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ORIGINAL PAPER

An Update of Public Perceptions of Synthetic Biology: Still Undecided?

Mirko Ancillotti · Virgil Rerimassie · Stefanie B. Seitz · Walburg Steurer

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Abstract The discourse on the fundamental issues raised by synthetic biology, such as biosafety and biosecurity, intellectual property, environmental consequences and ethical and societal implications, is still open and controversial. This, coupled with the potential and risks the field holds, makes it one of the hottest topics in technology assessment today. How a new (bio)technology is perceived by the public influences the manner in which its products and applications will be received. Therefore, it is important to learn how people perceive synthetic biology. This work gathers, integrates and discusses the results of three studies of public perceptions of synthetic biology: (1) an analysis of existing research on how media portray synthetic biology across 13 European countries and in the USA, (2) the Meeting of Young Minds, a public debate between prospective politicians and synthetic biologists in the Netherlands and (3) the experiences of citizen panels and focus groups in Austria, the UK and the USA. The results show that the media are generally positive in their reports on synthetic biology, rather unbalanced in their view of potential benefits (emphasized) and risks (downplayed), and also heavily influenced by the sources of the stories, namely scientists and stakeholders. Among the prospective Dutch politicians, there were positive expectations as well as very negative ones. Some of these positions are also shared by participants in public dialogue experiments, such as not only the demand for information, transparency and regulation but also a sense of resignation and ineluctability of scientific and technological progress.

Keywords Synthetic biology · Public perception · Technology assessment · Media · Public engagement

M. Ancillotti (✉)
Centre for Research Ethics & Bioethics, Uppsala University, Husargatan 3, Box 564, 751 22 Uppsala, Sweden
e-mail: mirko.ancillotti@crb.uu.se

V. Rerimassie
Department of Technology Assessment, Rathenau Instituut, P.O. Box 953662593 HW, Den Haag, The Netherlands
e-mail: v.rerimassie@rathenau.nl

S. B. Seitz
Karlsruhe Institute for Technology, Institute for Technology Assessment and Systems Analysis, Karlstraße 11, 76133 Karlsruhe, Germany
e-mail: stefanie.seitz@kit.edu

W. Steurer
Department of Political Science, University of Vienna, Universitätsstrasse 7, 1010 Vienna, Austria
e-mail: walburg.steurer@univie.ac.at

Introduction

Synthetic biology (SB) is not only the latest—and a rapidly developing—new approach to biotechnology; it is more: SB brings the engineering approach to the life sciences and, thus, is likely to change how we live and understand the world [1–3]. The discourse on fundamental issues such as biosafety and biosecurity, intellectual property rights, environmental consequences, and ethical and societal implications is still open and

controversial [3–5]. For all these reasons, and for the potentialities and risks this field holds, SB is one of the hottest topics in technology assessment (TA) [5, 6].

The rather problematic, albeit central, issue in the assessment of new and emerging sciences and technologies (NEST) such as SB concerns how and to what extent the public should be involved. Two main impulses can be recognized: on the one hand, a tendency to rely on experts' analyses, and on the other, the drive for public deliberation, i.e. to include the views of the public and social interests in the determination of the path of science and technology. Moreover, within the last 10–15 years, there has been an increase in calls for more public engagement [7].

What should be distinguished from the issue of the role of the public, whether it be involvement or engagement, is the public perception of science and technology, in this case of SB. There is a need to investigate public perceptions because they influence how biotechnology outcomes, products and applications will be received. As a consequence, it is important to know early on how people perceive SB. The aim is not to learn how to present SB in a way that will make it acceptable but to involve the public in building the conditions for making it useful for and utilizable by society.

The investigation of the ethical and societal implications of SB can benefit from empirical data on the current public perception of the field. There are two ways to conceive this task: either to investigate and try to measure public perceptions (e.g. conducting group interviews or public events), or to analyse how SB is presented to the public and what information is spread by the media. The present work encompasses both research approaches.

The idea for this joint paper arose during the authors' participation at the international summer school 'Analysing the Societal Dimensions of Synthetic Biology' organized by the EA European Academy of Technology and Innovation Assessment in Berlin in September 2014.[1] Each participant presented a text as a contribution to the summer school, enriched by the lessons learnt from successive discussions. Participants' contributions were published as chapters in a book edited by Kristin Hagen, Margret Engelhard and Georg Toepfer [8]. In the present paper, the authors have summarized and pooled the salient points of their respective chapters and, where possible, compared the results of their original studies with others' research and input. In line with the research performed by the authors in their respective book chapters [9–12], the present work will primarily clarify the rationale for investigating the public perception of SB: first, explaining why the analyses of NESTs should take place at an early stage, and second, analysing how SB was encountered in three different arenas.

The second part of the paper is organized as follows. The first section is focussed on the media. It is possible to assume that media play a role in how the public perceives a new biotechnology and that this can affect how the public debate evolves. Therefore, previous studies on how the media have covered SB in Western countries are thoroughly analysed. Second, the results of a study looking at a debate held in the Netherlands between future politicians and future synthetic biologists are discussed. This provides valuable testimony on how SB is received by prospective politicians—varying from right wing to left wing and from Christian to animal welfare-inspired positions—and, as such, on what directions a future debate on SB may take. Third, the experience of citizen panel discussions with Austrian citizens is described. The citizen panels were specifically dedicated to discussing SB and its ethical, legal and social implications, as well as questions of governance. The results are then compared with similar research previously reported, in order to further contribute to the understanding of the current public perceptions of SB.

The final aim is to draw a picture of public perceptions of SB in Western countries and to suggest fruitful ways to involve the public in understanding and assessing such biotechnology.

Why Public Perception of Technology Matters

New and emerging technologies are shaped by society in the sense that their inventors usually aim to address existing shortcomings of existing technologies. But, despite these good intentions, new technologies and technological applications often also turn out to have negative, unwanted effects. Therefore, TA and related disciplines aim to analyse NEST as early as possible in order to provide knowledge for the anticipatory governance of these effects [13]. However, the main challenge is the lack of knowledge concerning the future

[1] For more information, see http://www.ta-synbio-summerschool.de/. Accessed 12 January 2016.

consequences of NEST, which are just about leaving the labs—as is the case for SB. Moreover, SB can even be seen as a prime example of a 'technoscience' in which the traditional boundaries between (knowledge-oriented) natural science and (application-oriented) engineering dissolve and basic scientific research ab initio is placed in a context of utilization [14].

As early as 1980, David Collingridge [15] described this dilemma: While at a later stage of development and implementation, sufficient knowledge is available to assess the societal consequences of a technology in an evidence-based way, and it is hard to change developmental paths since technology options are closed and investments have been made. In contrast, at early stages of research and development, these barriers to readjustments are very low. At the same time, however, little is known about the impacts of the technology and decisions have to be taken in the face of large gaps in knowledge. Therefore, TA scholars and others have been working on approaches to overcome this drawback of early assessment in order to keep the advantages of a timely assessment [13].

Thereby, the most promising way appeared to be the inclusion of interdisciplinary and transdisciplinary experts as well as—and perhaps especially—the general public in order to elicit perceptions and values on which to build an assessment framework. This has been implemented in numerous different approaches, many in the tradition of social constructivist studies of science and technology (for an overview, see [16]). This can be traced back to the different understandings of the relationship between science and society in the last quarter of the twentieth century [17] and the (perceived) loss of trust in technocratic decision-making by society [18]. Consequently, concepts like 'Mode 2 Knowledge Production' [19] or 'Post-Normal Science' [20] aim at strengthening the role of non-scientific actors [21]. Taking into account that new technological developments are not linear but rather shaped by society [22], speculative foresight through public involvement can help us understand risks as systemic and detect threats which are hard to predict from solely an expert perspective [23]. This way, laypeople contribute to knowledge production as 'experts for the everyday' [24] and help make the assessment of NESTs much more robust.

Thus, one of the most common (communicated) types of motivations for engaging the public is the 'substantive' ones, according to Andy Stirling [25]: In this sense, choices concerning the nature and trajectory of innovation can be co-produced with publics in ways that authentically embody diverse sources of social knowledge, values and meanings. These types of motivations can be found especially in the TA context, where the focus is not as much on the implementation of the results of the participative exercise [26].

Besides this, Stirling [25] identified two other major motivations for public engagement: the 'normative' and the 'instrumental'. The first sees the involvement of citizens as the right thing to do for reasons of democracy, equity and justice. Here, proponents of participation introduce their own values by advocating public engagement and emphasizing the importance that the results of the exercise will truly be part of the decision-making process. The second focuses on the effects the exercise has on the engaged public, allowing them to learn about the issues discussed and the actors involved. This is often accompanied by the presumption that the increased knowledge will also increase acceptance.

Quite recently, an innovation concept has emerged that incorporates these ideas of early assessment and shaping research and development (R&D) processes along with societal values and needs: responsible research and innovation (RRI) [27]. It was introduced into the science and innovation governance by the European Union by individuals who likely have quite strong normative imperatives. However, public engagement in the R&D process, which is a strong element of RRI, also appears to hold many of the substantive imperatives [28]. Yet in RRI, public participation is presented as a vehicle for meeting societal needs and ensuring successful innovations—and at best preventing conflicts [14]. It is important to distinguish between the different notions of 'participation': The inclusion of the views and expertise of non-scientific actors in knowledge production and decision-making processes is not the same as citizen participation within the political system, in the sense of direct democracy. Although the growing popularity of citizens' participation within the political system appears in parallel to the trend of more participation in the scientific context, this should not be confused with participatory approaches in TA [29]. Nevertheless, scholars promoting public engagement with science share—in the words of Jack Stilgoe—a normative commitment to the idea of democratic science policy and have argued that public engagement can be part of this [7].

With regard to SB, public engagement—especially in the context of this paper—is to be regarded first and

foremost as a tool for knowledge production in the course of an early societal assessment. However, publicly accessible material is rare, hard to locate and in most cases only available in the national language. In the following sections, we aim to line up all the empirical data we gathered in the course of the above-mentioned summer school.

Encountering Synthetic Biology within Different Public Arenas

Ever since the emergence of the field, SB has been increasingly attracting the interest of scientists in Europe [30]. At the same time, many organizations have engaged in mapping the ethical, legal and societal implications (ELSI) and potential risks of the field early on. The European Commission, for instance, supported several ELSI programmes dedicated to SB, such as 'SYNTH-ETHICS' and 'Synthetic Biology for Health: Ethical and Legal Issues' (SYBHEL), which both ran from 2009 to 2012. Such initiatives were also undertaken in several EU member states [31]. Given Europe's experience with fierce—and often unsettled—debates on biotechnology, early engagement with SB seems sensible since the field may very well also lead to controversies. With this in mind, the Global Network of Science Academies (IAP) issued a statement in 2014, calling for a global commitment regarding SB [32]. According to IAP chairman Volker ter Meulen, it is time to settle the 'synthetic controversy', and he notes that if SB is to thrive, the world needs to decide now how the field should be regulated and supported [33]. In his response 'Don't shut the door on the synthetic biology debate', in *The Guardian*, Science-and-Technology-Studies scholar Jack Stilgoe asked why the public is shut out of the conversation about the benefits of the field [34]. This is a valid question, since public awareness is quite low. According to the 2010 Eurobarometer survey dedicated to biotechnology, 83 % of the European respondents never heard of SB [35].

In the years that have passed since then, the awareness of the field will certainly have grown. Yet, since SB is still predominantly confined to laboratory practice, it is safe to assume that public awareness is still low. In any case, there is still a lack of data on how SB is actually perceived by the European public. In order to foster RRI in SB, the current expert-driven ELSI discourse needs to be broadened and substantiated, in order to open up visions, purposes, questions and dilemmas regarding SB to collective deliberation [36]. Nevertheless, there are already good examples of studies in Europe, for instance in the UK [37, 38] and Austria [39, 40], aiming to introduce a public perspective on SB.

In this section, the authors aim to modestly contribute to reducing the lack of data on public perceptions of SB. In order to do this, we will briefly present the main results of three previous studies we have performed—on the image of SB in three different public arenas—and relate these results to other available research findings.

Firstly, this concerns the media portrayal of SB across 13 European countries and the US. This is of interest because the generation of public interest is still largely tied to mass media, which can focus public attention on an issue and are able to display conflicting social positions and interpretations, and are thus able to make them a point of reference for policy decisions. Still today, the formation of public opinion is dominated by the mass media [41]. If one assumes that the audience takes up the topics presented by the media and the framings used by journalists, media content analyses allow for an estimation of the thematic input for public debate [42].

Nevertheless, it is not enough to depend solely on media content analysis as an indication of public debate. Therefore, we have also included available public engagement exercises on SB in our analysis: the Meeting of Young Minds, a public debate between 'future politicians and synthetic biologists' in the Netherlands, as well as experiences with citizen panels and focus groups in Austria, the UK and the USA. These mirror the public opinion and debate out there in a lively manner and broaden the picture offered by media analyses. Yet, this is not free from drawbacks: The fundamental problem seems to be that the wider public (however defined) is apparently not interested enough in NESTs to participate spontaneously and take an active part in the public debate [43]. This seems to make it difficult for stakeholders if there is uncertainty associated with the eventual nature of new products, processes, benefits and risks of a NEST-like SB [44]. However, in combination with media content analyses, it offers an interesting overview.

Media Portrayal of SB

Background

In September 2014, the Wilson Center issued a set of guidelines for stakeholders and journalists in

communicating SB [45]. This report is only the latest in a series of recommendations aimed at promoting responsible and balanced communication. Whilst SB has not yet fully entered public awareness, the way it is—and should be—communicated has already gained centrality. There is fear that news media may produce excessive hope and hype about its potential applications or that, on the contrary, they may produce uneasiness [45]. Both may cause a decrease in trust in the institutions promoting SB and, eventually, hamper its potential benefits or downplay its uncertainties and potential risks.

Since the media can be considered to play an important role in the selection of both which issues to bring forth and the form for bringing them to the public's attention [46], knowing how the media present SB can offer indications of how the future debate on it may evolve. Following this reasoning, Ancillotti and Eriksson investigated how SB was depicted in the respective three major Italian and Swedish newspapers between 2009 and 2013 [10].

The research was conducted as a qualitative content analysis. The articles were found using relevant search terms ('synthetic biology' and 46 other combinations), and the stories' content pertinence (whether or not they were about SB) was assessed using SB authoritative definitions as a reference point [1, 32, 47]. All articles with even a slight connection to SB were included and placed in various categories, according to the extent to which SB was central in them, and were formally and content coded. The language used by the journalists was analysed, considering what metaphors and explanation models were employed and what the framing keywords were (intended as recurrent and salient terms used by the journalists to describe SB). Furthermore, the overall tone of the articles—intended as the general impression that an article transmits to the readers—was assessed. The analysis also encompassed what topics and applications, risks, and benefits were more recurrently connected to SB. In addition, it was examined whether the media portrayal of SB included calls for oversight and/or public involvement, and whether the newspaper article contents mirrored the academic debate.

In the following, the main findings of the study will be discussed together with results from ten previous studies, in order to provide a critical overview of the quantity and modality of media coverage of SB in Western countries [41, 48–56]. The countries considered in these studies are the USA on the one hand and 13 European countries (Austria, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the UK) on the other, which offers a good overview of how SB has been depicted by the European media. This corpus of studies focussed mainly on the press (newspapers and magazines), but some have also taken into account audiovisual material such as radio and television broadcasts [49, 53] and various online content [54].

Coverage and Sources

It is currently not possible to assess whether or not the coverage of SB in the media is substantial, for two reasons. Firstly, the methods used for searching the stories varied significantly, i.e. some studies only used synthetic biology as a search term in the databases [41, 48, 52], while others, including our chapter, resorted to a wider set of search terms and also included stories not using the term synthetic biology [10, 49–51, 53–56]. Secondly, in order to draw quantitative conclusions regarding the coverage of SB, there would have to be adequate comparators and this falls beyond the intent of this study.

What clearly emerged from analysis is that the coverage steadily increased until 2010, when it peaked, and then returned in 2011 to approximately the same level as in 2009, maintaining this trend until 2014 (the last year surveyed). In the case of Germany, there was a slight increase in 2014 [2]. SB did not gain great media resonance per se; instead, its coverage was highly event driven, with significant upticks represented by announcements of technological advancements [41, 57, 58], institutional initiatives [59, 60] and elite scientists communicating their own futuristic visions or professional speculations, e.g. George Church's January 2013 comments on the possibility to revive Neanderthals [61] or Craig Venter's announcement in March 2013 that his group was close to creating life from scratch [62].

There is general agreement that SB coverage is heavily influenced by journalists' sources, which are often represented by a restricted number of elite scientists. Although the fact of relying on frames created by 'scientific sponsors or supporters' can be considered journalistic praxis, as highlighted by Kruvand [54], the help provided in interpreting the scientific developments de facto generated stories with striking similarities in all the countries. This is probably due to a marked dependence on the common sources of the stories, and to a lack of

critical scrutiny on behalf of the media [56]. It can be assumed that the media frame issues and thus influence the opinions of the public, even though the extent to which this is true is not quantifiable, through underscoring specific facts or values and providing interpretation schemes [63, 64]. In the case of SB, the frame providers seem to be primarily those who work with and have an interest in it. As Lehmkuhl [41] observed, scientists themselves, prior to science journalists, frame the content of the articles and emphasize usefulness and controllability. A paradigmatic case is that of Craig Venter. In our study, it was found that he was present in 63 % of the stories [10], while in Gschmeidler and Seiringer [53], he was mentioned in 43 % and in Ancillotti et al. [56] in 44 %, to give just a few examples.

Balmer and Herreman [50], whose study is centred on Venter, place the accent on the consequences of the uncritical usage of experts' framing. Stakeholders use framings that highlight or erase certain ethical concerns; by adopting their framings, journalists 'not only shape ethical spaces, but also make normative pronouncements on ethical issues' [50]. Sources' influence can be spotted not only in a story's tone but also in the choice of metaphors and in the applications, risks and benefits envisioned.

Language, Metaphors and Tone

In our study, we investigated what the most frequent framing keywords in the stories were [10]. These data give an idea of how SB was depicted to the public. Consistent with the results of SYNTH-ETHICS [51] and Pauwels et al. [52], it was found that journalists tend to make clusters of terms, such as artificial, synthetic, creation, manufacture and bacteria, around the notions of the creation of life and of artificial life.

Journalists largely employed stylistic devices in describing and making sense of SB, as usually happens in the popularization of scientific achievements [65, 66]. This tendency was detected in the first studies, by Pauwels and Ifrim [48] and Cserer and Seiringer [49], and continued until the last ones, by Schmid-Petri et al. [55] and Ancillotti et al. [56].

Most prominent were construction metaphors, in which SB was described as the creation or design of new microorganisms through bricks, blocks or even Legos. Gschmeidler and Seiringer [53] remarked that a dimension of playfulness is connected to Legos, which may question the seriousness of the field. Cserer and Seiringer [49] observed that experts describe SB in terms of its 'engineering work culture', and this is reflected in the epithets, such as architects, engineers and designers, used by journalists to describe scientists.

The second most recurrent set of metaphors related to IT language, in which the cell was described as the hardware and the genome as the software. Venter, for example, in his highly related press release and speech announcing the 'creation' of the first synthetic cell, described it as the first organism with computers as parents [67, 68]. The media simply echoed these words, which sells well.

Recurrent were also apparently religious metaphors concerning the supposed hubris involved in the human creation of life and the associated 'playing God' leitmotif. This argumentative scheme has partially lost its original power and is often interpreted more as a journalistic device than as an expression of religious unease. Indeed, in the analyses, it is often coupled with, or directly followed by, the 'Frankenstein' motif [56].

The tone of the stories on SB was extremely positive. Pauwels and Ifrim [48] observed that, even in a generally positive tone, the USA was more optimistic while Europe was found to be more precautionary. The difference seems to become less important in the aftermath, with all the analysis of the stories revealing a very positive attitude. Schmid-Petri et al. [55] proposed an interesting reason accounting for this, relating to the young age of SB and the concomitant lack of scandals or problems connected to it. The communication with scientists and other stakeholders never took place as a reaction to crisis but was rather always based on a proactive communication, at their initiative, and is consequently positively framed and future-oriented [55].

Reported Applications, Risks and Benefits of SB

In their study, Ancillotti and Eriksson found that the applications of SB and the topics connected to it, as reported by journalists, mainly concerned healthcare, the environment and energy production [10]. Ethical issues were raised in about a third of the stories, but not as matters of concern. Indeed, the tone was neutral, in most cases only mentioning the fact that SB may create certain moral tensions, without further qualifications. It was observed that the major benefits envisioned in the stories from Italy and Sweden overlapped with the

most commonly treated topics/applications, since they were rarely presented in a neutral way but rather very often had their good sides emphasized. For example, it is not obvious that SB should be described as something positive for the environment or human health; nonetheless, merely five negative stories regarding these fields could be found. The remaining stories were neutral or positive, pointing at the possible use of SB in bioremediation or new drug/vaccine production. The considered risks, mainly biohazards and bioterrorism, were mentioned only a few times, receiving much less consideration in both quantity and weight (they were neutrally presented) than the positives.

These findings are again rather consistent with the other studies. The study by Kruvand [54]—which investigated a different period (2008–2011), more media outlets and another country (the USA)—found that the number of stories that mentioned only benefits outnumbered those that mentioned only risks and those mentioning both risks and benefits. Moreover, Kruvand [54] observed that in the stories mentioning both risks and benefits, the former tended to be mentioned near or at the end of the stories.

Pauwels et al. [52] found that, with respect to the previous period investigated in Pauwels and Ifrim [48], the coverage became more balanced. However, and as an overall conclusion from the studies, it can be stated that press coverage is not balanced yet.

Promotion of Public Involvement

The study by Ancillotti and Eriksson also investigated whether the media promoted or raised the issue of public involvement in the SB discourse, but very little of this was found in the material [10]. However, the role of educating citizens should not primarily be assigned to the media, even though they can of course be very useful in attracting public attention to important scientific and technological issues, such as SB. Pauwels et al. [52] rightly remarked that SB can be easily replaced by the next big new thing in media coverage, and for this reason, media should never be used as a substitute for public engagement.

In his study, Lehmkuhl [41] observed that only actors in the so-called periphery (civil society, organizations, and scientists) had a say, whereas none from the (political) centre (referring to the deliberative model of public sphere by Habermas [69] and Gerhards et al. [70]) did. According to Habermas, this would indicate that the public debate on SB has not yet earned political relevance.

Dutch Future Politicians Meet Future Scientists: a Meeting of Young Minds[2]

Background

In the Netherlands, the Rathenau Instituut—which aims to contribute to societal debate and to the formation of political opinion on issues that relate to or are the consequence of scientific and technological developments—engaged with SB quite early in its development [12]. In fact, the report ‘Constructing Life’ [71] was one of the first studies on the potential societal impact of SB. In 2007, the institute published a Dutch version of the report [72] and a policy brief [73] based thereon. As a result of these efforts, members of the Dutch Labour Party (Partij voor de Arbeid) asked questions to draw the attention of the Cabinet to the developments in SB in 2007 [74]. In the years to come, SB did not become a real topic of debate, which is perhaps not surprising since the field is still predominantly in an experimental phase. Nevertheless, given the significance of SB, the Rathenau Instituut undertook various actions to broaden the societal debate on the field, as well as engage with SB researchers. In order to facilitate more political debate on SB, the institute organized a debate between ‘future politicians and future synthetic biologists’, a *Meeting of Young Minds*, in 2011.

The idea of the event was inspired by the international Genetically Engineered Machines competition, better known under its acronym iGEM. iGEM is the popular global student competition in the field of SB, in which students use standardized and interchangeable genetic building blocks (BioBricks™) to design microorganisms with novel properties. By 2011, 8 years since the conception of iGEM at the Massachusetts Institute of Technology, the competition had grown into a full-blown international competition with no less than 160 teams from 30 countries participating. Due to this explosive growth, the organization decided that year to regionalize the competition into three preliminaries (or jamborees, in iGEM jargon). The European-African jamboree was to be held in Amsterdam. This gathering of ‘future synthetic biologists’ sparked the idea of

[2] For a more detailed discussion of the organization and results of this event, see Rerimassie (this volume).

bringing them into debate with 'future politicians'. This idea resonated quite well with the culture of iGEM, since its participants not only work in the laboratory but also need to pay close attention to the societal aspects of their research and reach out to society. Therefore, the iGEM organizational committee was very willing to cooperate with the Rathenau Instituut [75].

In turn, the future politicians were sought in the circles of Dutch political youth organizations (PYOs). PYOs are tied to a specific political party and are open to young persons between approximately 14 and 27 years old. The aim of PYOs is to promote and maintain the causes of the political party they are connected to. In order to do this, they use a wide variety of means, such as participating in debates, initiating petitions and organizing publicity stunts. PYOs have considerable membership numbers and are moreover seen as an incubator for political talent.[3] In fact, many prominent Dutch politicians were active in a PYO in younger years, such as Mark Rutte, the country's current Prime Minister [76]. The Rathenau Instituut found seven (out of nine) PYOs—varying from right wing to left wing and from Christian to animal welfare-inspired—willing to develop a tentative view on SB and bring this into debate.[4] As the PYOs were not familiar with SB, the Rathenau Instituut facilitated their opinion-making process by, for instance, making available relevant reports and organizing an expert meeting in collaboration with the iGEM team from the Delft University of Technology [77]. Since this was the first time the PYOs would learn about SB, the Rathenau Instituut needed to ensure that it provided a balanced view of it. Accordingly, some of the experts who attended the expert meeting stemmed from the field of SB itself, while others came in from the perspective of risk assessment, intellectual property and philosophy. Also, with regard to the various reports we provided, we aimed to provide multiple perspectives on SB. In order to prepare themselves, the PYOs were asked to draft a political pamphlet in which they outlined their views on SB, as well as offered position statements, here based on [78]. This provided valuable input on how to organize the debate. Three core themes on which the PYOs seemed to disagree were identified: promises, regulation and ownership. Each of the themes would be discussed in one round. In terms of the debate format, each round would start with two representatives of opposing PYOs defending a position statement and reacting to each other. Next, the other PYO spokespersons could join in the discussion, and last, six representatives from iGEM could also join the debate.[5]

Eventually, the Meeting of Young Minds was held on the night preceding the European-African jamboree and turned out to be a well-attended (notably by iGEM participants), lively debate.

Main Results

As described in Rerimassie [12], the Meeting of Young Minds had the following aims: firstly, to broaden the—so far modest—debate on SB in the Netherlands by introducing non-neutral publics, secondly, to provide data on how Dutch political parties might gauge SB, in the absence of partisan viewpoints on it, i.e. contribute to the understanding of what kind of issues are likely to play a role in the emerging debate on SB, and lastly, to facilitate mutual learning and understanding among the participants. The Meeting of Young Minds was analysed in the 2013 report 'Politiek over leven' [78]. In 2014, an updated English translation of this report, called 'SynBio Politics', was published [75]. Based on these studies and Rerimassie [12], this section will provide a brief impression of the viewpoints of the PYOs regarding SB; the discussion will be limited to positive or negative expectations the PYOs demonstrated. Finally, the role of the iGEM teams during the debate will be briefly discussed.

[3] Currently, the largest PYO is SGPJ, tied to the Reformed Political Party (SGP) with approximately 9000 members. The smallest is the much younger organization PINK!, which is tied to the animal welfare party (Partij voor de Dieren), with about 900 members [76].

[4] The participating PYOs were the following: Young Democrats (linked to D66, the Liberal Democrats), DWARS (linked to GroenLinks, the Green Party), Young Socialists (linked to the PvdA, the Labour Party), PINK! (linked to the Partij voor de Dieren, the animal welfare-concerned Party for the Animals), CDJA (linked to CDA, the Christian Democrats), SGPJ (linked to SGP, the [Christian] Reformed Political Party) and PerspectieF (linked to ChristenUnie, the Christian Union) [75].

[5] Due to time restraints, we did not engage with the iGEM teams as intensively as we did with the PYOs (when the trajectory with the PYOs started, the iGEM competition activities had already been underway for some time). Rather, together with the European iGEM committee, we reached out to iGEM teams that seemed to be excelling in their human practices activities. Eventually, we merely asked to appoint a spokesperson who would represent them during the debate. However, despite prior involvement, we assumed that their representatives could play an important role during the debate, given their knowledge of SB and human practices experiences.

First, positive expectations concerning SB could certainly be found. The *Young Democrats*, for instance, were very favourable towards it and pleaded for freedom of research despite potential risks: 'just imagine what the impact will be on innovation if you want to stop everything until you're sure that it leads to a great invention that will solve worldwide hunger or something (…) I would say that synthetic biology offers enormous opportunities and there is simply no world that exists without risks'. The *Young Socialists* concurred: 'even if it brings new risks, it may also improve our lives'. *DWARS*—connected to the Dutch Green Party *GroenLinks*—also saw the potential of SB in the fight against climate change but expressed more concern about the potential risks than the aforementioned PYOs did. Their representative ended up concluding that 'we cannot stop technological developments (…). We shouldn't be afraid of the things we don't know. We need to look at what these new technologies can do in our society, and we must use them in a safe and responsible manner'. This is a striking remark, considering the very strict general stance of *GroenLinks* towards genetic modification. That being said, *DWARS* drew a clear line regarding the deliberate release of organisms modified by means of SB: 'we're extremely cautious about releasing products into the environment, because it can be harmful for ecosystems. This can have serious, unpredictable consequences'.

The remaining PYOs were even more worried about the developments. The Christian-Democratic representative of the CDJA, for instance, not only worried about disturbing ecological balances but also expressed anxiety concerning heavily redesigning—or even creating—organisms as such: 'some biologists see it as improving nature. We don't find this a desirable development, and we believe that this only should be allowed in exceptional cases (…) for example, only for the development of new drugs for very serious diseases (…). If you're talking about synthetic biology in the sense of improving or creating organisms, I think that goes very far indeed, and then you have to be very strict in your regulations'. The spokesperson for *PerspectieF* and *SGPJ*—two smaller Christian parties that often collaborate—also argued: 'you shouldn't give scientists a blank check. First you need to discuss which developments mankind can afford (…). We should expect no paradise from synthetic biology (…) perhaps expectations won't come true. My argument is that as a politician you have the responsibility to check things'. Last, *PINK!*, the youth branch of the Dutch animal welfare party, also perceived hubristic ambitions in SB but added: 'we don't even need this technology for many of the problems we face. Hunger in the developing world isn't a matter of food production but of distribution. For our environmental problems, we also have solutions available. We just need to use them'.

The representatives of the iGEM teams, in turn, played an important role in the discussion. First, several spokespersons highlighted how SB could contribute to the common good. The representative of iGEM Imperial College London, for instance, remarked: 'for our project we looked at desertification, and it is a fact that every day an area 1.5 times the size of Amsterdam turns into desert every single day. […]. I think that synthetic biology is one of those great areas that might enable us to actually do something about it and yes, I completely agree that it should be completely safety tested […] but do we really want to bypass this great opportunity of being able to actually undo the damage we've done?'. At the same time, several representatives raised the importance of taking ethical concerns and public opinions seriously, such as the spokesperson of iGEM Imperial College London: 'I really think it's important (…) to achieve transparency, and in the UK we do it through public engagement. It's a political tool used to spread awareness (…) when they're empowered with the knowledge, they can then formulate their own independent opinions'.

In conclusion, by organizing the Meeting of Young Minds, the Rathenau Instituut aimed to broaden the (to date) modest debate on SB in the Netherlands. Moreover, it provided a glimpse of how Dutch political parties might perceive SB. There were positive expectations as well as negative ones. Interestingly, the concerns of sceptical PYOs related not only to the potential risks of SB but also to anxiety regarding radically redesigning life and organisms as such. In any case, given the major differences heard during the event, SB may turn out to become a topic of fierce political debate in the Netherlands.

Citizen Panels with Members of the Austrian Public

Background

In Austria, public awareness of SB is—as in EU member states in general—persistently low [35]. In addition, Austrians are particularly sceptical towards the genetic

modification of plants and animals, and biotechnology in general [35, 79, 80]. In order to learn about the deeper motives for (negative) attitudes towards SB on the one hand and to get citizens' recommendations for how the research field should be regulated on the other, citizen panels were conducted with members of the Austrian public from a variety of socio-demographic backgrounds. The idea was to gather situated and nuanced knowledge about 'general' publics' perceptions of the challenges and opportunities associated with SB, to understand how SB is made sense of and framed, and to learn how members of the public cope with the hypes and hopes, fears and concerns evoked by visions of SB.

During November and December 2012, a total of eight citizen panels were conducted in the cities of Vienna and Innsbruck.[6] In order to account for different age groups, genders, levels of education and employment statuses, participants were sampled purposively [81]. In each city, two citizen panels were conducted with participants aged 18 to 49, and two with participants aged 50+. Individual citizen panels comprised five to 12 people and lasted 2 to 3 h. Overall, the panels were organized as face-to-face meetings composed of information and discussion phases. They were led by two trained moderators who provided background information on SB and its application, and invited participants to discuss and challenge this information [82–84]. As such, in their conceptualization, the Austrian citizen panels were similar to focus group discussions [85–88].[7]

Concerning the procedure, the citizen panels were divided into five thematic units, with the moderators following a semi-structured topic guide composed of open questions. Each citizen panel started with an introduction and the disclosure of the topic by the moderators. In the first thematic unit, the importance of science and technology in the participants' lives in general was discussed. The second unit was dedicated to information and discussion about SB and its ethical and social implications. Third, concrete applications of SB from three different fields (agriculture, medicine and environment) and the respective challenges and opportunities were discussed. Fourth, participants were asked to formulate recommendations for the governance of SB. The sessions ended with an invitation to imagine and describe a future in which SB would be part of the participants' everyday lives.[8]

All discussions within the citizen panels were audio recorded with the informed consent of the participants, rendered anonymous and transcribed verbatim in order to facilitate data analysis. Data analysis was performed using a mixed methods approach combining structured content analysis [89, 90] and interpretive frame analysis [91, 92], so as to get a fine-grained picture of manifest as well as latent content and frames within transcripts. Use of the qualitative data analysis software Atlas.ti facilitated the management of the data [93].

Main Results

When first confronted with the term synthetic biology, citizen panel participants were quite puzzled. They struggled particularly with the contradiction between the two words 'synthetic'—usually understood as something artificial, unnatural or man-made—and 'biology'—as representing nature. Overall, the term synthetic biology was associated with something negative or undesirable, such as unhealthy foodstuffs, E numbers or synthetic energy drinks. In addition, it brought to participants' minds science fiction novels, which seldom have a happy ending. Interestingly, however, the low level of awareness of the term synthetic biology stood in contrast to the considerable number of participants who knew about the practices and techniques used by synthetic biologists. Thus, participants were well aware of the construction of biological parts and organisms in laboratories with the help of modern technologies but simply did not associate this with the term synthetic biology.

Overall, the participants tended to focus primarily on the challenges and risks presented by SB. One of the main issues raised in all citizen panels was the uncontrollability of the whole field—starting from researchers in their laboratories, over field release, to the

[6] The citizen panels were conducted under the supervision and coordination of Herbert Gottweis within the framework of work conducted for the Austrian Research Promotion Agency (FFG) in its function as partner of ERASynBio. The citizen panels were organized and conducted by Ursula Gottweis and Walburg Steurer. Viktoria Veith contributed through participant recruitment.

[7] For a detailed description of citizen panel design, sample and topic guide, see [11].

[8] The topic guide was inspired by those used in two engagement experiments carried out in the UK [37, 38]. The selection of example cases for the application of SB was inspired by a focus group study conducted by a group of researchers from the Chair of Ethics at the Friedrich-Alexander University Erlangen-Nuremberg, which has yet to be published.

commercialization and distribution of products to consumers. Unknown risks, long-term impacts, side-effects and dual use were central concerns. There was a clear understanding that intended harm (connected to fears of the misuse of SB for warfare and terrorist purposes) and unintended harm (meaning accidents, unforeseeable mutations and evolution within natural ecosystems) constitute separate challenges. Participants were afraid not only that newly created organisms could 'escape' from laboratories or bioreactors and cross-breed with existing organisms in the environment but also that products of SB, such as pharmaceuticals produced in modified organisms, would not have undergone thorough testing yet, which consumers could be used as 'human guinea pigs', and that new discoveries could fall into the wrong hands. Furthermore, participants were sceptical regarding the 'real' aims behind research in SB and cautioned that economic interests would be its primary driver. Within this argumentation, (pharmaceutical) industries, multinationals and advanced societies in general were perceived as the beneficiaries of new discoveries, while access to products for less developed countries would be prevented by large corporations holding patents and monopolies. Finally, moral and ethical concerns were raised regarding the construction of life, man interfering with nature and risks of purposeful selection and eugenics.

Even though there was consensus among participants that the risks of SB would outweigh the benefits, they also showed cautious enthusiasm about certain applications. Support was especially pronounced concerning the medical field; for instance, the application of SB in developing drugs for diseases, such as Malaria or cancer, was very welcome. In addition, a number of participants appreciated the use of SB to produce biofuels in modified plants, such as algae, with the arguments that arable farmland could be saved and that the growing demands for energy could be met without harming ecosystems by consuming fossil fuels, palm oil or crops. On the other hand, participants voiced the criticism that the arguments of 'cheap drugs for the poor' and 'feeding the growing world population' would be misused as door-opener arguments and that especially the example of anti-malarial drugs would be exploited for the promotion of SB.

Generally, support for SB was always conditional and tied to a number of demands, which should be reflected in governance. To start with, transparency and information were defined as essential. This has two main dimensions: Firstly, participants claimed that the risks and unknowns of SB should be communicated from the outset, and the sponsors of research be disclosed; secondly, there was a strong wish that products of SB would be labelled as such, as labelling is a precondition for consumer autonomy. As a second demand, participants urged that the safety and security of SB must be guaranteed. Thus, prevention, precaution and containment were seen as crucial. Thirdly, there was a wish for a thorough balancing of the risks and benefits of research and product development, as well as a desire that alternatives be investigated. Finally, participants claimed that gaps between industrialized societies and developing countries should be avoided and equal access to new products guaranteed.

In addition to openly stated opinions, a number of implicit attitudes and coping strategies for the perceived challenges and opportunities of SB could be identified through fine-grained analysis. Firstly, participants tended to draw parallels between SB and related research fields or past experiences in order to make sense of SB. Thus, comparing the unknown with the familiar makes the former become tangible and understandable. The parallel most prominently drawn was to biotechnology, with a tendency to see SB as a progression of traditional genetic engineering or as the same thing. Secondly, as participants expressed distrust towards scientists, stakeholders and policy-makers, two main coping strategies emerged. On the one hand, there was resignation. Resignation means, firstly, the perception of oneself as being 'only a layperson' who lacks an overview, and secondly, a feeling of not being able to stop science from progressing anyway. On the other hand, and in contrast to this passive role, participants also tended to appeal to personal responsibility by pointing to consumer behaviour. This can be interpreted as a defence reaction to perceived manipulation through advertisement, loss of personal autonomy and lack of transparency and information.

To summarize, participants showed a sceptical and ambivalent fundamental attitude towards SB, with a tendency to equate it to genetic engineering, which evokes negative imaginaries in Austria.

Discussion of Similar Studies

So far, public engagement experiments are rare in the field of SB. However, a number of activities have been conducted in the UK, Austria and the USA, offering an

opportunity to identify some commonalities with and differences to the Austrian citizen panel study.

In Austria, a focus group study was carried out in 2008, wherein the flow of information about SB from the laboratory through newspaper articles into lay discussion groups was investigated [39, 40]. One of the main findings of this study was that participants tended to anchor SB within biotechnology—a tendency which was still persistent in our citizen panel discussions 4 years later. Furthermore, also in this study, a sceptical fundamental attitude towards SB was identified, as well as a strong perception of risks, such as uncontrollability, unpredictability of side-effects and long-term impacts, or economic interests. Overall, SB was associated with the same imaginaries as biotechnology and as such was perceived as 'old wine in new bottles' [39].

Additionally, in the UK, two public dialogue projects have been conducted on the issue of SB. First, the Royal Academy of Engineering organized an exploratory dialogue activity with 16 members of the public, which was followed by a telephone survey of 1000 adults in the UK [38]. In contrast to the Austrian studies, participants in this public dialogue were quite positive regarding the application of SB, primarily in medicine and biofuel production. However, there was a strong desire that research be conducted within confined spaces, while field release raised concerns. Consequently, regulation was vital, as was government funding, as this would guarantee control over the field to some extent. Second, a major citizen panel project with 160 participants was initiated by the Biotechnology and Biological Sciences Research Council (BBSRC) and the Engineering and Physical Sciences Research Council (EPSRC), and carried out by the TNS-BMRB in the cities of London, Edinburgh, Newcastle and North Wales [37]. Within this dialogue project, it was shown that UK residents find SB exciting and scary at the same time. There was optimism that it could solve (future) challenges, such as serious diseases, food scarcity, energy shortage or global warming. On the other hand, economic interests, inequalities in access to benefits between the West and developing countries, moral concerns regarding the transgression of nature, misuse, or health and environmental impacts, constituted points of concern. As a consequence, in this study as well, regulation and control were defined as vital. Most interestingly, as in the Austrian citizen panels, UK participants voiced the feeling of being powerless to have any influence on science or policy-makers—thus, participants in the UK also showed resignation.

Finally, a focus group experiment running over 4 years was conducted in Baltimore, MD, in the USA, with 18–65-year-old adults [94, 95]. In this study, converging with the Austrian citizen panels, there was a striking tendency to draw parallels to related research fields such as genetic engineering, stem cell research, or cloning. Furthermore, US participants also struggled with the term synthetic biology, while showing a low level of awareness. Another finding was that applications matter to participants, while, interestingly, the production of synthetic biofuels found the most support—even stronger than the support for drug development, which was vital in the above-cited European studies. Concerns were mostly raised about unpredictability, biosafety, biosecurity, moral questions about 'playing God' and 'messing with nature'. Most interestingly, the metaphor of 'playing God' was not a primary concern in the Austrian citizen panels and focus groups. However, again converging with the Austrian study, regulation and transparency constituted pivotal requirements in the US study.

Integrating and Discussing Results

To summarize, public perception of SB in three different domains highlights that synthetic biology remains a rather problematic or unknown entity for most people, especially in Europe. This may be because the media do not always mention the term in their stories about SB, and their coverage remains event-driven. The fact that SB does not attract media attention as an issue is mirrored in the level of awareness shown by the public. Both the lay public involved in citizen panels and focus groups as well as Dutch PYOs needed an introduction to the theme before they were able to formulate their opinions. However, not all members of the public are completely unaware; as seen, a considerable part of the participants in the Austrian citizen panels knew about the practices and techniques synthetic biologists use.

The message transmitted by the media is highly processed; but more than being affected by journalistic sensationalism, as has been the case in the past with certain science and technology breakthrough communications, it seems that scientists and stakeholders have taken the lead and provided the content and form of what is transmitted to the audience. Indeed, the indications from the public engagement experiments convey a

different situation from that illustrated by the media stories. Whilst the media tended to highlight the benefits and to only marginally consider the possible risks, the public and the PYOs showed concern for many issues, such as biosecurity and biosafety, bioterrorism, the environment, commercialization of SB products and fairness. With the exception of the Young Democrats, whose position was particularly pro-active, the support for SB was always conditional and tied to a number of demands, which should be reflected in governance.

A worrisome pattern emerged in the attitudes of both citizens and young politicians regarding science: It is a kind of resignation, a sense of ineluctability of scientific and technological progress. This may partially be due to the way scientific developments are conveyed by the media to the public. Adrian Mackenzie recognizes two ways in which SB is actually fostered by appeals to the public [96]: firstly, scientists going out and announcing that their research is 'momentous and vital', as exemplified by J. Craig Venter, and secondly, scientists interpreting doing science as rendering it more accessible or interesting to the public. The difference is not merely in a more or less hyperbolic communication style but in the way and the extent that one conceives science as a societal enterprise. SB media communication was dominated by Venter's style. Science should not only have a dialogue with society to fill a perceived knowledge gap or to enhance citizens' scientific literacy; outreach should be a first step toward legitimating the research or the field object of the communication, to be reached as a consequence of genuine public deliberation.

In the citizen panels, participants' feelings of resignation were tied to distrust not only of scientists and stakeholders but also of policy-makers. The views expressed by the PYOs seem more positive than those of the general public but can still be regarded as a good approximation of public opinions, given their plurality. What clearly emerged in the citizen panels is the request for information and transparency from the outset, which likely represents the only way to fruitfully involve the public in understanding and assessing SB. Interestingly, this does not seem to be the case exclusively for SB: Similar attitudes and requests have been seen previously in the context of another NEST, i.e. nanotechnology [97, 98]. Initiatives such as the *Meeting of Young Minds* in the Netherlands, and the organization of forums convening citizen briefs and panels, can facilitate the assessment of SB. However, the mainstream media coverage of a field remains one of the most impacting methods for science outreach, and the hype that has characterized elite scientists' communication of the field so far, besides being ethically questionable, may also turn out to be counterproductive. Scientists have a deontological duty connected to their role to communicate their research in an open and balanced way, as has been reiterated in many guidelines created ad hoc (see, e.g. the CODEX website [99]), as well as individual obligations as researchers involved in a field characterized by dual-use aspects [100].

One obvious reason for scientists and stakeholders to promote the early involvement of the public, and to consider the ELSI of SB, stems from the worry that its public reception may be one of fear or major criticism. Claire Marris defines this preventive worry as 'synbiophobia-phobia' [101]. The authors experienced something similar to this in the context of the discussion at the international summer school 'Analysing the Societal Dimensions of Synthetic Biology'. Participants were ready to find marks of such concerns among the public in others' empirical research, but it turned out that it was a kind of preventive worry of the participants themselves: It remains to be seen whether 'synbiophobia' will emerge. Nevertheless, what can be clearly discerned is publics' desire for information, transparency and regulation.

Conclusions

The media were found to be generally positively inclined towards SB, rather unbalanced in the consideration of potential benefits (emphasized) and risks (downplayed), and heavily influenced by the main sources of the stories, namely scientists and stakeholders. The identified language and metaphors are those found in the common jargon used by journalists in reporting on biotechnologies, primarily genetic engineering. The media did not promote or raise the issue of public involvement in the SB discourse.

Among the PYOs, there were positive expectations as well as very negative ones. Concerns related not only to the potential risks of SB, but in some cases also to anxiety concerning radically redesigning life and organisms as such.

The citizen panels highlighted some continuity with the positions of the PYOs, mainly the demand for information and transparency, but also a sense of the ineluctability of scientific and technological progress. The

citizens showed a sceptical and ambivalent fundamental attitude towards SB, with a tendency to equate it to genetic engineering.

With a view to the further accompaniment of the SB innovation process in the spirit of RRI, or the mutual design of SB governance according to grass-roots democratic principles, compiling public perceptions is only the first step. It remains a joint endeavour to integrate public perceptions and requests into governance decisions. Especially since there is not yet a statutory procedure that ensures that the voice of the public is heard, this very much depends on the goodwill of elected representatives in the legislative institutions. Today, these are individuals with strong normative imperatives who bring the concerns of the public into these processes, e.g. via TA projects that include political advice, who are not officially legitimated to do so. Thus, how to ensure that the results of open societal debate enter the political decision-making process remains an open question. This has to be answered, e.g. in the course of the RRI implementation process. However, this unanswered question not only applies to SB but is also crucial for a responsible development of this promising technoscience in order to obtain a technology for public welfare without regrets.

References

1. Benner SA, Sismour AM (2005) Synthetic biology. Nat Rev Genet 6(7):533–543
2. Konig H, Frank D, Heil R, Coenen C (2013) Synthetic genomics and synthetic biology applications between hopes and concerns. Curr Genomics 14(1):11–24. doi:10.2174/1389202911314010003
3. Deplazes-Zemp A, Gregorowius D, Biller-Andorno N (2015) Different understandings of life as an opportunity to enrich the debate about synthetic biology. NanoEthics 9(2):179–188. doi:10.1007/s11569-015-0226-1
4. Kaiser M (2012) Commentary: looking for conflict and finding none? Public Underst Sci 21(2):188–194. doi:10.1177/0963662511434433
5. Dana GV, Kuiken T, Rejeski D, Snow AA (2012) Synthetic biology: four steps to avoid a synthetic-biology disaster. Nature 483(7387):29
6. Boldt J, Müller O, Maio G (2009) Synthetische Biologie: Eine ethisch-philosophische Analyse. EKAH, Bern
7. Stilgoe J, Lock SJ, Wilsdon J (2014) Why should we promote public engagement with science? Public Underst Sci 23(1):4–15. doi:10.1177/0963662513518154
8. Hagen K, Engelhard M, Toepfer G (eds) (2016) Ambivalences of creating life—societal and philosophical dimensions of synthetic biology. Springer, Berlin
9. Seitz S (2016) Let's talk about… synthetic biology—emerging technologies and the public. In: Hagen K, Engelhard M, Toepfer G (eds) Ambivalences of creating life—societal and philosophical dimensions of synthetic biology. Springer, Berlin, pp 157–175
10. Ancillotti M, Eriksson S (2016) Synthetic biology in the press—media portrayal in Sweden and Italy. In: Hagen K, Toepfer G, Engelhard M (eds) Ambivalences of creating life—societal and philosophical dimensions of synthetic biology. Springer, Berlin, pp 141–156
11. Steurer W (2016) "Some kind of genetic engineering… only one step further"—public perceptions of synthetic biology in Austria. In: Hagen K, Toepfer G, Engelhard M (eds) Ambivalences of creating life—societal and philosophical dimensions of synthetic biology. Springer, Berlin, pp 115–140
12. Rerimassie V (2016) Early engagement with synthetic biology in the Netherlands—efforts by the rathenau instituut. In: Hagen K, Toepfer G, Engelhard M (eds) Ambivalences of creating life—societal and philosophical dimensions of synthetic biology. Springer, Berlin, pp 199–213
13. Grunwald A (2010) Technikfolgenabschätzung - eine Einführung. 2. Auflage. Edition Sigma (Gesellschaft - Technik - Umwelt, Neue Folge 1), Berlin
14. Grunwald A (2012) Synthetische Biologie als Naturwissenschaft mit technischer Ausrichtung. Plädoyer für eine "hermeneutische Technikfolgenabschätzung". Technikfolgenabschätzung – Theorie und Praxis 21(2):10–15
15. Collingridge D (1980) The social control of technology. Open University Press, London
16. Kollek R, Döring M (2012) TA-Implikationen der komplexen Beziehung zwischen Wissenschaft und Technik. Technikfolgenabschätzung – Theorie und Praxis 21(2):4–9
17. Bauer MW, Allum N, Miller S (2007) What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. Public Underst Sci 16(1):79–95. doi:10.1177/0963662506071287
18. Jasanoff S (2003) Technologies of humility: citizen participation in governing science. Minerva 41(3):223–244. doi:10.1023/A:1025557512320
19. Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M (1994) The new production of knowledge. The dynamics of science and research in contemporary societies. SAGE Publications, London
20. Funtowicz SO, Ravetz JR (1993) Science for the post-normal age. Futures 25(7):739–755. doi:10.1016/0016-3287(93)90022-L
21. Nowotny H, Scott P, Gibbons MTC (2001) Rethinking science: knowledge in an age of uncertainty. Wiley, Cambridge
22. Kiran AH (2012) Does responsible innovation presuppose design instrumentalism? Examining the case of telecare at home in the Netherlands. Technol Soc 34(3):216–226. doi:10.1016/j.techsoc.2012.07.001
23. Hellström T (2003) Systemic innovation and risk: technology assessment and the challenge of responsible innovation. Technol Soc 25(3):369–384. doi:10.1016/S0160-791X(03)00041-1
24. Hahn J, Seitz SB, Weinberger N (2014) What can TA learn from 'the people'? A case study of the German citizens' dialogues on future technologies. In: Michalek TC,

Hebakova L, Hennen L, Scherz C, Nierling L, Hahn J (eds) Technology Assessment and Policy Areas of Great Transitions. Technology Centre ASCR, Prague, pp 165–170
25. Stirling A (2008) "Opening Up" and "closing down": power, participation, and pluralism in the social appraisal of technology. Sci Technol Hum Values 33(2):262–294. doi:10.1177/0162243907311265
26. Hennen L (2012) Why do we still need participatory technology assessment? Poiesis Prax 9(1–2):27–41. doi:10.1007/s10202-012-0122-5
27. von Schomberg R (2013) A vision of responsible research and innovation. In: Owen R, Bessant J, Heintz M (eds) Responsible innovation: managing the responsible emergence of science and innovation in society. Wiley, Hoboken, pp 51–74
28. Stilgoe J, Owen R, Macnaghten P (2013) Developing a framework for responsible innovation. Res Policy 42(9):1568–1580. doi:10.1016/j.respol.2013.05.008
29. Walk H (2013) Herausforderungen für eine integrative Perspektive in der sozialwissenschaftlichen Klimaforschung. In: Knierim A, Baasch S, Gottschick M (eds) Partizipation und Klimawandel - Ansprüche, Konzepte und Umsetzung. Oekom Verlag, Munich, pp 21–35
30. ERASynBio (2014) Next steps for European synthetic biology: a strategic vision from ERASynBio. European research area network for the development and coordination of synthetic biology in Europe. https://www.erasynbio.eu/lw_resource/datapool/_items/item_58/erasynbiostrategicvision.pdf
31. Rerimassie V, Stemerding D, Zhang W, Srinivas KR (2015) Discourses on synthetic biology in Europe, India and China. In: Ladikas M, Chaturvedi S, Zhao Y, Stemerding D (eds) Science and technology governance and ethics. A global perspective from Europe, India and China. Springer, Dordrecht, pp 145-164
32. IAP (2014) IAP statement on realising global potential in synthetic biology: scientific opportunities and good governance. Trieste
33. ter Meulen V (2014) Time to settle the synthetic controversy. Nature 509(7499):135. doi:10.1038/509135a
34. Stilgoe J (2014) Don't shut the door on the synthetic biology debate. The Guardian, 8 May
35. Gaskell G, Stares S, Allansdottir A, Allum N, Castro P, Esmer Y, et al. (2010) Europeans and biotechnology in 2010. Winds of change? Eurobarometer
36. Owen R, Stilgoe J, Macnaghten P, Gorman M, Fisher E, Guston D (2013) A framework for responsible innovation. In: Owen R, Bessant J, Heintz M (eds) Responsible innovation: managing the responsible emergence of science and innovation in society. Wiley, Chichester
37. BBSRC, EPSRC (2010) Synthetic Biology Dialogue. http://www.bbsrc.ac.uk/web/FILES/Reviews/1006-synthetic-biology-dialogue.pdf
38. The Royal Academy of Engineering (2009) Synthetic Biology: public dialogue on synthetic biology. London. www.raeng.org.uk/synbiodialogue
39. Kronberger N, Holtz P, Kerbe W, Strasser E, Wagner W (2009) Communicating synthetic biology: from the lab via the media to the broader public. Syst Synth Biol 3(1–4):19–26. doi:10.1007/s11693-009-9031-x
40. Kronberger N, Holtz P, Wagner W (2012) Consequences of media information uptake and deliberation: focus groups' symbolic coping with synthetic biology. Public Underst Sci 21(2):174–187. doi:10.1177/0963662511400331
41. Lehmkuhl M (2011) Die Repräsentation der synthetischen Biologie in der deutschen Presse. Abschlussbericht einer Inhaltsanalyse von 23 deutschen Pressetiteln. Deutscher Ethikrat, Berlin
42. Brüggemann M (2014) Between frame setting and frame sending: how journalists contribute to news frames. Compr Ther 24(1):61–82. doi:10.1111/comt.12027
43. Bogner A (2012) The paradox of participation experiments. Sci Technol Hum Values 37(5):506–527. doi:10.1177/0162243911430398
44. Torgesen H, Schmidt M (2013) Frames and comparators: how might a debate on synthetic biology evolve? Futures 48:44–54
45. Mazerik J, Rejeski D (2014) A guide for communicating synthetic biology, vol Synbio 8. Wilson Center, Washington, DC
46. Nisbet MC, Brossard D, Kroepsch A (2003) Framing science: the stem cell controversy in an Age of press/politics. Int J Press/Pol 8(2):36–70. doi:10.1177/1081180x02251047
47. The Royal Academy of Engineering (2009) Synthetic biology: scope, applications and implications. London
48. Pauwels E, Ifrim I (2008) Trends in American and European press coverage of synthetic biology. Tracking the last five years of coverage synthetic biology project, vol Synbio 1. Woodrow Wilson International Center for Scholars, Washington, DC
49. Cserer A, Seiringer A (2009) Pictures of synthetic biology. Syst Synth Biol 3(1–4):27–35. doi:10.1007/s11693-009-9038-3
50. Balmer A, Herreman C (2009) Craig Venter and the re-programming of life: how metaphors shape and perform ethical discourses in the media presentation of synthetic biology. In: Nerlich B, Elliott R, Larson B (eds) Communicating biological sciences: ethical and metaphorical dimensions. Ashgate, Farnham, pp 219–234
51. SYNTH-ETHICS (2010) Identification of ethical issues and analysis of public discourse. vol Report WP1
52. Pauwels E, Lovell A, Rouge E (2012) Trends in American and European Press Coverage of Synthetic Biology. Synthetic Biology Project, vol Synbio 4 Wilson Center, Washington, DC
53. Gschmeidler B, Seiringer A (2012) "Knight in shining armour" or "Frankenstein's creation"? the coverage of synthetic biology in German-language media. Public Underst Sci 21(2):163–173
54. Kruvand M (2013) Science and humanity in the era of synthetic life. How the news media cover synthetic biology. Int J Commun Linguis Stud 10(2):17–27
55. Schmid-Petri H, Knocks S, Sager P, Silke A (2014) La Biologie Synthétique Dans la Société. Une Nouvelle Technologie Dans le Débat Public. TA-SWISS, Berne
56. Ancillotti M, Holmberg N, Lindfelt M, Eriksson S (2015) Uncritical and unbalanced coverage of synthetic biology in the Nordic press. Public Underst Sci. doi:10.1177/0963662515609834

57. Gibson DG, Glass JI, Lartigue C, Venter JC (2010) Creation of a bacterial cell controlled by a chemically synthesized genome. Science 329(5987):52–56
58. Gibson DG, Benders GA, Andrews-Pfannkoch C, Denisova EA, Baden-Tillson H, Zaveri J, Stockwell TB, Brownley A, Thomas DW, Algire MA, Merryman C, Young L, Noskov VN, Glass JI, Venter JC, Hutchison CA 3rd, Smith HO (2008) Complete chemical synthesis, assembly, and cloning of a mycoplasma genitalium genome. Science 319(5867): 1215–1220. doi:10.1126/science.1151721
59. Synthetic Biology Roadmap Coordination Group (2012) A synthetic biology roadmap for the UK. Technology Strategy Board, Swindon
60. PCSBI (2010) New directions: the ethics of synthetic biology and emerging technologies. PCSBI, Washington
61. Can Neanderthals Be Brought Back from the Dead? (2013). Spiegel Online International, 18 January
62. Coghlan A (2013) Craig Venter close to creating synthetic life. New Scientist, 12 March 2013
63. Nelson TE, Clawson RA, Oxley ZM (1997) Media framing of a civil liberties conflict and its effect on tolerance. Am Polit Sci Rev 91(3):567–583
64. Scheufele DA (1999) Framing as a theory of media effects. J Commun 49(1):103–122
65. Scheufele DA, Lewenstein BV (2005) The public and nanotechnology: how citizens make sense of emerging technologies. J Nanoparticle Res 7(6):659–667
66. Hellsten I, Nerlich B (2011) Synthetic biology: building the language for a new science brick by metaphorical brick. New Genet Soc 30(4):375–397. doi:10.1080/14636778.2011.592009
67. JCVI (2010) First Self-Replicating Synthetic Bacterial Cell
68. Venter JC (2010) Craig Venter: watch me unveil "synthetic life". TED Conferences
69. Habermas J (1992) Faktizität und Geltung. Beiträge zur Diskurstheorie des Rechts und des demokratischen Rechtsstaats. Suhrkamp, Frankfurt
70. Gerhards J, Neidhardt F, Rucht D (1998) Zwischen Palaver und Diskurs. Strukturen öffentlicher Meinungsbildung am Beispiel der deutschen Diskussion zur Abtreibung. Westdeutscher Verlag, Opladen
71. de Vriend H (2006) Constructing life. Early social reflections on the emerging field of synthetic biology. Rathenau Institute, The Hague
72. de Vriend H, Van Est R, Walhout B (2007) Leven maken. Maatschappelijke reflectie op de opkomst van synthetische biologie. Rathenau Instituut, The Hague
73. Van Est R, De Vriend H, Walhout B (2007) Bericht aan het Parlement. Synthetische biologie: nieuw leven in het biodebat. Rathenau Instituut, The Hague
74. Parliamentary papers (2007) Annex to Papers of Parliament, Aanhangsel Handelingen II 2007/2008. nr. 2070800670
75. Rerimassie V, Stemerding D (2014) SynBio politics. Bringing synthetic biology into debate. Rathenau Instituut, The Hague
76. Politiek P (n.d.) Politieke jongerenorganisaties. http://www.parlement.com/id/vjbzm2hqjfm5/politieke_jongerenorganisaties
77. Workshop on synthetic biology (2010). iGEM TU Delft
78. Rerimassie V, Stemerding D (2013) Politiek over Leven. Rathenau Instituut, The Hague
79. Pardo R, Engelhard M, Hagen K, Jørgensen RB, Rehbinder E, Schnieke A, Szmulewicz M, Thiele F (2009) The role of means and goals in technology acceptance. A differentiated landscape of public perceptions of pharming. EMBO Rep 10(10):1069–1075. doi:10.1038/embor.2009.208
80. Rehbinder E, Engelhard M, Hagen K, Jørgensen RB, Pardo-Avellaneda R, Schnieke A, Thiele F (2009) Pharming. Promises and risks of biopharmaceuticals derived from genetically modified plants and animals ethics of science and technology assessment, vol 35. Springer, Berlin
81. Barbour R (2014) Introducting qualitative research: a student's guide second edition edn. Sage, London
82. Abelson J, Eyles J, McLeod CB, Collins P, McMullan C, Forest P-G (2003) Does deliberation make a difference? results from a citizens panel study of health goals priority setting. Health Policy 66(1):95–106
83. Abelson J, Forest P-G, Eyles J, Smith P, Martin E, Gauvin F-P (2003) Deliberations about deliberative methods: issues in the design and evaluation of public participation processes. Soc Sci Med 57(2):239–251. doi:10.1016/S0277-9536(02)00343-X
84. Abelson J, Gauvin F-P, MacKinnon MP, Watling J (2006) Primer on Public Involvement. Document prepared for the Health Council of Canada
85. Krueger RA, Casey MA (2009) Focus groups: a practical guide for applied research, 4th edn. SAGE Publications, Los Angeles
86. Bloor M, Frankland J, Thomas M, Robson K (2001) Focus groups in social research. Sage, London, Thousand Oaks, New Delhi
87. Liamputtong P (2011) Focus group methodology: principle and practice. Sage, London
88. Barbour R (2008) Doing focus groups. Sage, London
89. Mayring P (2008) Qualitative inhaltsanalyse: grundlagen und techniken, 10th edn. Beltz, Weinheim
90. Kuckartz U (2012) Qualitative inhaltsanalyse: methoden, praxis, computerunterstützung. Beltz, Weinheim
91. Schön DA, Rein M (1994) Frame reflection: toward the resolution of intractrable policy controversies. Basic Books, New York
92. Fischer F (2003) Reframing public policy: discursive poltics and deliberative practices. Oxford University Press, Oxford, New York
93. Friese S (2012) Qualitative data analysis with ATLAS.ti. Sage, London
94. Pauwels E (2009) Review of quantitative and qualitative studies on U.S. Public perceptions of synthetic biology. Syst. Synth. Biogeosciences 3(1–4):37–46. doi:10.1007/s11693-009-9035-6
95. Pauwels E (2013) Public understanding of synthetic biology. Bioscience 63(2):79–89. doi:10.1525/bio.2013.63.2.4
96. Mackenzie A (2013) From validating to objecting: public appeals in synthetic biology. Sci Cult 22(4):476–496
97. Fleischer T, Haslinger J, Jahnel J, Seitz SB (2012) Focus Group Discussions Inform Concern Assessment and Support Scientific Policy Advice for the Risk Governance of Nanomaterials. iJETS 10 (1):79–95
98. Oerlemans AJ, van Hoek ME, van Leeuwen E, van der Burg S, Dekkers WJ (2013) Towards a richer debate on tissue engineering: a consideration on the basis of NEST-ethics. Sci Eng Ethics 19(3):963–981. doi:10.1007/s11948-012-9419-y

99. Eriksson S (2015) Being an expert. CODEX-Rules and guidelines for research. Swedish Research Council. http://codex.vr.se/en/index.shtml
100. Eriksson S (2012) Moral Obligations for Synthetic Biology Research. EUBARnet Review series on policy, ethics and security, paper no. 7
101. Marris C (2015) The construction of imaginaries of the public as a threat to synthetic biology. Sci Cult 24(1): 83–98