 DECIDE project,[7] and its European development is being extended in its successor EC FP7 project FUND.

It is not a game played to win, but a semi-structured group discussion for 6-8 people over 1½ - 2 hours, through the medium of cards. Series of cards are dealt out and discussed in three stages.

a) Story Cards - imaginary narrative contexts, based on real life situations or ones reasonably envisageable. The aim is to introduce the technology through people who are involved in it, or affected by it, often presenting an ethical dilemma.
b) Information Cards - essential information to cover the basic science involved, its potential applications and the regulatory context, aimed at being fair and objective.
c) Issue Cards - a range of questions, perceptions, issues and opinions to explore the ethical and social implications of the technology. Cards present differing or even directly opposed views, aiming to cover a fair range of opinions and attitudes known or likely to exist.

The group uses these to discuss and form their own views - agreed or divergent. These are expressed in the final phase by producing group statements or opinions, based on "Clusters" of selected cards, and by individual voting on a range of policy options. Policy options can be broad overall policies for the technology, or focused on the acceptability (or otherwise) of particular applications, or, in this present case, both.

The game is very much what each particular group of people makes of it. Participants are encouraged to contribute their own ideas and insights, to write their own cards, or produce alternative policy positions to vote on, if they want to. People often do. The aim is that the expert input is in the cards, not in a specialist who is present to help the participants. The original Democs aim was that facilitation should be minimal, or not at all. In practice, experience suggests that unfamiliar and very technical subjects like synthetic biology seem to work better with someone present who has become at least somewhat familiar with the material under discussion, though not necessarily a technical expert.

The approach is a compromise between providing enough information for people to discuss meaningfully without prior knowledge, and a degree of inevitable framing by the content of the cards. This puts a considerable onus on the writers of a particular game, and the peer review process, to achieve the necessary rigour and balance with as little personal bias as possible. Analogous questions arise in the preparation of focus group stimulus material or providing citizens jury expert inputs, or the framing of questionnaires.

Unlike most public engagement activities, which sample representative populations but access relatively few people, Democs seeks to enable a much broader degree of lay participation, by starting with people in the contexts where they normally get together - friends in a pub, neighbours, a club, church or community group, a group of students, and so on. The technique thus falls between focus groups and opinion polling in the type of information generated and numbers of people who can engage. Its advantage is that it can be played by any group of people who care to take part, anywhere, and its spontaneity comes from less reliance on expert facilitation. The primary aim is to get people engaging. Just to play the game with otherwise unengaged citizens is its own justification.

It can provide considered views and comment from a much wider range than are tapped by normal focus group sampling and in far more depth than from tick box opinion polling. By the same token, however, it does not seek formally representative samples of the population. Diversity can eventually be achieved if enough games can be played among enough varied sectors of the community, locations, age-groups, etc., as has been done with stem cells and GM crops for example. The games are thus able to produce empirical data, but it must be understood and interpreted with care, and its limitations recognised, as is pointed out below.

People already deeply engaged with the issue in question may find the game superficial, because it is aimed squarely at people who are not expert and may know little about it. Nonetheless, it has found a considerable role in teaching ethics to science students in a participative way. A cut down "expert" version on nanobiotechnology, focusing only on issue cards, has been used to help scientists in the field to explore ethical issues. The beta test of the present game was done with the science and engineering undergraduates of the Edinburgh University team in the 2009 iGEM international synthetic biology competition, and featured in their presentation.

3. Creating the Game

Devising the content of a Democs game is a complex task, requiring many iterations. It is a compromise of several factors. The game must achieve the right range of factual information so that people who know nothing of the issue can grasp the essential facts sufficiently to be able to discuss its wider implications. It therefore must avoid unfamiliar acronyms, jargon and complex technical or abstract terms. Each piece of information, concept, question or dilemma has to be compressed into something like 30-35 words per card, and preferably less.

Whilst the designer has a full picture of the logic and interrelations of the information contained in the cards, a player will handle only a selection of the cards, giving fragments of the picture. This indeed is part of the group dynamic, that each person contributes to a greater whole. But the group still examines only a subset of the full information set contained in the cards. Each card should generally make sense on its own. Exceptionally, cards can be cross referenced, but it detracts from the flow of the game.

Synthetic biology proved harder to design than any previous Democs game. The first task was to identify the key features of what it entails, for the Information Cards. But synthetic biology is not a single straightforward idea, but a set of research concepts which tend to presuppose a knowledge of molecular biology, genetics and cell science, and a grasp of engineering and information processing. The game therefore needed to build creative bridges to relate unfamiliar concepts to things with which people are familiar. Analogies were drawn with Lego, flat-pack self-assembly furniture, bespoke tailoring, designing car parts for an assembly line. Comparisons were made with other areas like genetic modification, industrial insulin production, and ecological risks from introduced species.

The second task is to give a realistic sense of the "state of the art" – what applications exist, what may be reasonably expected, what challenges need to be overcome and controversies resolved. Story Cards are especially useful here, to make an imaginative link to human situations and concrete applications. But synthetic biology has few such examples. The human stories therefore reflected issues like research funding, patents, and the student iGEM competition, as much as applications like artemisinin and spider silk. Inevitably, a measure of personal judgement was needed to disentangle viable technologies from more speculative ones, and to be realistic about the dreams of an emerging field whose scope and limits are not yet known.

The third task is to cover the main ethical and social issues, including any important regulatory or political factors, and the international context. The aim is for a balance of questions, arguments, counter-arguments and points to ponder. A proposition may be summarised well in one card, but its criticisms may require three cards. Decisions have to be taken about minority views and how to portray disputed evidence - to give a hearing to a heterodox view without creating the impression that it necessarily carries equal weight with "conventional" wisdom.

A set of five policy propositions were devised, with different weighings of risks and benefits, but also enabling any principled objection to be expressed. Following the example of the nanobiotechnology Democs game, it was decided to use a second vote on the degree of acceptability of different potential applications of synthetic biology, giving players the opportunity to give their own words of explanation. A decision was taken to keep the feedback form to a minimum - covering only gender, age, group, date, location, and two questions on what worked and what didn't. Finally, an instruction manual was produced, adapting existing versions, suitable for a non-expert to organise a game and act as "dealer".

The content of the cards was derived from extensive reading of the scientific review literature, among which the BBSRC and International Risk Governance Council reviews, and a Royal Society workshop report were useful sources, and more limited ethical and social research. We are also grateful to many people who gave advice and comment, including Andrew Millar, Alistair Elfick and Chris French (Edinburgh University) and Paul Freemont (Imperial College) on scientific aspects, and Jane Calvert (Innogen) and Emma Frow (Genomics Forum) on social and ethical dimensions.

The content of the cards was prepared by Donald Bruce of Edinethics Ltd. and iterated with comments from Perry Walker of nef and Christine Knight and other staff at Genomics Forum. The game was beta-tested with the Edinburgh University iGEM team. Suitable images were identified and permissions obtained. Design work was by Design by Knight. The game was finally printed and distributed in November 2009. The information and issue card wordings are listed in Tables 5 and 6, and the story cards are reproduced in Tables 7A and 7B.

4. Dissemination

The game was presented at various meetings, notably the Synthetic Biology Policy Reference Group at the Royal Society. It was also offered to the BBSRC/EPSRC public consultation starting in early 2010 (whose results have just been published).[8] Although initially TNS-BMRB (who carried out the BBSRC/EPSRC consultation) were keen to use it as a tool to help people explore the concepts of synthetic biology, a late decision was made by the consultation's steering group not to use the game. An important opportunity was missed to use the skills and experience that had gone into the game and also to obtain useful comparative data about public attitudes to synthetic biology using different methods.

There have been various opportunities for wider dissemination of the game. It has been published for downloading on the Genomics Forum website, and linked to the Edinethics website. The publicity in April 2010 about Craig Venter's research led to Edinethics writing an article for the Channel 4 TV News website, which also refers to the game. Interaction with the FUND project has also raised interest in this synthetic biology Democs game in other European countries. For example, trial games have been run in France and Ireland.

5. Who Played the Games?

In parallel with creating the game, we sought to identify groups who would play it and volunteer facilitators who would be responsible for setting up games. This drew upon the existing database of New Economics Foundation, the Scottish science centres, personal contacts, etc. The uptake was significantly lower than that for other Democs games. It has evidently proved more difficult to interest broader publics in playing the synthetic biology Democs game than games on most other subjects. There seem to be several reasons for this, including the relative obscurity of the subject in most people's experience, the technical difficulty of its concepts for non-scientists, and having relatively few concrete applications to "get one's head round".

We are indebted to the volunteer facilitators who offered to try the games out on colleagues, students, friends and other groups. The Bristol groups BRIS were science students. Glasgow group GLAS were MSc biology students. The groups labelled "LSE", although facilitated by a social science researcher at the London School of Economics, were all third year science and engineering students at Imperial College London. These groups appreciated the chance to explore ethical issues. The QMUE and SIBE groups were students on a public dialogue course of Queen Margaret University, Edinburgh, and came from various backgrounds, including science communication, voluntary and public sectors, and academe. SIBE is the Scottish Initiative for Biotechnology Education one of whose research associates facilitated this group. PICK were four public health researchers at Edinburgh University. DUNS were seven members of Dunscore Church of Scotland in rural Dumfriesshire. NEF were staff at the New Economics Foundation (nef) office in London. SRT was a working group of mixed scientific and lay backgrounds doing a study on the ethics of synthetic biology for the Church of Scotland, as part of its Society, Religion and Technology Project.

The nature of Democs games is that they are played with groups where these can be found. Its great advantage is in engaging people locally who would normally have no opportunity to discuss an emerging technology. But this has two inherent drawbacks. Firstly, the grassroots emphasis does not normally allow us to sample the population representatively. Democs results can only be considered representative once a large enough number of games have been played and in a variety of social contexts (which was achieved for example with the GM Nation game). Secondly, since the game is voluntary, not all the data may be obtained or sent back. For example, SIBE did not fill in any comments on their votes on the Applications of synthetic biology. PICK did not make cluster cards and made only one Applications vote, whereas the SRT game provided cluster card and feedback form information but no votes.

The synthetic biology game participants so far are a fairly small and rather skewed sample. The majority were in the 18-30 age range (Table 10). A substantial proportion were science students. Thus, 75% of the 51 BRIS, GLAS and LSE players had a "not bad" or "quite good" prior knowledge of synthetic biology, whereas 68% of the 25 QMU, SIBE, PICK and DUNS players had "very little" knowledge. The DUNS church group was more typical of non-scientific lay people, but was entirely from the 45 and above age groups.

6. Data Analysis

This report summarises the results from several sets of games for which information has been sent back and informal reports of some others. The data which have been analysed came from 82 participants in the 15 games for which we have received results, played in Scotland and England between November 2009 and March 2010. Games may also be played by people who have downloaded them from the Genomics Forum website. It is important to be clear that data presented below do not necessarily represent a typical sample of Scottish or wider UK populations. Thus we have so far been able to play only a few games among a more typical age range and from wider social contexts, and the feedback from such games has been limited. The results are thus to be seen as work in progress.

The Scottish groups analysed were GLAS, QMUE, SIBE, DUNS and SRT. There were small differences in the Policy Votes from the averages from the whole data set (Table 1). But the Applications Votes (from 27 participants) are substantially different (Table 2), with lower "yes" votes for all but one application. For example, for biofuels, 75% voted "yes" and 20% "possibly" overall, but the Scottish games gave 39% and 48%, respectively. But at this point in time, not enough Scottish games have been played and fed back to report specifically on what Scots participants are making of synthetic biology. It was possibly more significant that these games also represented people who were mostly not science students. More data would be needed to establish whether this more guarded view of synthetic biology applications was typical of the general population. More groups are being contacted in different parts of Scotland, to widen the use of the game. These will be reported as soon as enough data have been assembled.

a) Policy Voting (Table 1)

Five policy options were created. No.1 was an objection in principle. Nos.2 to 5 are a spectrum of risk regulation from complete ban (2) to minimal regulation (5), with options of full containment (3), and release allowed under controls and licensed researchers (4).

No one wanted to stop synthetic biology either on principle or because it was too risky (options 1 and 2). On the other hand, most disagreed with leaving its development up to the market with minimal regulation. Almost everyone agreed with strict containment of any modified organisms (Option 3). However, most people also agreed or could live with Option 4, which would require researchers to be licensed but would also allow for released organisms under strict control. The logic was that if you agreed to Option 3 you could at best only live with Option 4. This suggests that the distinction between these options is not clear enough. It may be that having two issues (controlled release and licensing researchers) in one option has resulted in ambiguous responses. The requirement to licence researchers should in future become a separate policy option.

Four additional policy options were suggested. LSE group A voted on "Synthetic biology should be regulated within an institution where the institution should be regulated." LSE group C voted on "SynBio products should undergo rigorous/dedicated testing before approval for use to determine risks." Bristol added "Commercial limitations and arguments should direct the area", but no one voted on it. QMUE added, "Furry creatures should be prioritised", possibly as a joke.

The general support for contained organisms is an interesting preliminary result, bearing in mind that quite a lot of players were science students. This implies that there was not a strong acceptance of the common argument put forward by synthetic biology proponents (given in Issue Cards B25 and B26), that released synbio organisms would be less fit in the environment or could be made unable to replicate. It would be valuable now to play games with players from wider lay publics, to see if they reflect a similar priority to Option 3.

b) Votes and Comments on Applications of Synthetic Biology (Table 2)

For all eight applications, most people voted "yes" or "possibly" to the question: "Would this application be acceptable?", ranging from 68% (virus research) to 96% (biofuels). Biofuels from plant wastes had the most specific support (almost ¾ voted yes), with about two-thirds for pharmaceuticals and around 60% for new industrial materials. Out of 537 total votes, only four "no" votes were cast - for virus research, environmental detection and industrial materials – and only 26 "doubtful". Virus research had the least "yes" votes (31%) and the most "doubtful" (17%). Nitrogen fixation in food crops showed more uncertain in the support (43% "yes", 42%

"possibly"), but the associated comments did not suggest a strong antipathy that might have been expected in an application with GM crop associations.

As expected, this case-based questionnaire elicited primarily consequential responses about applications rather than normative insights. Underlying themes express concern over what the economic and industrial status quo would do with the innovations. The predominant values were that human or environmental benefits made strong reasons to proceed with the application, but that risks, effectiveness or the industrial practicalities might in some cases call these into question. One said (of environmental clean up): "Human welfare. It's immoral not to" (BRISA-05). The need to balance risks and benefits is a dominant thread in the comments across most of the applications. Opinions varied about how well this can be handled, and about the level of risk that is justified. Many thought there needed to be quite strong regulation, or gave their support conditional on satisfactory testing for unintended consequences and side effects. On the other hand, some argued that you need to take some risks to learn anything, and that the benefits of synthetic biology were worth the risks. Despite these concerns, only for virus research (20%) did the combined votes for either "no" and "doubtful" exceed 10%. Some participants wanted more risk information about specific applications, in order to evaluate whether we should take the risks or not. This point is discussed further in the feedback section.

There was substantial variation among the results from the locations. The high degree of support for the applications perhaps reflects the high proportion of biological science students among the sample (BRIS, GLAS, LSE), but the reservations expressed by these groups indicated that this was by no means an uncritical approval. Indeed, their biological insights led some to raise questions about the risks or the effectiveness of the proposed approach.

1. Making biofuels from plant wastes

The 51 BRIS, GLAS and LSE game participants overwhelmingly voted "yes", citing the benefits of reduced fossil fuels use in climate change and fuel security. But there was some ambivalence about land use. Some saw the advantages of "generating biofuels without devoting land to them is therefore a very good thing" (BRISC-10), and of using plant wastes and cellulose. But some also saw problems. "I don't know how you can avoid competition for land, unavoidably there would be economic drivers that would be difficult to control" (BRISC-13). "Would depend on its integration with food crops without competing for them" (GLAS-01). A lone "doubtful" thought "it would harm the environment and damage the natural (sic)" (GLAS-04).

The QMUE, Dunscore and nef participants voted less positively, and had mixed comments, seeing the environmental and fuel benefits, but asking about the risks. Some advocated alternatives of changing our lifestyle, using less fuel, or using other renewable energy sources.

2. Detecting pollutants in the environment

The potential to clean up drinking water especially in the Third World was seen as a major benefit, with an obvious moral impetus, but many also recognised the drawbacks that would need to be overcome - especially the practicalities and financing of the large scale use that would be needed, and possibly the fate of the test organisms in the water.

3. Cleaning up pollutants in the environment

Again, the obvious benefits were recognised, and stressed by the "Yes" voters, but many comments noted uncertainty about the fate of the micro-organisms and their effects on human health, on the balance of microbe populations, ocean ecosystems, or the environment generally. This was especially among "Possibly" voters, but also from some "Yes" voters. "Once again the risks need to be assessed, but finding pollutants is good for humans and ecosystems as they can then be removed. What happens to the micro-organisms when they've found the pollutants? Are they self-sustaining?" (BRISB-10). "It would be a great use but what if the organism itself became an environmental contaminant?" (BRISA-03). "Often pollutants are merely in excess, so we shouldn't remove it all" (BRISA-05). "Pollutants can be cleaned by better methods. Microorganisms might be a source of pollutants themselves", (LSED-03). One "Possibly" commented on the use of synbio micro-organisms for both detection and clean-up.

4. Making new industrial materials

Some found this intriguing and beneficial, seeing the usefulness of the material, "Good idea due to the tensile strength inherent to spider silk", (LSEC-03). But to some it seemed perhaps implausible or hard to grasp. "Seems very fanciful. Yet if the science is there, then the obstacle is production with low costs" (GLAS-01). "Not sure what the technique involves" (GLAS-03). There was less clear benefit, but no really negative comments. "I don't have a problem with this although other applications are more worthy" (BRISB-06). One person voted "possibly", noting the potential for misuse, "Only if application is constructive, not destructive" (LSED-04). The advantages of keeping the organisms contained were noted by quite a few players.

5. Micro-organisms to make synthetic pharmaceuticals

The large majority of the comments were straightforwardly positive for the medical benefits, better effectiveness of drugs, reduced costs, better access to drugs, etc. "The purpose of Syn Bio is the new products to be more efficient in the treatment and more cost effective" (LSEA-01). Several noted that we are already doing this (e.g. insulin). Again, contained use was seen as an advantage. A very small number raised risk issues but only in a general way.

6. Creating synthetic viruses to research pandemic flu

This was by some way the least supported application, with more "possibly" votes than "yes". Most respondents understood the dilemma captured for example by GLAS-07, "It might help in future pandemics & save lives but if they are dangerous care must be taken to contain them in a lab." There were some optimistic responses. "In a well-run, regulated lab it should be OK" (BRISA-05). "Interesting, if one does not take risks, one does not gain reward" (LSEC-01). But others were dubious. "Synthetic viruses might trigger the next pandemic?" (LSED-03). "If something goes wrong with this, it has severe consequences; and this is not unlikely to happen" (LSEC-03). But only two voted "no". Regulation and containment were seen as very important, with greater or lesser degrees of precaution expressed. "Access should be very limited. Only use if have to, especially if dangerous strains are concerned in case they escape" (LSEC-06). "I can accept this given enough safety regulation, but I can see much opposition" (LSEA-03). One picked up the potential importance for developing countries (DUNS-07), but only three referred to potential malign uses.

7. Genetically engineered biological devices to detect infections

Comments were brief and in less depth, suggesting that players connected less with this application than some others. "Useful but minor application" (DUNS-05). Like environmental clean-up, over a third voted "possibly" rather than outright "yes". The detection of infection was recognised as important but so were potential risks: "Implanting synthetic bacteria would concern me - possible recombination with bacteria already present." (BRISC-12). "Don't like the idea of bacteria in me" (sic) (LSED-05).

8. Enhancing food production by helping plants absorb nitrogen

In keeping with the almost equal "yes" and "possibly" votes, the comments expressed were mixed, and covered quite a range of issues. "We're already playing with everything else - why not this as well?" (BRISB-07). "Not sure this warrants a syn bio approach" (BRISB-06). Quite a lot saw the benefits for feeding a growing world population, and some the environmental and resource benefits. LSEC-01 captured all three senses: "If fertilisers are pollutants, save resources, reduce costs. Solve food shortage." Others were unsure if it would work, or that this was the best solution. "Good for the environment but the nitrogen fixation technique seems difficult to be incorporated into plants and may not work" (GLAS-07). "Other ways of producing food more efficiently and distributing it more fairly" (DUNS-07). Although this received the second lowest "yes" vote of all the applications, no one voted "no", and only two "doubtful" (but did not say why).

Surprisingly, only three commented on genetic modification aspects. One saw it very positively, "It would certainly help in food production. Fertilisers are not safe and should be replaced with genetically modified plants" (GLAS-02). Another said "Trials needed because genes can potentially be passed on" (LSEC-06). A third posed the rhetorical question, "Will GM save the world?" (LSED-02). One "possibly" voter observed "industry rather than morals" (PICK-01).

Some made exactly the same comments for several applications. On biofuels, environmental detection and clean up one observed "Would probably need to know more about potential risks and disbenefits before definitely saying yes. And also for reasons of transparency and accountability" (NEF-01). In voting "possibly", LSEC-03 said of both environmental detection and clean-up, "The constant challenge of synthetic biology on interrupting evolution of designed organisms might constitute a problem." The "designed micro-organisms might become out of control".

c) Cluster Subjects (Table 3)

Cluster subjects reflect the discussion themes on which the groups focused spontaneously as they work through the cards. The reporting of these was less helpful than usual, because many of the clusters were merely descriptive. Table 3 lists only the cluster cards which made a reasonably clear point or posed a question, grouped into approximate categories. There was a fairly even spread amongst basic philosophical/theological questions, ownership and justice issues, risks, and regulation. A few groups highlighted benefits, and two addressed public communication and perception. In some Democs topics, certain cards emerge which were used many times in clusters. For these synthetic biology games, however, no particular cards or subjects stood out amongst the broad range of cards that were cited in the clusters (Table 4).

The cluster subjects show that participants were clearly interested in underlying philosophical issues, like playing God, naturalness, and how we relate to other organisms and to nature, for example: "Playing God - A classic argument but one which is important and over-arching, covering a range of objections beyond the religions". But it was seldom clear what their conclusions were on such issues. One cluster identified a question in an intriguing way, but left it unresolved: "Enslaving microbes - Should we be using microbes like tools? The possible exciting new opportunities of syn bio." It was also interesting that most of these philosophical questions were coming from groups which were mainly scientists.

Taken together, the linked issues of risks, ownership and regulation of synthetic biology exercised the most groups. Again, many of the issues were presented as dilemmas or questions without drawing a conclusion – open source or patents, commercial incentives vs. public ownership of knowledge, who should regulate and what should be regulated, creating or controlling pandemics, etc. "Amateur synbiologists?" and garage biology seemed to be a concern, along with creating viruses, and, for some, the manipulation of life forms. But no definite recommendations were made on these points. LSEA thought that "Biofuels should be in government hands, perhaps? Danger of monopoly? Patents restricting research and development?", but no groups made the opposite plea for greater private ownership.

Dunscore made two clear policy recommendations: "Funding should not be from just one source. It should be government, charitable trusts and companies. Companies' use of copyright (sic) should be more controlled." "Regulation essential. International body to oversee regulation – linked to research body." The need to link research directions with international and government oversight suggested that it was not sufficient to leave the emergence of synthetic biology to market forces and scientific curiosity. Given the general tenor of the issues flagged up in the cluster cards, these two suggestions may have found some support in other groups. But the scarcity of clear recommendations was perhaps the most striking feature of the clustering.

d) Feedback about playing the game (Table 11)

There was considerable variation in feedback on the games played. Sometimes people gave exactly opposite views, e.g. about the value of clustering, and on the card about women car designers. Most groups clearly enjoyed the experience of discussing synthetic biology, and doing so in a group context with different views. People thought the Demos game format gave a good way of doing that. Many appreciated the chance to learn about a new area of technology and explore some of its implications. Some thought they wanted more time to discuss.

There were some unusual findings. The first group to use the game was a youth group in Bo'ness in West Lothian. Although one undergraduate member of the group enjoyed it, the rest found it difficult to relate the game at all, suggesting the majority age range here was too young. One group in Edinburgh, despite clearly enjoying the game, nonetheless refused point blank to make cluster cards, which has never happened before in a Democs game. The SRT group studying the ethics of synthetic biology felt that the application voting grid presented the benefits but not the possible downsides. This misunderstood the aim of this vote: to help focus participants' thinking, based on the benefits, risks and wider ethical issues already aired in the cards. But it might be useful to find ways to correlate the applications with relevant cards.

Many people said there was too much information to digest. For example: "In general it was felt to be too long and possibly too complicated, with not enough distinctions between the different card types." The same group also felt they needed more information. This perhaps reflects the unfamiliarity of the subject. The dealer reported that "it was seen as something far too distant from everyday experience".

7. Conclusions

The difficulties expressed in some of the feedback suggests that synthetic biology is a more difficult subject for the average citizen to engage with than many other Democs games such as stem cells or climate change. The fact that it was easier to attract groups of scientists to discuss than other people also seems to indicate a low public awareness of the issue. The cluster card subjects showed a consistent picture that participants identified questions and dilemmas quite well from the subject matter in the cards, but were not inclined to articulate conclusions from them. This suggests that the role of this synthetic biology Democs game is more in opening up questions that people had not previously thought about, rather than helping them to crystallise their thoughts on a matter they already knew something about. The impression is that people have gone away thinking, which is one aim of the grassroots model of engagement embodied in Democs. People need time to evaluate new technologies. The primary outcome of this project is in the very creation of the synthetic biology Democs game, which is a tool which can now go on being used anywhere. It enables public engagement to continue in a way which the more common “set piece” consultations, because of their time limited nature, cannot do.

From this sample of people, there did not emerge a serious fundamental objection to the very idea of synthetic biology. Although the sample was skewed by science students, the overall impression is fairly positive towards the technology even among more “lay” people, albeit with a tendency to vote “possibly” rather than “yes” than the more scientific groups. There was also a sense of caution from many people about the import of making significant modifications of this sort. For example, the question “Do we know enough to be doing this?” was posed several times in different ways, seen both in clustering and the comments on the applications votes. Risks were raised as much by scientists as anyone, on occasion coming directly out of their scientific understanding. It is interesting that there were not more definite conclusions from clustering, given that so many of the participants were science students. As has been observed with other Democs games such as GM crops, there is clearly a role for games like this to help address the well recognised need to train science and engineering students in ethical and social issues.

There was strong overall support in the voting for most of the applications, and particularly from the scientific groups. It was reassuring to see the degree to which risks and other issues were recognised in the places in the game process where opportunities were given to articulate. There was not much evidence of a merely naïve optimism, nor of overwhelming sense that we were embarked on a course for disaster. Although it was not clear in overall terms what needed to be regulated, the sense was that regulation was needed in these particular areas. Virus research, garage biology and uses for terrorism were all seen as problematic, suggesting that these issues need addressing in policy. Few explicit links were made to genetic modification concerns, but similar issues of risk, of the power of monopoly, patenting, and private ownership were noted.

The Dunscore group represented a much older and less technical group, and was specifically Christian. It did not produce a strong objection to synthetic biology, either as a reflection of age range or belief. Indeed it showed quite positive outcomes, while making more definite recommendations than most other groups. One of this group commented on why he/she voted mostly yes to 6 of the 8 applications: “a good consciousness raising exercise has encouraged my positive response. But do I know enough?” This seems to express an overall conclusion from this first round of playing the Democs game on synthetic biology.

It would be premature to draw strong conclusions at this point about the overall support for or concerns about synthetic biology among UK or Scottish citizens. The data set is too small to make definite conclusions, but it indicates the need to continue the use of the game with a wider citizenry, to explore the preliminary indications from this first round. A main impression is that people are not familiar enough with the issues, and will need more time to digest and reflect. As with nanotechnology, this may be a case which indicates the limitations of what “upstream engagement” can reveal or achieve in the short term. If, on the other hand, this Democs game starts a process of wider deliberation on synthetic biology, it will have achieved a valuable result.

7. Acknowledgements

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8. Tables

9. References

[1] House of Lords (2000), *Science and Society*, Report of the House of Lords Select Committee on Science and Technology, London: HMSO.
[2] Gavelin, Karin and Wilson, Richard (2007), *Democratic Technologies? The Final Report of the Nanotechnology Engagement Group*, London: Involve.
[3] The Royal Society and the Royal Academy of Engineering (2004) *Nanoscience and Nanotechnologies: Opportunities and Uncertainties.* London, UK: The Royal Society.
[4] BBSRC (2007), Booklet of a Synthetic Biology Workshop held at Alexandra House, Wroughton, 8-9 February 2007, Swindon: BBSRC.

[5] Further information about the Democs game can be found on the New Economics Foundation website www.neweconomics.org
[6] Bruce, Donald (2008), *Engaging Citizens on Nanobiotechnology Using the Democs Game*, EC NanoBio-RAISE Programme report, www.nanobioraise.org
[7] Duensing, Sally and Lorenzet, Andrea (2007), *Decide Evaluation Report*, March 2007, EC FP6 Decide Programme, http://www.playdecide.org/
[8] Bhattachary, Darren, Pascall Calitz, Juliet, and Hunter, Andrew (2010), *Synthetic Biology Dialogue*, BBSRC, EPSRC and Science Wise Public Consultation, Swindon: BBSRC, http://www.bbsrc.ac.uk/web/FILES/Reviews/1006-synthetic-biology-dialogue.pdf

Table 1: Five Synthetic Biology Policy Options: Summary of Votes

VOTE 1 : FIVE SYNTHETIC BIOLOGY POLICY OPTIONS : SUMMARY						LSEA	LSEC	QMUE (possibly meant as a joke)	BRIS (but no one voted on it)
Policy	1	2	3	4	5	6	7	8	9
Policy position	Synthetic biology should be stopped as it intervenes too far in nature, or is ´playing God´.	Synthetic biology should not be allowed as it poses too great a risk to health or the environment.	Synthetic biology may be used to make products (e.g. fuels, drugs), provided any organisms which are used are kept strictly contained.	Synthetic biology may be done, provided researchers are licensed, and that strict regulations apply to any released organisms	Synthetic biology should be encouraged to develop with minimal regulation.	Synthetic biology should be regulated within an institution where the institution should be regulated	Syn Bio products should undergo rigorous/dedicated testing before approval for use to determine risks	Furry creatures should be prioritised	Commercial limitations and arguments should direct the area
ALL RECORDED VOTES (76)									
Agree	0	1	49	38	4	6	5	2	0
Live with	7	6	24	23	8	0	1	1	0
Disagree	64	67	0	8	54	0	0	0	0
Don't know	5	2	3	7	10	0	0	1	0
Total votes	76	76	76	76	76	6	6	4	0
Agree	0%	1%	64%	50%	5%	100%	83%	50%	0%
Live with	9%	8%	32%	30%	11%	0%	17%	25%	0%
Disagree	84%	88%	0%	11%	71%	0%	0%	0%	0%
Don't know	7%	3%	4%	9%	13%	0%	0%	25%	0%
SCOTTISH VOTES (26)									
Agree	0	0	11	14	0	0	0	2	0
Live with	1	0	14	11	3	0	0	1	0
Disagree	23	25	0	0	21	0	0	0	0
Don't know	2	1	1	1	2	0	0	1	0
Total votes	26	26	26	26	26	0	0	4	0
Agree	0%	0%	42%	54%	0%			50%	
Live with	4%	0%	54%	42%	12%			25%	
Disagree	88%	96%	0%	0%	81%			0%	
Don't know	8%	4%	4%	4%	8%			25%	

These data do not include votes from the 6 players in the SRT game, which have not yet been returned.

Table 2: Synthetic Biology Applications: Summary of Votes

VOTE 2 : SYNTHETIC BIOLOGY APPLICATIONS : SUMMARY

		Biofuel	Env.detect	Env.Clean	Materials	Pharma	Virus research	Infection	N-fix	
		Making biofuels from plant wastes	Detecting pollutants in the environment	Cleaning up pollutants in the environment	Making new industrial materials	Micro-organisms to make synthetic pharmaceuticals.	Creating synthetic viruses to research pandemic flu.	Genetically engineered biological devices to detect infections.	Enhancing food production by helping plants absorb nitrogen.	Total of Votes
All Recorded Results										
Yes	Y	52	40	35	42	47	20	34	28	298
Possibly	P	14	23	26	13	15	24	26	27	168
Undecided	U	2	2	7	8	3	8	3	8	41
Doubtful	D	1	3	1	5	1	11	2	2	26
No	N	0	1	0	1	0	2	0	0	4
Total		69	69	69	69	66	65	65	65	537
										Average
Yes	Y	75%	58%	51%	61%	71%	31%	52%	43%	55%
Possibly	P	20%	33%	38%	19%	23%	37%	40%	42%	31%
Undecided	U	3%	3%	10%	12%	5%	12%	5%	12%	8%
Doubtful	D	1%	4%	1%	7%	2%	17%	3%	3%	5%
No	N	0%	1%	0%	1%	0%	3%	0%	0%	1%
										Average
Yes+Possibly	YP	95.7%	91.3%	88.4%	79.7%	93.9%	67.7%	92.3%	84.6%	86.7%
Doubtful+No	DN	1.4%	5.8%	1.4%	8.7%	1.5%	20.0%	3.1%	3.1%	5.6%
Undecided	U	2.9%	2.9%	10.1%	11.6%	4.5%	12.3%	4.6%	12.3%	7.7%
Scottish Results										
Yes	Y	9	14	10	5	12	6	10	5	71
Possibly	P	11	7	9	7	7	11	11	11	74
Undecided	U	2	2	3	6	2	4	1	5	25
Doubtful	D	1	0	1	4	1	1	0	1	9
No	N	0	0	0	1	0	0	0	0	1
Total		23	23	23	23	22	22	22	22	180
Yes	Y	39%	61%	43%	22%	55%	27%	45%	23%	39%
Possibly	P	48%	30%	39%	30%	32%	50%	50%	50%	41%
Undecided	U	9%	9%	13%	26%	9%	18%	5%	23%	14%
Doubtful	D	4%	0%	4%	17%	5%	5%	0%	5%	5%
No	N	0%	0%	0%	4%	0%	0%	0%	0%	1%
Yes+Possibly	YP	87.0%	91.3%	82.6%	52.2%	86.4%	77.3%	95.5%	72.7%	80.6%
Doubtful+No	DN	4.3%	0.0%	4.3%	21.7%	4.5%	4.5%	0.0%	4.5%	5.5%
Undecided	U	8.7%	8.7%	13.0%	26.1%	9.1%	18.2%	4.5%	22.7%	13.9%

VOTE 2 : SYNTHETIC BIOLOGY APPLICATIONS : By Location

			Biofuel	Env.detect	Env.Clean	Materials	Pharma	Virus research	Infection	N-fix	Average
DUNS	Yes	Y	0%	29%	57%	43%	43%	71%	43%	71%	45%
	Possibly	P	0%	57%	29%	29%	14%	14%	57%	29%	29%
	Undecided	U	0%	14%	14%	14%	29%	14%	0%	0%	11%
	Doubtful	D	0%	0%	0%	14%	14%	0%	0%	0%	4%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%
QMUE	Yes	Y	0%	50%	25%	25%	50%	50%	25%	25%	31%
	Possibly	P	0%	25%	75%	50%	25%	0%	50%	50%	34%
	Undecided	U	0%	25%	0%	25%	0%	25%	0%	0%	9%
	Doubtful	D	0%	0%	0%	0%	25%	0%	0%	0%	3%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%
LSE-total	Yes	Y	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Possibly	P	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Undecided	U	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Doubtful	D	0%	0%	0%	0%	0%	0%	0%	0%	0%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%
BRIS-total	Yes	Y	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Possibly	P	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Undecided	U	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Doubtful	D	0%	0%	0%	0%	0%	0%	0%	0%	0%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%
GLAS	Yes	Y	0%	43%	86%	57%	0%	43%	14%	29%	34%
	Possibly	P	0%	43%	0%	29%	43%	43%	43%	71%	34%
	Undecided	U	0%	0%	14%	14%	57%	0%	29%	0%	14%
	Doubtful	D	0%	14%	0%	0%	0%	14%	14%	0%	5%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%
SIBE	Yes	Y	0%	25%	75%	25%	0%	25%	25%	50%	28%
	Possibly	P	0%	75%	25%	75%	50%	75%	50%	50%	50%
	Undecided	U	0%	0%	0%	0%	0%	0%	25%	0%	3%
	Doubtful	D	0%	0%	0%	0%	50%	0%	0%	0%	6%
	No	N	0%	0%	0%	0%	0%	0%	0%	0%	0%

These data do not include votes from the 6 players in the SRT game, which have not yet been returned. The full set of comments made by participants about their votes on these applications is available, but they have not been included in this report for space reasons.

Table 3: Synthetic Biology Cluster Card Subjects (with definite views or questions) grouped by Category

MAIN GROUPS OF SYNTHETIC BIOLOGY CLUSTER SUBJECTS

Category	Unique no	No.	Name of cluster	What is the meaning of this cluster?
Philosophical	BRIS-101	P	Playing God	Questions concerning natural/unnatural
Philosophical	BRIS-109	P	Ethics	What right, it is it allowed or is it against religious perspectives of life?
Philosophical	BRIS-114	P	Next steps/practical applications	Philosophical basics and future aims
Philosophical	LSEA-103	P	How to classify life?	Where do you draw the lines with synbio & how do advances effect nature?
Philosophical	LSEB-102	P	Playing God	A classic argument but one which is important and over-arching, covering a range of objections beyond the religions
Philosophical	LSEC-104	P	Design evolution	Engineering designing organisms the way we want 'tinkering' with nature. Reshape living organsims to our own design.
Philosophical	LSEC-105	P	Enslaving microbes	Should we be using microbes like tools? The possible exciting new opportunities of syn bio
Philosophical	LSEE-102	P	Ethical dilemma	When & where to stop? How much do we know?
Philosophical	LSEE-105	P	Terrorism & security	Avoiding disaster. Use for good vs use for evil. Intentions - bad or good?
Philosophical	DUNSC-102	P	Ethics	Look carefully at ethical principles and aim to apply. Be aware and specific
Philosophical	NEF-101	P	Ethical dilemmas / playing god	Morality of whether we should allow synthetic biology to proceed. Right to modify/create organisms
Ownership	BRIS-102	O	Ownership and property	Who owns the technology? Who benefits? How do we decide? Are there different risks and benefits depending on ownership?
Ownership	BRIS-112	O	Ownership and access	Patents: who owns the area? Amateur syn-biologists?
Ownership	LSEC-101	O	Economic benefits and costs	Who should fund research? Who should benefit: Open soucrce vs patents & monopolies
Ownership	LSEE-106	O	Socialism vs capitalism	Politics of synthetic biology. Open source vs profits
Ownership	QMU-102	O	Equity and justice	Ownership, equity, applications and consequences
Ownership	DUNSC-105	O	Funding questions	Funding should not be from just one source. It should be government, charitable trusts and companies. Companies use of copyright s
Ownership	NEF-103	O	Ownership, control & economic impact	Dilemma between incentives and public ownership of knowledge
Risk & Envir	BRIS-103	E	Risk	The unknown "applications" and control of these: geopolitics/environmental impact
Risk & Envir	LSEA-101	E	Environmental	Impact on Environment Crops / Fuel
Risk & Envir	LSEA-102	E	Risk of SynBio	Dangers of manipulating of organisms and interfering with nature and life
Risk & Envir	LSEB-105	E	Regulation	Creation of dangerous viruses from parts? Indiviudals in garages playing with bio? Safety vs restriction
Risk & Envir	QMU-101	E	Viruses and vaccines	Create or control pandemics
Risk & Envir	DUNSC-103	E	Benefits	Lots of potential benefits need to be weighed against the risks
Risk & Envir	NEF-102	E	Risk & Uncertainty	There is uncertainty so how do we make decisions about how far we are prepared to go
Benefits	BRIS-106	B	Products	Groups specific end products (or processes) that syn bio could enable
Benefits	BRIS-113	B	Immediate outcomes of synbio	Material outcomes and direct human benefits of synthetic biology
Benefits	LSEC-103	B	Environmental cleaner	Synthetic biology could be effectively used to remove contaminants, air pollution, etc.
Benefits	QMU-103	B	Resources	Saving humanity by creating new resources
Benefits	SIBE-102	B	Potential applications	Positive benefits of research
Regulation	BRIS-108	L	Regulation	What will and will not be allowed, where is the "line" and regulations formed?
Regulation	BRIS-110	L	Regulatory ethics	Who and how far is synthetic biology allowed to proceed?
Regulation	LSEB-104	L	Commerialisation	Biofuels should be in government hands, perhaps? Danger of monopoly? Patents restricting research and development?
Regulation	LSEC-102	L	Regulation of Synthetic Biology	Should there be regulation of the field and who should regulate it? Is the current regulation sufficient?
Regulation	LSED-103	L	Regulation	How to regulate funding and potential dangers. How to protect information
Regulation	QMU-104	L	Risk and regulation	Knowing and managing both risks and potential
Regulation	DUNSC-101	L	Principles & Procedures for research	There should be an international overseeing body
Regulation	DUNSC-104	L	Risk and regulation	Regulation essential. International body to oversee regulation - linked to research body
Medical	LSEA-104	M	Medical	Impact on medical community - cheaper drugs, smart antibiotics
Public attitudes	BRIS-111	C	Ethics/morality	Should/shouldn't we? Lay public perceptions and concerns
Public attitudes	LSEB-101	C	iGEM	iGEM is an excellent testbed for the other clusters! Good way of gauging public reception
Public attitudes	LSEB-103	C	Propaganda	Science communication: how Synbio portrays itself to those outside the field (contrast with scare stories, compare with media hype)

Table 4: Synthetic Biology Democs Clusters: Numbers of Clusters and Cards most used

Card no.	Times used	Information Cards	Card no.	Times used	Issue Cards	Card no.	Times used	Story Cards
A22	9	Environmental Clean-up	B36	7	Justice and Equity	S05	12	A Probe to test Water for Poisons
A32	8	Smart Antibiotics and Vaccines	B29	7	What about Risks of Weapons and Terrorism?	S01	10	Cheaper Drugs for Malaria?
A04	8	Synthetic Biology is ... bespoke 'tailoring' from parts of different organisms	B24	7	How Precautionary Should We Be?	S03	11	Pioneers and Patents
A27	7	Alternative Fuels : Hydrogen	B18	7	Over-reacting	S04	10	The Science Festival Debate
A24	7	Spider Silk and Other Novel Materials	B08	7	An Ethical Objection to Not Proceeding	S02	9	Dr Smart and the Funding Council
A18	7	Creating Exchangeable Parts	B37	6	Artemisinin for Malaria : Distribution and Justice	S07	8	Rhoda Jameson, Entrepreneur
A07	7	Synthetic Biology: New or Old?	B35	6	Who should do Synthetic Biology?	S06	6	Rick: DIY DNA
A30	6	Synthetic Biology and Nanobiotechnology	B34	6	Garage Biotech (Biohacking)			
A23	6	Capturing Carbon Dioxide?	B31	6	Virus Research for Pandemic Protection			
A20	6	Innovation Depends on Understanding	B25	6	Would an Uncontrolled Release Actually Matter?			
A19	6	Where has Synthetic Biology got to So Far?	B09	6	Making Machines ... but What About Living Organisms?			
A17	6	Recoding Bacteria to Make New Chemicals						

Events	Nos. of Clusters
BRIS	14
GLAS	4
QMU	4
SIBE	2
LSEB	5
LSEA	4
LSEC	5
LSED	4
LSEE	6
Dunscore	5
SRT	4
NEF	3

Table 5: Synthetic Biology Democs Game: Information Cards, and number of times used in clusters

A	SYNBIO INFORMATION CARDS	Content of card	use
A01	Synthetic Biology is ... applying Engineering Logic to Biology	Just as a car is made up of exact engineered parts, synthetic biologists treat living organisms as a set of complex biological ‘parts’. These can be rearranged and modified to make the organism perform new functions. A bit like Lego.	4
A02	Synthetic Biology is ... Adapting What’s Evolved for New Purposes	A team of women engineers at Volvo said cars have evolved with men in mind; let’s redesign a car in ways women would find better. Synthetic biologists seek to take living organisms which have evolved, and redesign them for human purposes.	5
A03	Synthetic Biology is ... rearranging the ‘parts’ of Living Organisms	Synthetic biology seeks to take the basic parts that make up living organisms - genes, proteins, enzymes, cells etc. - and modify and recombine them to make organisms like bacteria do new functions that are useful to us.	4
A04	Synthetic Biology is ... bespoke ‘tailoring’ from parts of different organisms	As a clothes designer takes ideas and materials from many places, synthetic biologists select things organisms do - say the way one responds to light, or another makes a protein - and join them into a ‘bespoke’ organism they hope will do exactly what they want it to do.	8
A05	Is this a Biological Revolution?	Yes and no. Scientists have modified many living organisms, but synthetic biology could go much further, making more radical changes. But most of it is still in basic research. No one knows how much will really work, or get beyond just simple organisms.	4
A06	Synthetic Biology takes Genetic Modification much Further	Genetic modification (GM) adds, say, 2-3 extra genes to an organism, to perform one new function, like getting bacteria to make insulin. Synthetic biology would make multiple genetic changes to alter whole processes in the organism, like how it uses energy.	4
A07	Synthetic Biology: New or Old?	Since 1982 most insulin for diabetics is made in vats by E.coli bacteria, genetically modified with a human gene. Synthetic biology is building on such work, with the knowledge gained from 25 years of molecular biology.	7
A08	Expanding how we Use Micro-organisms Industrially	Micro-organisms are already used industrially, for example in making beer, foods, chemicals, drugs. A lot of synthetic biology is about what new things microbes could be made to do.	4
A09	BioBricks : Exchangeable Biological Parts	Just as machines are made of well known, standard, interchangeable parts, BioBricks are attempts to identify or construct exchangeable biological ‘components’, each with known properties, to build up into complex systems.	2
A10	BioBricks and Self-assembly Furniture?	BioBricks are like creating a set of parts to make up a flat-pack for self-assembly furniture. The parts are genes or molecules from biological cells, and the completed unit is a modified organism, or a module within it with some special function.	2
A11	BioBricks : Building a Toolkit of Useful Biological Parts	One BioBrick might be a biological sensor, taken from a bacterium which detects a toxin. It’s joined to another ‘brick’ which sends a signal to warn a third brick, which is a switch, which turns on a last brick which triggers antibody production. And so on ...	2
A12	Adding New Letters to the DNA Code	The DNA ‘code’ is made of millions of combinations of 4 letters A,C,G,and T, which stand for 4 special molecules which are ‘read’ by enzymes. Scientists have now made synthetic molecules to add new ‘letters’ to the code, and have modified the enzymes to read them.	5

A13	Synthesising DNA Sequences	A key factor in making synthetic biology possible is that scientists can now make short pieces of the DNA code in their laboratories. These pieces can be joined up to create the complete DNA sequence of any organism, and even make new sequences.	1
A14	The Minimal Genome Project	If BioBricks try to build organisms in parts from the bottom up, the ‘minimal genome’ aims to do the opposite, stripping down a bacterium to establish the smallest number of genes - maybe only 350 - needed for life ... or at least bacterial life.	1
A15	Smallest Genome: a Backbone for Designer Microbes	Finding the simplest array of genes that support life could provide a backbone or ‘chassis’ of a simple designer bacterium, to which scientists could plug in biological parts (BioBricks) to perform a selected function.	2
A16	Genome Transplantation	Living organisms are made of cells, which are directed by the DNA inside them. One goal is to synthesise a semi-artificial genome from small DNA sections, and insert it into a living cell, so that the new genes take over the operation of the cell.	3
A17	Recoding Bacteria to Make New Chemicals	Bacteria like E.coli exist in many forms, some harmful some not. Scientists have ‘re-coded’ some forms, replacing some genes by other ones, to produce useful materials that the bacteria do not make in their ‘wild’ forms, like spider silk protein or an anti-malarial drug.	6
A18	Creating Exchangeable Parts	Like lego parts can be used in different designs, it’s hoped that parts developed for one synthetic biology application can be transferred to another. So the module that makes the anti-malarial drug Artemisinin (story card 1) is being adapted to make biofuels.	7
A19	Where has Synthetic Biology got to So Far?	A lot is hoped for but only a few applications are so far emerging. Mostly it’s still quite basic research, to find out what works. Some of this is funded publicly, some by commercial companies, and some by the military.	6
A20	Innovation Depends on Understanding	The modifications attempted in synthetic biology will require a comprehensive understanding of genes, cell behaviour, and how these interact with each other. The aim is to make very precise changes which have predictable results.	6
A21	iGEM: The Best BioLego Competition!	The annual International Genetically Engineered Machine (iGEM) competition is a focus of innovation. Young bioengineers from university or national teams to devise ingenious projects to produce novel biological devices and parts.	0
A22	Environmental Clean-up	Synthetic biology offers a lot of potential for cleaning up the environment, like sensors to detect toxins, and perhaps modified bacteria that could remove the toxin and render it safe.	9
A23	Capturing Carbon Dioxide?	Absorbing carbon dioxide from the air is what plants do in photosynthesis. Could synthetic biology adapt the same biochemical mechanisms to remove CO2 from power stations and cars?	6
A24	Spider Silk and Other Novel Materials	If we can find out how living organisms make natural materials like spider silk, and incorporate this into designer bacteria, we could make new strong and lightweight engineering materials with many uses.	7
A25	Reading Ancient DNA Codes	DNA is like code, which enzymes in the body can read and copy. Some enzymes have been modified to read ancient DNA sequences from archaeological and fossil specimens, like from 45,000 year-old cave bear bones	3
A26	Synthetic Biology to Make Novel Crops	If the toolkits of synthetic biology work, they could be used to modify crops to overcome technical hurdles which held back some ambitious aims of GM crops - fixing nitrogen, making biofuels or pharmaceuticals in plants.	3
A27	Alternative Fuels : Hydrogen	Minimal genome bacteria and BioBrick components could be combined to make engineered bacteria able to break down water to make hydrogen as an alternative transport fuel, cheaply on a large scale.	7

A28	Alternative Fuels from Plant Wastes	Biofuel production from food crops is unsustainable. But cellulose in plant wastes would be an almost limitless source. It needs getting a lot of genes and enzymes to work together. Synthetic biology offers a real possibility to crack the problem.	4
A29	Biological Computing	Another aim of synthetic biology is to construct biological parts into integrated molecular circuits that act like electronic circuits. A true biological computer is still a remote idea, however.	4
A30	Synthetic Biology and Nanobiotechnology	Genes are nano scale in size, so a lot of synthetic biology overlaps with nanotechnology. Indeed, it may provide key tools and devices for ‘nano-medicine’, say, to help control insulin for diabetics, or enable drugs to find diseased cells.	6
A31	Detecting Infection in Urinary Catheters	A biological sensor is being researched aiming for early detection of bacterial infections on catheters used in the urinary tracts of elderly patients. A fluorescent protein, genetically engineered into the tiny device (outside the body), glows if it finds an infection.	4
A32	Smart Antibiotics and Vaccines	Bacteria adapt to antibiotics and become resistant to them. Biologically engineered antibiotics might be able to monitor how the bacteria are adapting, and modify their action accordingly. Smart vaccines might also adapt to protect us from a new strain of flu virus.	8

Table 6: Synthetic Biology Democs Game: Issue Cards, and number of times used in clusters

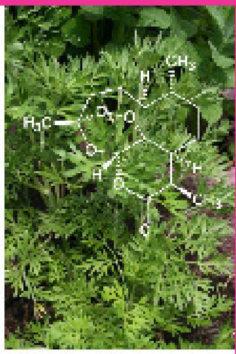
B	SYNBIO ISSUE CARDS	Content of card	used
B01	Synthetic Biology's Vision and Challenge	A prominent geneticist said of genetic engineering, 'This is where biology begins; until now we've been classifying butterflies.' Synthetic biology takes this the next step - the challenge to add whole new systems to living organisms, even to devise new genomes.	5
B02	Should we Treat Biology like Engineering?	Synthetic biology would treat biology as a branch of engineering. But are there important differences between these worlds and their values, which we lose sight of at our peril?	5
B03	Precision Engineering of Living Organisms?	Because it uses well defined parts, synthetic biologists claim they will make much more precise and controlled changes in living organisms than genetic modification has been able to do.	2
B04	Old claims for New Science?	Synthetic biology is making exactly the same claims for 'precision and predictability' as geneticists made 10 years ago to promote genetic modification. If GM wasn't so precise after all, should we trust this new claim?	2
B05	'Creating Life' is Hype!	The rhetoric of scientists claiming they are 'creating life' is hype. We might rearrange the components of existing living organisms into new life forms, but that's not creating life.	4
B06	What is Life?	'It would be a service to more than synthetic biology if we might now be permitted to dismiss the idea that life is a precise scientific concept.' (Editorial in the leading scientific journal Nature)	4
B07	Playing God? A Theological Question	If God created everything, including life, is it 'playing God' to think that we can outdo God's age-long processes of evolution, and rapidly design our own organisms? Or is it a good use of God-given skills?	4
B08	An Ethical Objection to Not Proceeding	The prospect of designing and creating new living organisms with precisely the functions we want opens up so many exciting possibilities in the fields of medicine, energy, materials, and much else, that to hold back would be ethically wrong.	7
B09	Making Machines ... but What About Living Organisms?	We think it's OK for humans to make all kinds of inanimate machines. But should we also design and make new living organisms that can reproduce themselves?	6
B10	Can Humans Re-design Evolution?	Evolutionary theory stresses that there is no design or designer in the life forms in nature. They are just the ones which adapted best. So should humans really try to 'design' new species? Can we claim to do better?	3
B11	Tinkering Too Much with Nature?	Some synthetic biologists speak of trying to rewrite the genetic code of living organisms. Is this sort of aim seeking to 'tinker' too much with nature?	4
B12	The Next Logical Step ... or One Step too Far?	We've changed living organisms by selective breeding over many generations, hybrid seeds and genetic modification. Is it different if we could create radically new organisms according to our own designs? Is there a limit somewhere?	1
B13	Synthesising an Organism - So What?	A molecular biologist wrote, 'I have no doubt that if we synthesised all the genes of a simple organism the result would be a fully functional genome. But would that prove anything we didn't already know?'	2
B14	How Radically Different an Organism should we Make?	We probably can't create a completely synthetic organism. But is it wrong to create a modified organism that is radically different from the one we started with? Is this crossing a moral boundary that we should not cross?	3
B15	Being Synthetic with which Species?	Most of synthetic biology is about altering simple micro-organisms. Suppose one day we could go further. Would we draw lines about remaking maize, mice, monkeys ... or humans? If so where, and why?	5
B16	Research and Responsibility	A Royal Society meeting report said, 'The extent to which the genome can be redesigned to produce a radically novel synthetic organism is of considerable interest.' Is this goal justified just because it's scientifically interesting? What else might have a bearing on it?	5

B17	What Values should Drive the Research?	In a society with mixed views, what values, ideas and needs should shape the direction and priorities of synthetic biology research?	5
B18	Over-reacting	Most scientists in this field acknowledge there are important ethical and social issues. But some fear that the promise of synthetic biology might be lost to unwarranted media or public controversy, or inappropriate regulation.	7
B19	Hype, Reality and Public Discussion	There's a lot of hype about synthetic biology. No one knows what will really be feasible, or economic. Quite a lot, but maybe less than its enthusiasts hope or its critics fear? How soon should we talk about this, if the picture is so unclear?	1
B20	Do We Know What We're Doing?	Do scientists indeed understand enough to modify biological systems substantially, or even synthesise new organisms? Or is it safer to 'leave it up to nature'?	4
B21	How Do We Know if We Know Enough?	If we claim we can redesign species that have evolved by mutation and natural selection, by what criteria should we judge if scientists know enough to make radical changes to an organism and release it to the environment?	3
B22	Is Technique Running Ahead of Understanding?	Some fear that commercial pressures, or environmental and humanitarian needs, will hurry scientists to make clever technical devices, but without understanding enough detail about the underlying science.	5
B23	How do you Assess Risks of Novel Organisms?	With GM crops we could compare risks with an unchanged or conventional crop. With radically altered bacteria there may be no close organisms to use as a baseline for comparison.	5
B24	How Precautionary Should We Be?	How precautionary should we be about the 'unknowns' of synthetic biology? ... proceed with caution? ... don't proceed till you know more? ... proceed with certain areas but not others? ... or what?	7
B25	Would an Uncontrolled Release Actually Matter?	Some scientists say a 'synthetic' bug would not cause havoc if it escaped from the lab, because it's too weak to survive out in the wild. Other scientists point to cases where introduced organisms have pushed out the existing ones (like grey squirrels over red).	6
B26	Can Synthetic Organisms be Made Inherently Safe?	Some synthetic biologists claim that 'inherently safe' organisms can be developed with functions built in that ensure they would not survive and propagate in nature. Critics say nothing is inherently safe, including synthetic organisms. What do you think?	4
B27	Engineered Bugs to Clean up the Environment?	Synthetic biology may be able to modify bacteria which can not only detect toxins in the environment but remove them as well ('bioremediation'). But can we avoid posing new risks from the modified bugs?	4
B28	Super-GM Crops?	If the tools of synthetic biology could one day also modify plants, say, to make pharmaceuticals and biofuels, can this also be done without adverse environmental impacts, or displacing food crops?	5
B29	What about Risks of Weapons and Terrorism?	There is much concern that synthetic biology could also be used to make deadly bioweapons or for terrorism. Is making novel bugs more or less likely than using existing ones like anthrax? The risks are uncertain and contentious.	7
B30	Governing Synthetic Biology for Security and Risks	Most proposals for how we should govern and oversee synthetic biology depend on scientists' awareness and reporting of its risks and potential misuses. But is this enough? What else would we do?	3
B31	Virus Research for Pandemic Protection	Researchers synthesised the polio virus from scratch, just by joining the right short sections of DNA. Other groups remade the 1918 pandemic Spanish Flu virus. Is this irresponsible, or is it justified to find what makes some viruses pandemic?	6
B32	Uncontrolled Access to Partial DNA Sequences	A journalist posed as a scientist and obtained partial DNA sequences from different suppliers, enough to start making a deadly virus. Would co-ordination among DNA supply companies control this enough?	4

B33	Is Self-regulation by Synthetic Biologists Enough?	The synthetic biology community proposes professional codes and advisory bodies to oversee what goes on. Some NGOs are suspicious of this, and argue that self-governance isn't enough. Who's right?	4
B34	Garage Biotech (Biohacking)	A 'Primer for Synthetic Biology' is available on the Web in non-technical language, raising concern that anybody could do synthetic biology in their garage. Should there be regulation to control who uses it?	6
B35	Who should do Synthetic Biology?	Given the risks and uncertainties involved, who should be allowed to practice synthetic biology and what obligations do they have?	6
B36	Justice and Equity	Will these developments make a positive difference to the rich-poor global divide, or will they tend to make it worse?	7
B37	Artemisinin for Malaria : Distribution and Justice	Artimisinin derived from yeast may be on the market soon to treat malaria (Story Card 1). It should be cheaper and more widely available. But it will undercut traditional producers in Asia. How can they be compensated?	6
B38	More Enterprise or More Accountability?	There is considerable private funding of synthetic biology. What is the right balance of commercial opportunity and public accountability for what's being developed - e.g. organisms which might make our future energy supplies?	3
B39	Should the Synthetic Biology 'Tool Kit' be Public or Patented?	If synthetic biology develops like a common tool kit and parts, who should own them? Should the 'know-how', parts and devices be mostly free for all to use, or mostly patented by organisations for commercial development?	5
B40	Patents and Monopoly in Synthetic Biology	Serious concerns have been voiced if patent offices grant patents on key inventions in synthetic biology, if they could give effective monopoly to a single company over, for example, biofuel production, akin to that in computer software.	5

Table 7A: Synthetic Biology Democs Game: Story Cards 1-4

S1 Cheaper Drugs for Malaria?



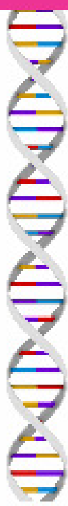
Malaria is one of the three biggest killer diseases worldwide. A current treatment uses a natural chemical artemisinin, taken from the plant *Artemisia annua*. Its benefits have long been known in Asia, but it costs too much to extract enough to treat the world's malaria sufferers. Synthetic biologists found out how the plant makes artemisinin, and have engineered this ability into *E.coli* bacteria and yeast. This makes them produce a chemical which can be turned into artemisinin cheaply, in large quantities. But this could undercut traditional ways of making the drug in developing countries. Does that matter if it means we can now make enough? And who should control the rights to this development?

S2 Dr Smart and the Funding Council

Nitrogen fertilisers can greatly improve crop plant growth but they're expensive and polluting. Some plants host special bacteria which are able to 'fix' nitrogen for them through the plant roots. But most food crops can't do this. Biochemist Dr Peter Smart has been trying for 30 years to work out how bugs do it, and transfer their ability into cereal crops. He thinks synthetic biology could now do the precise multiple genetic changes to make the breakthrough! He applies for a government research grant.

With a limited budget, the funding committee has a dilemma. How important is this compared with other scientific topics? Nitrogen fixation is an ambitious goal but it hasn't worked after many years. Does 'nature know best' after all, or should he get his grant?

S3 Pioneers and Patents



Controversial genome pioneer Craig Venter has a flair for innovation and big ideas. He aims to strip down a microbe to the smallest viable amount of DNA it needs to live – a 'minimal genome'. He wants to use this as a backbone or 'chassis' to which he adds different biological parts which do specific functions.
One idea is to produce hydrogen to replace oil. He's also been sailing the oceans, trawling marine bugs which might have useful 'parts'.

But he's also been applying for patents on his findings. This worries some people. They say we shouldn't patent life forms, or give monopolies to anyone on basic technology which may provide our future transport fuel. Should one company corner the global market, as we've seen with software? On the other hand how should we reward inventors for their innovation?

S4 The Science Festival Debate

There's a debate at the Science Festival. Synthetic biologist Jean Bold argues that humans have always altered nature. We've greatly changed animals and plants by selective breeding. Synthetic biology gives us ways to reshape living organisms to our own design, or make new ones, for energy and medical uses.

Ethicist Joe Zen says it's one thing to understand how living things work, but it's 'playing God' to rearrange them like a biological lego-set. Do we know *enough* to make such radical changes, or to design new bacteria safely?

'Let's press ahead with innovation!' Jean concludes. *'But aren't there moral limits in any innovation?'* Joe replies.

... so, who's right ...?

Table 7B: Synthetic Biology Democs Game: Story Cards 5-7

S5 A Probe to test Water for Poisons

An Edinburgh research team has links to Bangladesh, where arsenic can contaminate drinking water. Could they make a simple, cheap and sensitive test for arsenic in local wells? Back in Edinburgh, they put together genes and proteins from different organisms ('Bio-Bricks') to make up a tiny biological sensing device inside the cell of a microbe. Genes are added to the cell that respond when arsenic is present, causing a colour change.

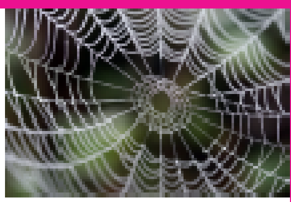
It shows the basic idea of synthetic biology: of putting biological parts together to make bacteria do new things. But it needs lots of development, to turn this first research result into a reliable probe. And if it's not for the western consumer market, who is going to fund it all?

S6 Rick: DIY DNA

Rick just graduated in molecular biology in California. He's brilliant in the lab, but potential jobs all want experience. In his final year project, his class got bacteria to make a new chemical flavouring in yoghurt. They won third prize in a global synthetic biology competition called iGEM. It didn't work completely, but he can see how to improve it. He's got a bit of money to order DNA sections, and get secondhand equipment. Could he do it in his garage?

His girlfriend is getting worried. She read that scientists reconstructed a deadly virus, by ordering small sections of DNA from different companies, then splicing them all together. Rick says it was legal and it was to combat pandemic flu viruses. 'That's not the point,' she says, 'it could be really dangerous. Shouldn't all this be regulated somehow?'

S7 Rhoda Jameson, Entrepreneur



Rhoda discovered how to modify bacteria to make spider silk protein. Spider genes were added to bacteria to make the protein. Then a tiny biological device like a needle was made to extract the protein. It seems to work, with no apparent negative effects. It could make a strong, lightweight engineering material, so Rhoda set up a small biotech company to commercialise her results.

But it will take several years to scale up to make the silk protein industrially in vats. Venture capital is running low. She needs more money. The military approach her with a big contract to develop the silk for bulletproof vests. The extra cash would enable her to bring medical applications of her silk to market much quicker. But it could tarnish the image of her company. Should she accept?

Table 8 **Vote 1: Five Synthetic Biology Policy Options**

Each person should vote by putting a cross in one of the 4 boxes, for *each* of the 5 policy options. If none of these 5 options fit, there is a space to add a Policy 6 of your own making		I agree with this policy	I could live with this policy	I disagree with this policy	I don't know
Policy 1	Synthetic Biology should be stopped as it intervenes too far in nature / or is 'playing God'				
Policy 2	Synthetic Biology should not be allowed as it would be too great a risk to health or the environment				
Policy 3	Synthetic biology may be used to make products (e.g. fuels, drugs), provided any organisms which are used are kept strictly contained				
Policy 4	Synthetic biology may be done, provided researchers are licensed, and that strict regulations apply to any released organisms				
Policy 5	Synthetic biology should be encouraged to develop with minimal regulation				
Policy 6					

Table 9: Vote 2 Synthetic Biology Applications (showing just options 1-4 out of 8)

Vote 2: Synthetic Biology Applications

	1. Making Biofuels from plant wastes.	2. Detecting pollutants in the environment.	3. Cleaning up pollutants in the environment.	4. Making new industrial materials.
	Using synthetic biology to make micro-organisms digest cellulose from plant wastes, to replace petrol and diesel by biofuels, without competing for land.	Using synthetic biology to make sensors to detect pollutants, such as arsenic in drinking water in Bangladesh.	Using micro-organisms created using synthetic biology to search out and digest pollutants in the environment.	For example, using specially adapted bacteria to mass produce spider silk in vats as a strong lightweight industrial material.
	Would this application be acceptable? *(Mark with an X for each application)*			
Yes				
Possibly				
Unsure / don't know				
Doubtful				
No				
Why? *(in your own words).*				

...continued overleaf

Table 10: Synthetic Biology Democs Game Feedback: Age, Gender & Knowledge

		Gender			Age						My knowledge of synthetic biology before playing the game					Do you feel you understand more about 'synthetic biology and its issues after playing the game?				
Event	People	M	F	NR	<18	18-30	31-45	46-60	Over 60	NR	Very little	Not bad	Quite good	Very good	NR	Not much	Just a little	Quite a lot	A lot	NR
BRIS	15	7	3	5	0	11	3	0	0	1	3	2	9	0	1	4	8	2	0	1
GLAS	7	5	0	2	0	7	0	0	0	0	1	4	0	2	0	0	0	7	0	0
LSEA	6	2	3	1	0	5	0	0	0	1	0	0	4	0	2	0	2	3	0	1
LSEB	5	5	0	0	0	5	0	0	0	0	0	4	1	0	0	0	2	3	0	1
LSEC	6	4	1	1	0	6	0	0	0	0	0	0	4	1	1	2	3	1	0	0
LSED	6	1	5	0	0	6	0	0	0	0	0	4	2	0	0	2	3	1	0	0
LSEE	6	4	1	1	0	6	0	0	0	0	0	3	1	2	0	0	2	2	2	0
QMU	4	3	1	0	0	0	4	0	0	0	3	1	0	0	0	0	2	2	0	0
SIBE	4	0	1	3	0	0	2	2	0	0	2	1	1	0	0	0	1	3	0	0
PICK	4	3	1	0	0	2	2	0	0	0	4	0	0	0	0	0	4	0	0	0
DUNS	7	3	3	1	0	0	0	3	3	1	5	1	0	0	1	0	2	3	1	1
NEF	6	1	3	2	0	1	2	1	0	2	3	1	0	0	2	0	4	0	0	2
SRT	6	2	3	1	0	1	1	3	1	0	1	3	2	0	0	0	2	2	2	
	82 100%	40 49%	25 30%	17 21%	0 0%	50 61%	14 17%	9 11%	4 5%	5 6%	22 27%	24 29%	24 29%	5 6%	7 9%	8 10%	35 43%	29 35%	5 6%	3 5%
Event		M	F	NR	<18	18-30	31-45	46-60	Over 60	NR	Very little	Not bad	Quite good	Very good	NR	Not much	Just a little	Quite a lot	A lot	NR
BRIS	100%	47%	20%	33%	0%	73%	20%	0%	0%	7%	20%	13%	60%	0%	7%	27%	53%	13%	0%	7%
GLAS	100%	71%	0%	29%	0%	100%	0%	0%	0%	0%	14%	57%	0%	29%	0%	0%	0%	100%	0%	0%
LSEA	100%	33%	50%	17%	0%	83%	0%	0%	0%	17%	0%	0%	67%	0%	33%	0%	33%	50%	0%	17%
LSEB	100%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	80%	20%	0%	0%	0%	40%	60%	0%	20%
LSEC	100%	67%	17%	17%	0%	100%	0%	0%	0%	0%	0%	0%	67%	17%	17%	33%	50%	17%	0%	0%
LSED	100%	17%	83%	0%	0%	100%	0%	0%	0%	0%	0%	67%	33%	0%	0%	33%	50%	17%	0%	0%
LSEE	100%	67%	17%	17%	0%	100%	0%	0%	0%	0%	0%	50%	17%	33%	0%	0%	33%	33%	33%	0%
QMU	100%	75%	25%	0%	0%	0%	100%	0%	0%	0%	75%	25%	0%	0%	0%	0%	50%	50%	0%	0%
SIBE	100%	0%	25%	75%	0%	0%	50%	50%	0%	0%	50%	25%	25%	0%	0%	0%	25%	75%	0%	0%
PICK	100%	75%	25%	0%	0%	50%	50%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%
DUNS	100%	43%	43%	14%	0%	0%	0%	43%	43%	14%	71%	14%	0%	0%	14%	0%	29%	43%	14%	14%
NEF	100%	17%	50%	33%	0%	17%	33%	17%	0%	33%	50%	17%	0%	0%	33%	0%	67%	0%	0%	33%
SRT	100%	33%	50%	17%	0%	17%	17%	50%	17%	0%	17%	50%	33%	0%	0%	0%	33%	33%	33%	0%

Table 11: Synthetic Biology Democs Game Feedback: Comments on the Game

Q.3	What was most satisfying or valuable about this Democs game?	Q.4	What was less than satisfying or disappointing, or any suggested improvements?
BRIS	I learnt more about the applications and development of synthetic biology	BRIS	We sometimes didn't have time for everybody's cards, or discussion got cut off by moving to the next activity.
BRIS	Learn other people's views on the subject	BRIS	Time frame, did not really allow time for adequate discussion of each topic.
BRIS	Interesting to see how process works. Quite complex issues to absorb from a non-scientific perspective.	BRIS	More time. Was a tendency to discuss issues that arose in earlier rounds - useful to have a rapporteur to note these for later discussions.
BRIS	Spending time to engage with the issues. Hearing how others reason.	BRIS	It feels a little bit constrained - especially the decision points and the groupings. Being able to link the issues as we saw them, or rank their importance to us might be good.
BRIS	Gaining knowledge of the subject and talking to other scientists about it.	BRIS	Everyone in the group had a similar background - so opinions were quite similar resulting in minimal debate.
BRIS	Always interesting to discuss debateable subjects! (Needed a bit more time for it though.)	BRIS	Many of the blue/green cards were a little uninteresting.
BRIS	Hearing about other people's views - particularly intelligent and engaged undergraduate and postgraduate students.	BRIS	Found vote 2 less interesting - all of the scenarios seemed similarly acceptable to me.
BRIS	Some discussion	BRIS	More time for discussing bullet points, 1/5 of cards
BRIS	I got to make some friends	BRIS	Too many rules, too many cards, don't like card games, way too simplistic
BRIS	Interesting to see how the game works generally	BRIS	Not a very diverse group so not a huge amount of discussion.
GLAS	The quality of information provided in few tables	GLAS	The slow rate of adoption of synthetic biology and genetically manipulated products especially in Britain
GLAS	It is a new way of studying science and thinking (?) about applications of science in future including ethical, cost and various factors and discussing new methods and new views of different people	GLAS	I would suggest for such activity to be made more common and making more number of people acquainted with science with its benefits, drawbacks and concerns
GLAS	The wide range of topics covered is interesting and the language used is simple and easy to understand as I have a lot of background knowledge	GLAS	It is aimed at all groups some with little or no knowledge of the subjects may not understand what is covered
GLAS	It covers a wide range of synthetic (?) topics. Good brief descriptions.	GLAS	To 'non-science' players of the game, I feel that the description of synthetic biology needs to be more descriptive yet also less so - It is a difficult balance.
GLAS	Very interesting and lines(?) very nice	GLAS	It should have more time for more interactions
GLAS	Improve my knowledge about synthetic biology	GLAS	
GLAS	The idea of synthetic biology was gained very easily, dealing with simple facts which turned out to be the base of synthetic biology. It was full of information.	GLAS	
LSEA	Learning different views	LSEA	None

LSEA	Hearing other opinions	LSEA	Maybe a time limit for each discussion
LSEA	Makes you think about different aspects and ethical issue of this subject	LSEA	For this game, having the knowledge about Synthetic Biology is essential
LSEA	Awareness to diversity of issues in SynBio, Other people's opinions on these issues	LSEA	Fixed time or timer of some sort to know how fast we should be going
LSEA	Hearing and debating different opinions and issues	LSEA	Maybe provide additional reading material so we can base our arguments more on facts
LSEB	Understanding the potential dangers to [sic] synthetic biology. The political side of science.	LSEB	Instead of forming clusters, form a spectrum of ideas linking each topic together.
LSEB	Opening egs on some the issues. Induces discussion.	LSEB	Clustering idea is stupid. Might not work for total amateurs in SythBio
LSEB	Putting them into clusters	LSEB	Distinct categories...Should be more of a spectrum as many are linked or can be linked, and feeding back to each other
LSEB	Discussion on ethics. Bringing together/categorising. Expressing ideas openly. Raise awareness on certain important issues.	LSEB	
LSEB	Exposed to various issues regarding synthetic biology. Better than having lectures on ethics.	LSEB	
LSEC	Discussion, arguing for and against, because potentially we can go on to modify regulations that affect future synthetic biology projects	LSEC	Nothing really!
LSEC	The confrontation with the ethical issues underlying the practice of SynBio	LSEC	Some of the cards did not makes sense, e.g. the one about women, men and cars.
LSEC	Broaden my aspects of synthetic biology on the ethics side of things	LSEC	It is not very scientific. Perhaps for people with very little/no background understanding of synthetic biology its OK. But for people who has a basic understanding of synthetic biology it's not of much help
LSEC	Debate/talking about an issue with other people. Amusing as some cards do not make sense.	LSEC	Some card do not make sense, question they ask at the end does not appear to be relevant to the information (green cards mostly)
LSEC	Learning about the diff points of views and ethical issues involved in Synthetic Biology	LSEC	Not very fun. Not too much critical thinking involved.
LSEC	Understanding other people's value & opinion	LSEC	No point system or goals. Doesn't really feel like a game but rather something to pus a talk/topic about synthetic biology
LSED	Discussion which leads to thinking	LSED	The cards are more or less similar to each other
LSED	For players who do not know about synthetic biology, this game will provide general idea of synthetic biology	LSED	I don't think it helps people who already know about this field to understand more about it. Can be more provoking
LSED	Made me think	LSED	More pictures
LSED	Other people's take on things	LSED	When dealing with general public, maybe give a general idea of what has been achieved already
LSED	Exposure to new viewpoints of other people	LSED	Issues are about the same
LSED	It is very interactive and I get to listen to many different opinions about issues surrounding SynBio	LSED	

LSEE	Making clusters. Talking about feminine cars	LSEE	Too much paperwork
LSEE	Hearing about new research. Talking about issues I had not imagined.	LSEE	Having the “playing God” argument. Clusters seemed superficial.
LSEE	Interesting topic discussion.	LSEE	Most discussion headed towards similar topics/not broad enough
LSEE	Battling the corporatocracy	LSEE	Everything is perfect
LSEE		LSEE	It was not fun
QMUE	Makes you think through potential & actual scenarios, ethical dilemmas but also potential usages	QMUE	We did a shortened version so difficult to compare when the game is played ‘for real’. But I found it difficult to digest all the info on hand - could be simplified bit more, or more info provided
QMUE	Group interaction/interpretation of knowledge	QMUE	Lack of knowledge of true risks and possible consequences
QMUE	Raises issues and understanding	QMUE	Quite structured
QMUE	Learning about a new topic	QMUE	
SIBE	Split of info into different types of card - especially stories	SIBE	We didn’t have enough time to really play. No one disagreed
SIBE	The new information	SIBE	The fact that we didn’t have enough time to read the information
DUNS	Discussions when clusters were being formed	DUNS	Difficult to complete forms on clusters
DUNS	Learned about the subject	DUNS	A bit long-winded - too much bits and pieces and not enough discussion
DUNS	Learning more about synthetic biology	DUNS	Cards a bit vague - should be shorter and more concise
DUNS	Good company, good food. Time to discuss issues in a safe environment	DUNS	Cards could have been more focused - bit repetitive. Not enough on the dangers/pitfalls of S.B.
DUNS		DUNS	To have more information
DUNS	Getting together with friends for constructive discussion	DUNS	Fewer cards / more specific
NEF	Good opportunity to discuss wider issues	NEF	Language not wholly clear. Very wordy. Could add more steers to controversy
NEF	Debating / thinking about issues with colleagues	NEF	My knowledge of synthetic biology is less than satisfying, so will try to remedy this!
NEF	Group involvement and discussion; increasing understanding of the debate; thinking on the spot	NEF	
SRT	Good discussions; made us think	SRT	Vote 2 sheet lacked balance - only presented positive implications of SB
SRT	Gaining wider understanding of the SB issues	SRT	A cards hard to understand without scientific background. Vote 2 paper focuses only on potential benefits. Risks should be illustrated as well
SRT	Allowed every group member to participate. Stimulated debate and simultaneously provided a learning experience	SRT	If anything questions / cards tended to have a positive bias. Perhaps should be more balanced.

SRT	It brought out the positives and encouraged discussion	SRT	Not enough room given on vote 2 for evaluating the risks or downsides of the suggestions
SRT	It helped me to learn more	SRT	I was surprised by how positive I was towards S.B. The Voting paper 2 seemed quite biased towards good applications of S.B.
SRT	Cards clearly summarise issues	SRT	The “Vote 2” summaries are biased towards the benefits, with no mention of the risks. This could bias the final voting on Vote 2